4th Cess Training Programme

Utilization of Agro-Residue Fibres in Indian Paper Industry

at

Chandigarh

9th - 12th May 2005

Sponsored by

सत्यमेव जयते

Developement Council for Pulp, Paper & Allied Industry

Ministry of Commerce & Industry
Govt. of India

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केन्द्रीय लुग्दी एवं कागज अनुसंधान संस्थान

Central Pulp & Paper Research Institute

AN ISO 9001-2000 INSTITUTION

In pursuit of cleaner production, resource conservation & quality excellence

S. JAGADEESAN
Joint Secretary

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वाणिज्य एवं उद्योग मंत्रालय
(औद्योगिक नीति और संवर्धन विभाग)
उद्योग भवन, नई दिल्ली–११००११
Ministry of Commerce & Industry
(Deptt. of Industrial Policy and Promotion)
Udyog Bhawan, New Delhi-110011

FOREWORD

The deployment of skilled and trained manpower in Indian paper industry is relatively lower as compared to the paper industry in the developed countries. Looking into the remarkable technological advancements and for their absorption & adoption into our conditions, there is a need for skilled & trained manpower in the paper industry. One of the objectives of **"Continuing Education & Training Programmes"** under the Cess funded schemes is to create an awareness on the technological needs & developments in technologies around the world. In fact, forest based pulp and paper mills have the advantage of better technologies and are well equipped with skilled & trained manpower. The Agro-based pulp and paper mills are having relatively lower trained & skilled manpower. I remember, when we started this continuing education & training programmes for the pulp and paper industry, there was an over-whelming response in three of the earlier training programmes completed, and more than 100 technical personnel had an opportunity to get the exposure to the technological advancements in pulp and paper mills.

I am sure that this specific training programme on **"Utilization Of Agro-Residue Fibres In Indian Pulp & Paper Industry"** scheduled to be held at Chandigarh from 9th to 12th May, 2005 covering wide range of topics is going to be a highly relevant for the agro-based pulp and paper mills.

The agro-based pulp and paper mills, which are presently contributing around 32% of the total paper production, will continue to play an important role in augmenting the demand of paper and paper products. In view of the emerging environmental and quality requirements, there is a need for induction of modern technologies in agro-based pulp and paper mills for their healthy growth.

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I am glad that this 4th training programme on **Utilization Of Agro-Residue Fibres In Indian Pulp & Paper Industry"** has been designed specifically for the agro-based pulp and paper mills covering wide range of subjects such as;- **raw materials handling, storage & up gradation; pulping, bleaching & washing practices, energy & environmental management, etc.,** and I am sure that this will help the senior technical personnel from the agro-based pulp and paper mills in absorption & adoption of the modern technologies will also help to educate these mills in achieving cost effective production with an improved quality standards.

I compliment CPPRI for having successfully organized these training programmes under the Cess funded schemes on various topics relevant to the Indian paper industry.

I would also like to thank all the faculty members for agreeing to spare their valuable time in sharing their vast knowledge & experiences during the training programme.

I wish this training programme a success.

(S. JAGADEESAN)
CHAIRMAN
CESS COMMITTEE(GOVT.OF INDIA)

केन्द्रीय लुग्दी एवं कागज अनुसंधान संस्थान
Central Pulp & Paper Research Institute
AN ISO 9001:2000 INSTITUTION
In pursuit of cleaner production, resource conservation & quality excellence
An autonomous organisation registered under societies Act under the administrative control of the Ministry of Commerce & Industry (Govt. of India)

Accredited by Member of the IAF MLA for QMS ANSI*RAB QMS ACCREDITED

Dr. A. G. KULKARNI
Director

PREFACE

The 4th training programme on **"Utilization Of Agro-Residue Fibres In Indian Paper Industry"** under the Cess funded sponsored schemes has been organized by Central Pulp & Paper Research Institute(CPPRI) specifically to give an opportunity to the agro-based pulp and paper mills to know about the latest trends in technologies around the world. The agro-based pulp and paper mills will continue to play a pivotal role in Indian paper industry by using the renewable resources for production of paper and paper products. This training programme has been exclusively formulated keeping in view of the needs of the agro-based pulp and paper mills. In all there will be 22 Lectures during this 4 days training programme and these Lectures will cover wide range of the topics such as:- **raw materials handling, storage & up gradation; pulping, bleaching & washing practices, energy & environmental management and quality etc.** Eminent faculty members combined with the senior Scientists from CPPRI will share their wide knowledge and experience during this training programme.

I must compliment CPPRI team led by Dr. Vimlesh Bist, Scientist E-I(Training Coordinator) in efficiently organizing this training programme, and I am sure that this training programme will be extremely beneficial for technical personnel from the agro based pulp and paper mills.

I would also like to thank all the paper mills for showing their keen interest in this training programme organized by CPPRI, and would urge upon all the pulp and paper mills to take the full advantage of these training programmes in future also.

I am sure that this training programme will give the required exposure to the mill's personnel.

I wish this training programme a success.

(Dr. A G Kulkarni)
DIRECTOR

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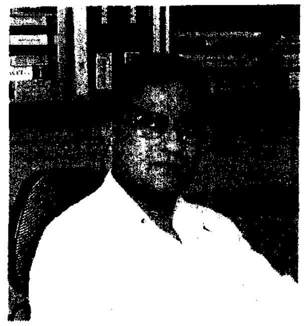
GENERAL INTRODUCTION OF NON WOOD FIBRES

AGRO RESIDUES - A POTENTIAL FIBRE SOURCE FOR PULP & PAPER MANUFACTURING



Dr. A. G. Kulkarni,
Director,
CPPRI, Saharanpur

About The Author

Dr. A.G. Kulkarni, Director Central Pulp & Paper Research Institute (CPPRI) Saharanpur, Uttar Pradesh, India has been with the CPPRI since its inception. He holds a Master degree in Chemistry & Doctorate in Black Liquor and Lignin Chemistry.

Dr. Kulkarni has pioneered the research work on Desilication of black liquor with eventual development of mill scale plant, installed at Hindustan Newsprint Ltd., Kerala and High Rate Bio-methanation of black liquor rich effluent and a mill scale unit is successfully operating at Satia Paper Mills is another achievement of Dr. Kulkarni. His contribution in the area of physico chemical & thermal properties of agro - residue non-wood black liquors has now made it possible to process this liquor in chemical recovery boilers. He has published more than 300 scientific papers in Indian and International journals. He is widely traveled in Europe, S. E. Asia, and Australia and has been on several foreign missions as UNDP/UNIDO Consultant.

His areas of specialization include pulping and bleaching, black liquor-its chemistry & processing, environment and energy management. Dr. Kulkarni holds several patents-important ones being on desilication of black liquor, thermal treatment of black liquors and Direct Alkali Recovery System etc. He is a member of several National and International Scientific & Technical organizations and also on board of Directors of Paper Mills & Research organizations

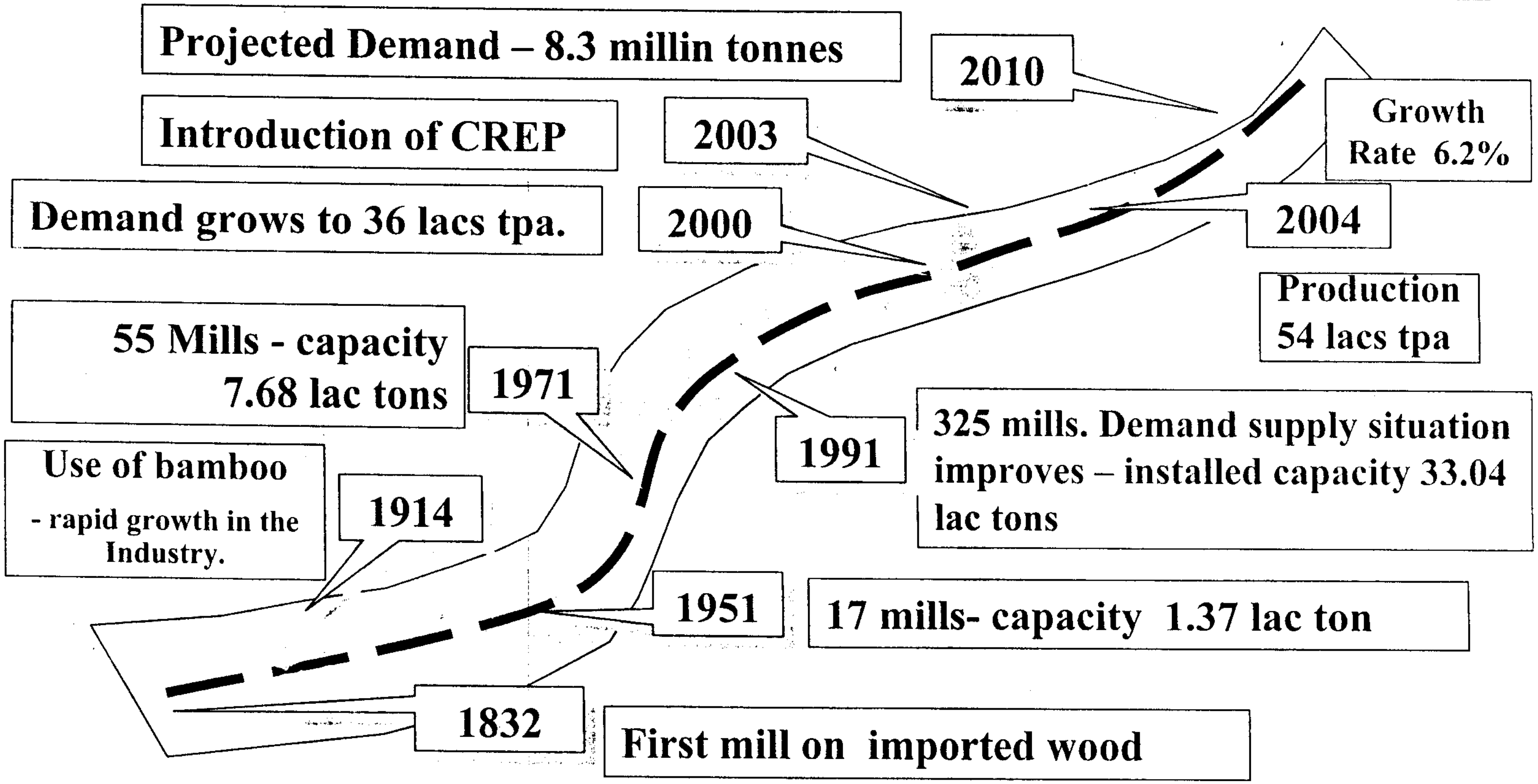
AGRO RESIDUES – A POTENTIAL FIBRE SOURCE FOR PULP & PAPER MANUFACTURING

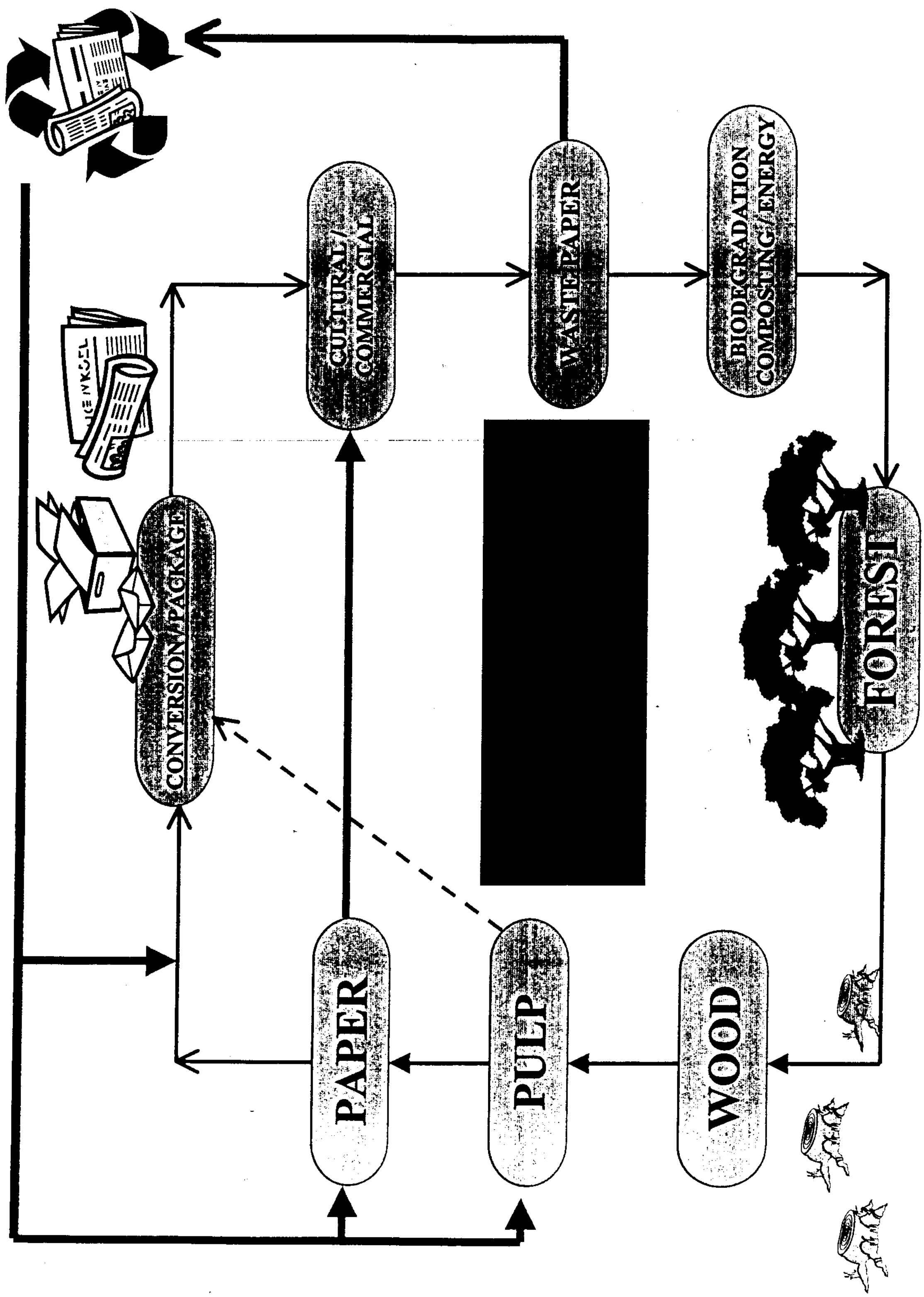
Dr.A.G.Kulkarni

The article on "Agro residues – a potential fibre source for pulp & paper manufacturing" discusses the chronological developments in Indian Paper Industry in terms of its growth, production level and levels of capacity utilization. The article also highlights the status of non-wood fibres in terms of availability, basic input requirements and challenges ahead of agro based industries.

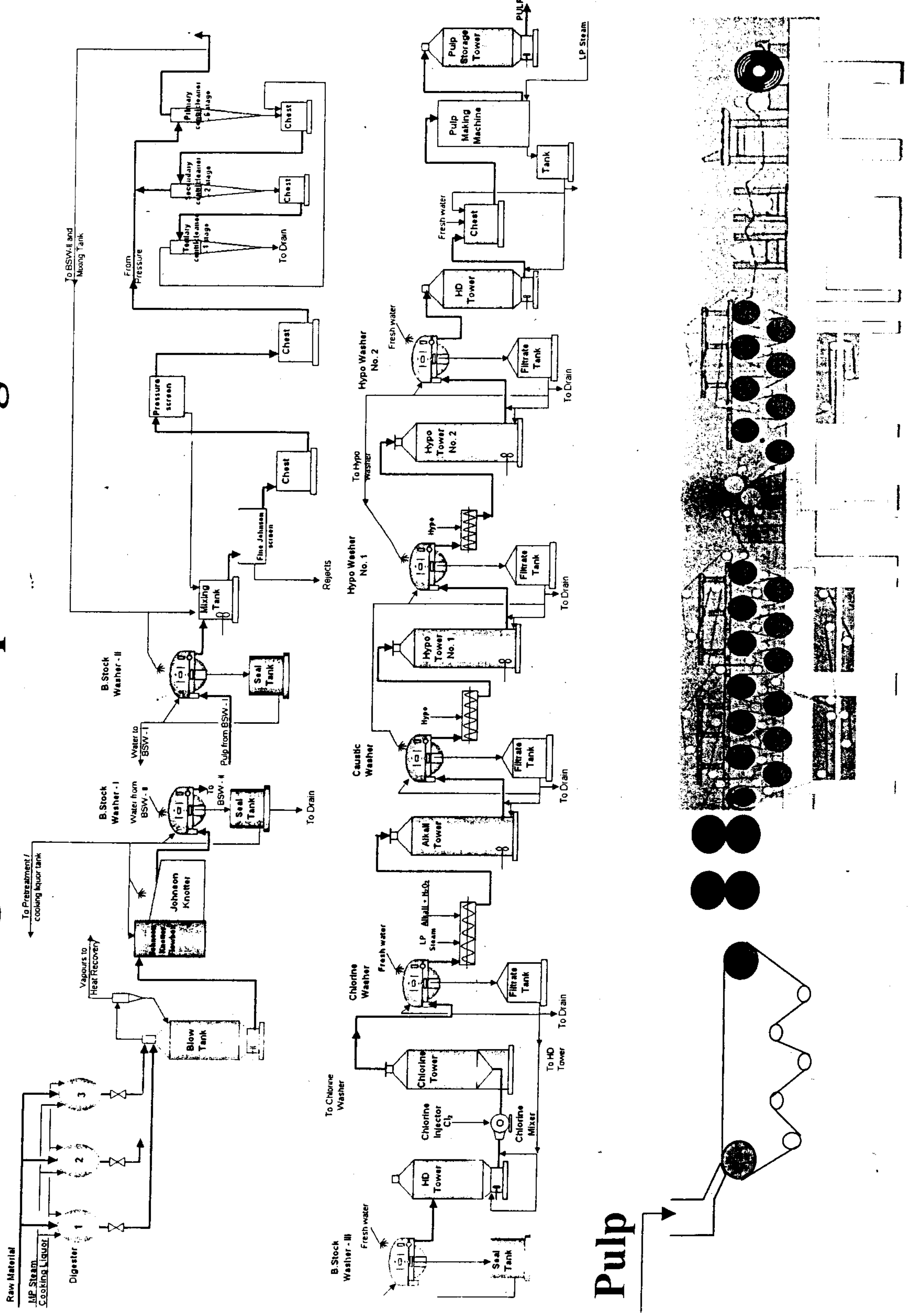
Paper Industry - Milestones

The industry at present is very well developed and established. In 1950 there were 17 paper mills, which increased to 75 during 1975 with an installed capacity of 1.0 million tons. At present there are about 618 units with installed capacity of 6.4 million tons per annum.

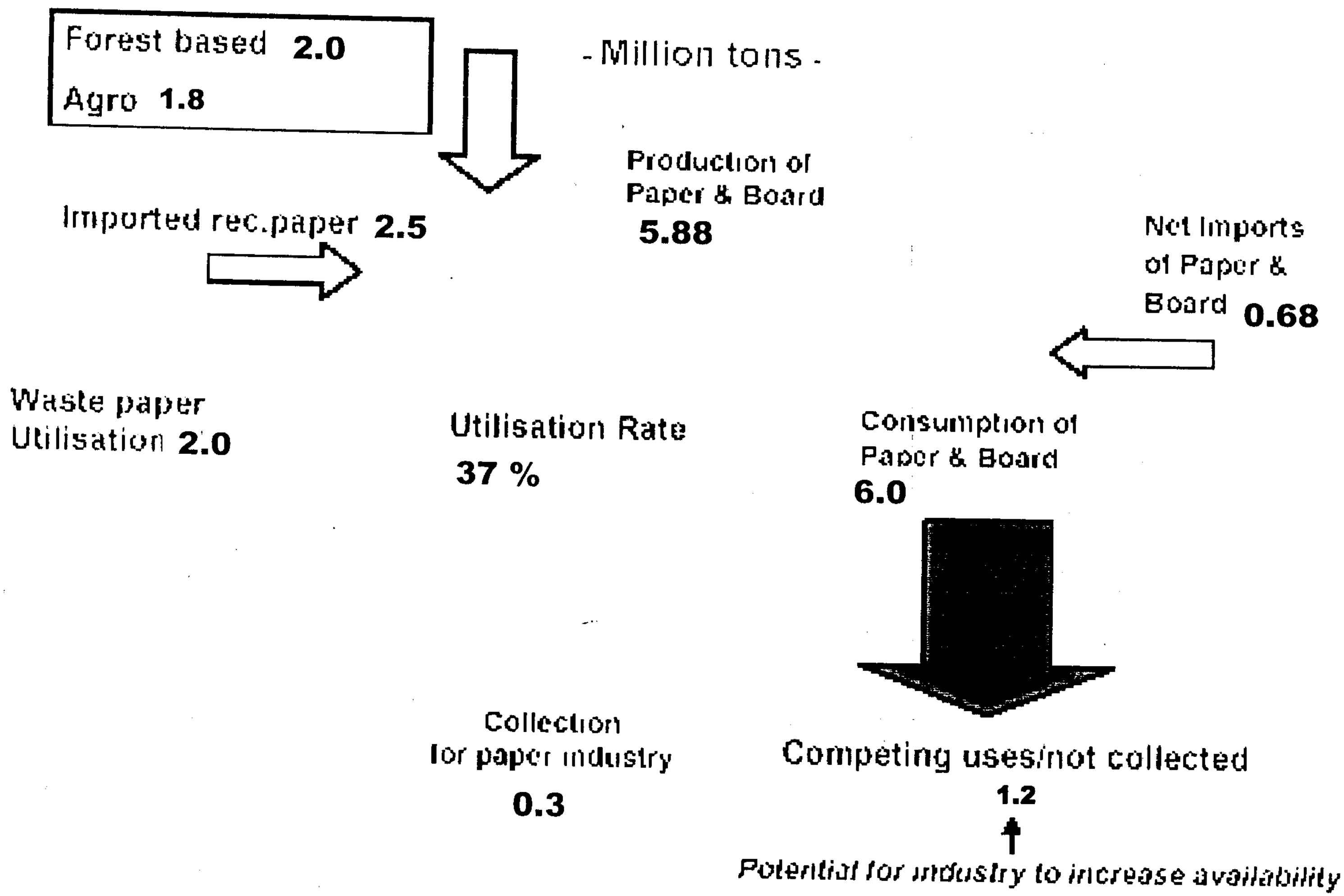



CONVERSION/PACKAGE
CULTURAL/ COMMERCIAL
WASTE PAPER
BIODEGRADATION COMPOSTING/ENERGY
FOREST
WOOD
PULP
PAPER

Flow Diagram of Papermaking Process



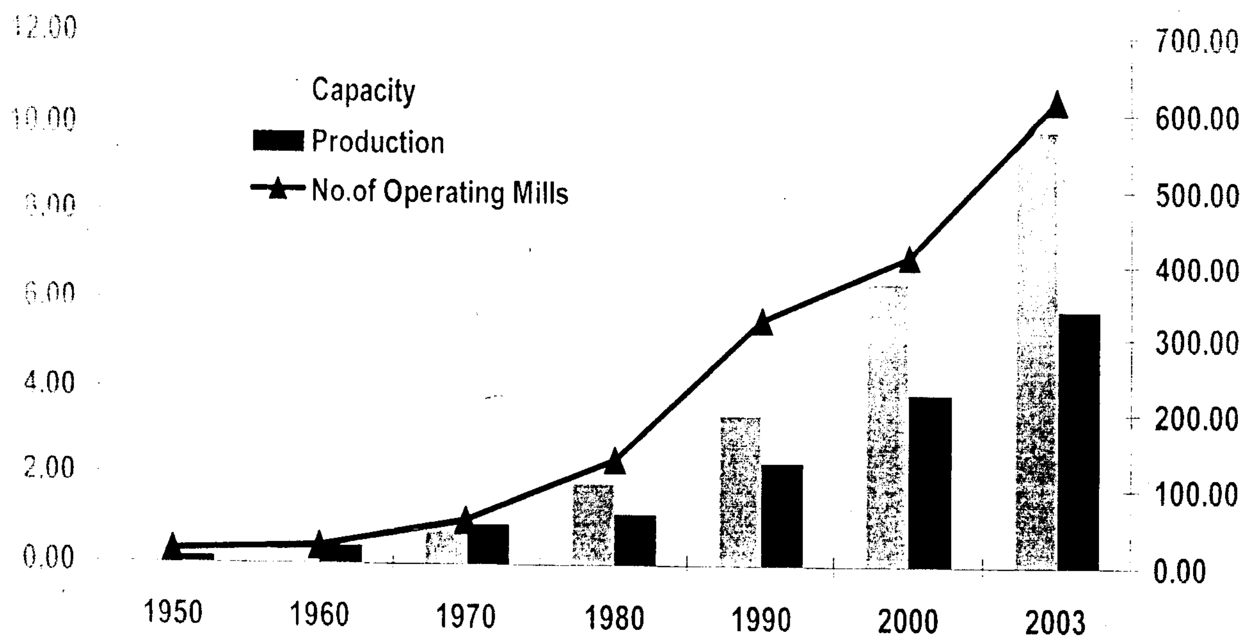
Fibre Flows in Indian Paper Production



Indian Paper Industry

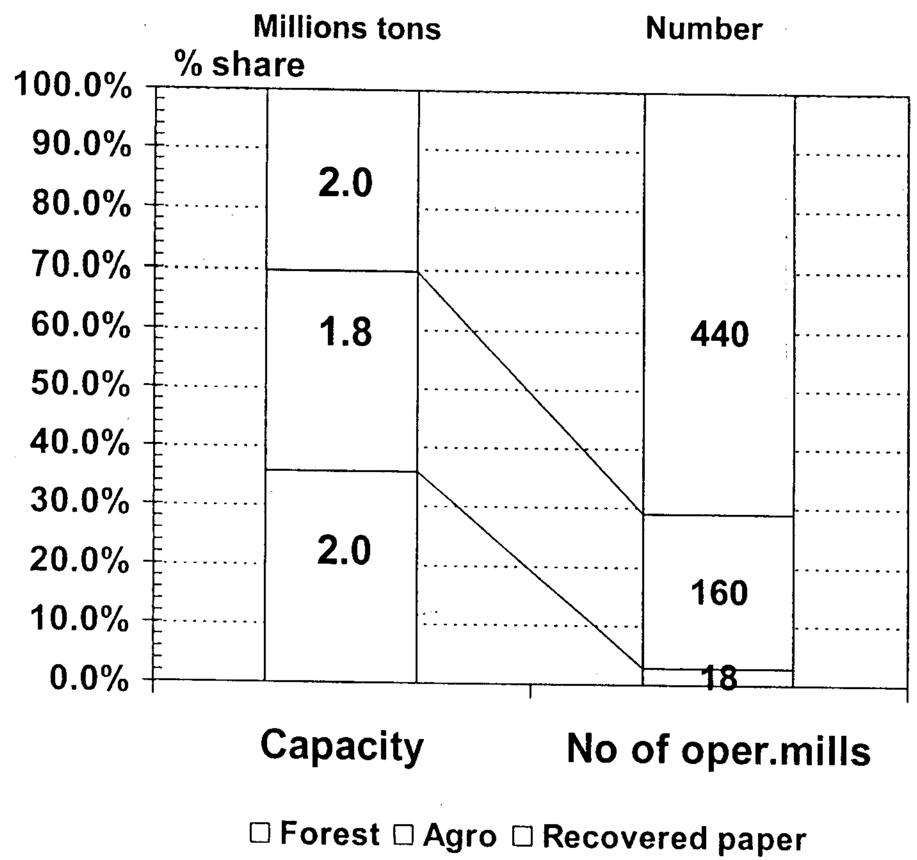
Indian paper industry is highly fragmented, and domestic market oriented. There are over 600 paper mills in operation.

Paper capacity and production in India 1950-2003



Structure of Indian Paper Industry

Today Indian production capacity is almost equally divided into three main fibre groups. By number less than 10 % of mills are forest based (average capacity is higher than that of agro and waste based mills)



Factsheet of Indian Paper Industry

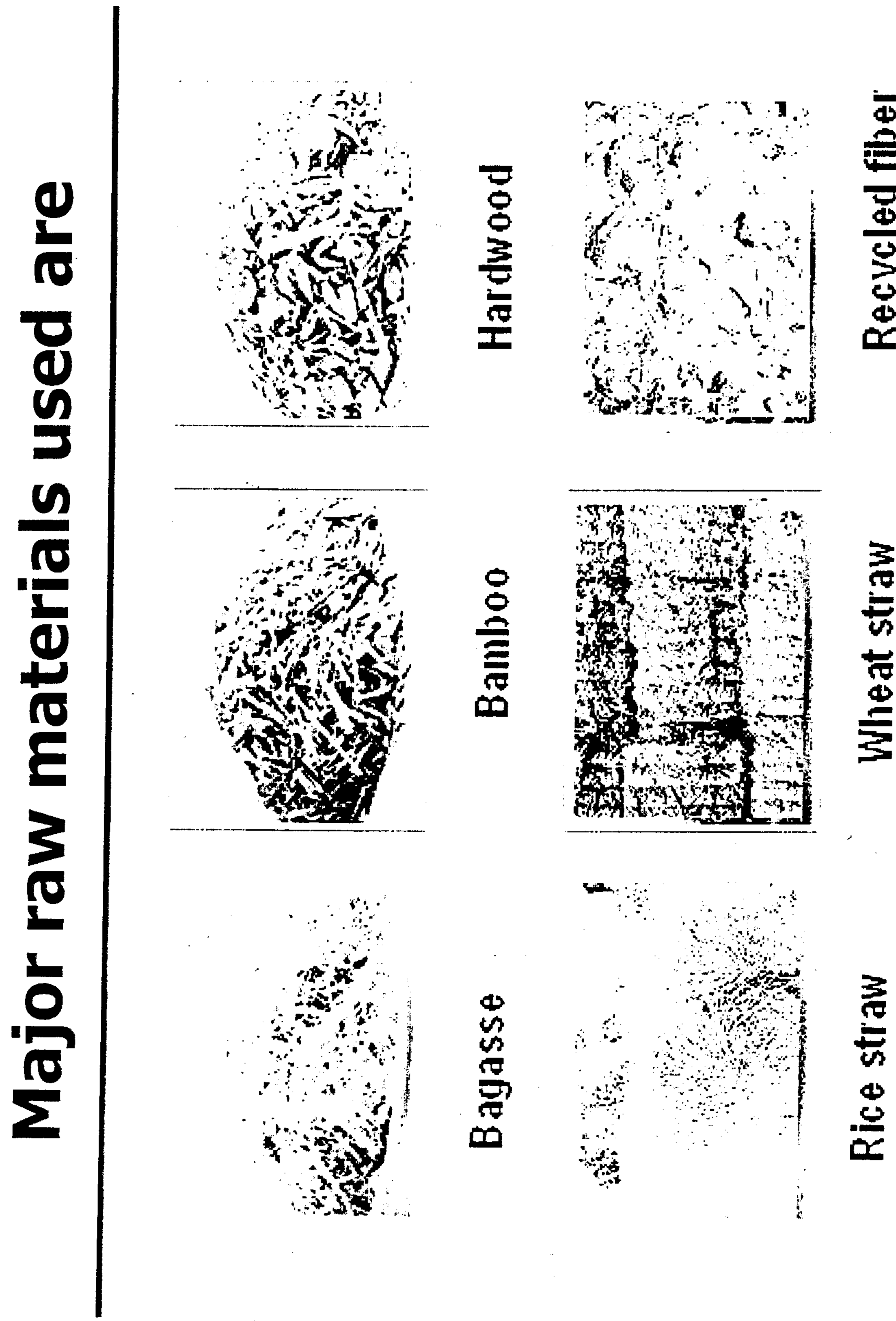
- Percapita consumption – 5.5 kg
- Production - 5.2 million tonnes – P&B
  0.6 million tonnes - Newsprint
- Turnover - Rs. 16000 Crores
- Exchequer - Rs. 2500 Crores
- Growth Rate,%- 6.2 / annum
- Employment - Direct-3 Lacs / Indirect-10 Lacs
- Export, - 230 million USD

Challenging Paper Demand Outlook

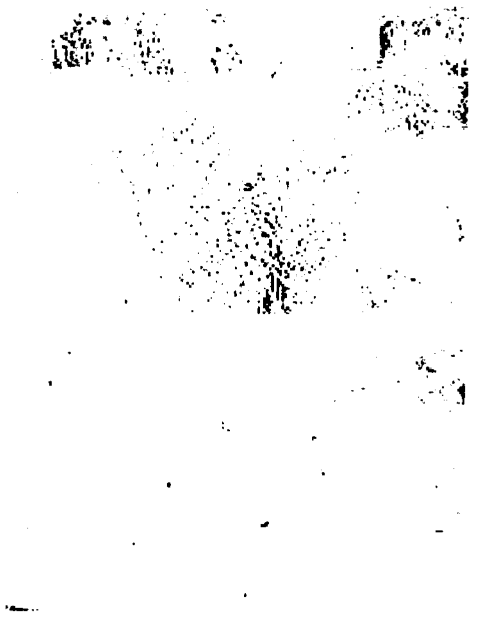
At 6.2 %/year demand growth scenario,

- Industry will be required to meet 4.6 million tons of additional paper demand during the next 10 years
- growing pressure to build new capacity – or imports will grow rapidly
- WTO membership will increase pressure to lower import duties
- competitive industry is needed to meet international competition
- Key question for industry expansion is

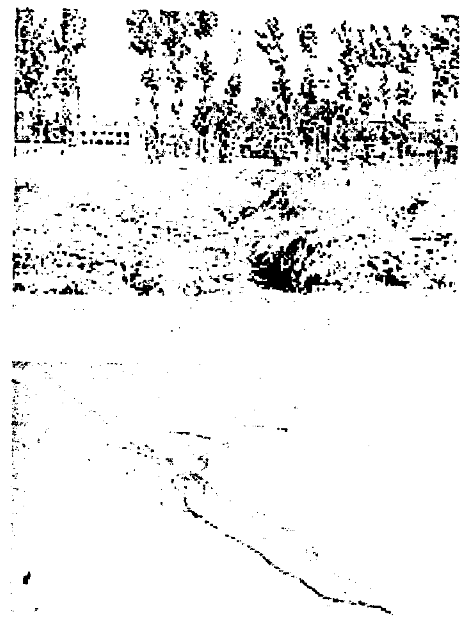
⇨ *How to secure future fibre supply for the paper industry?*


Major raw materials used are
Bagasse
Bamboo
Hardwood
Rice straw
Wheat straw
Recycled fiber

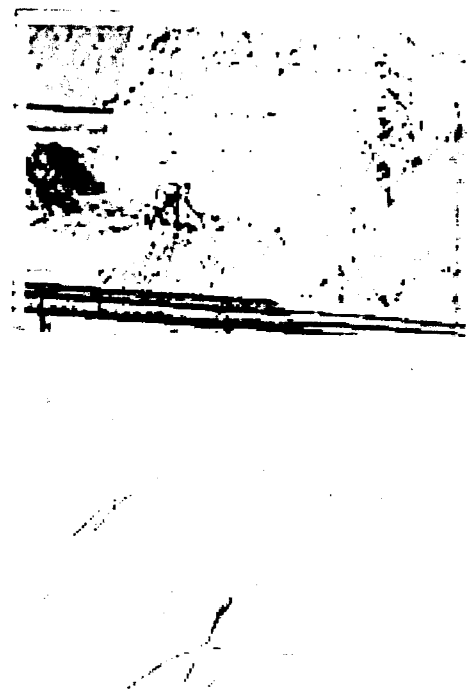
Pulp Fibers from Agro Residues



Rice Straw

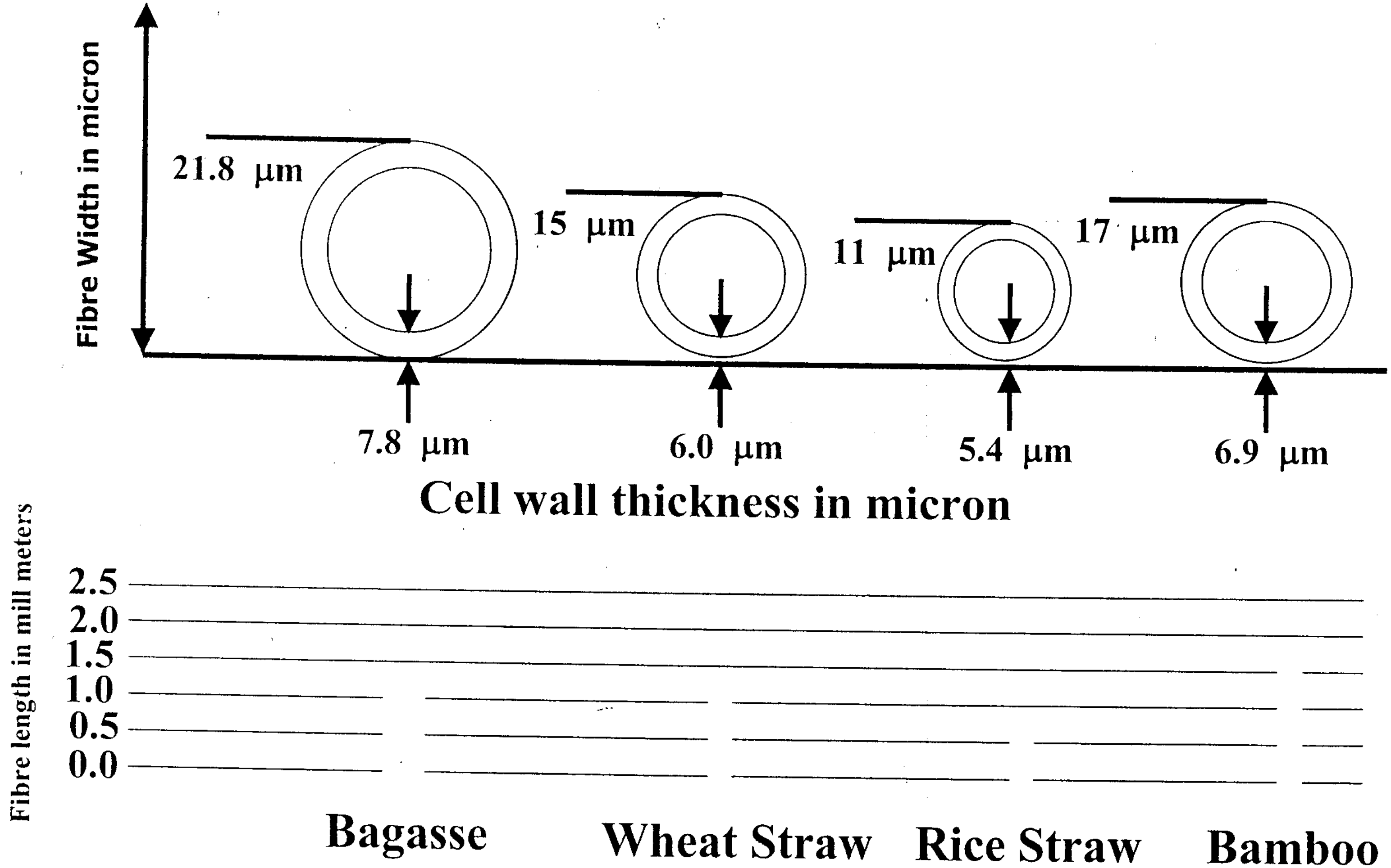


Wheat Straw



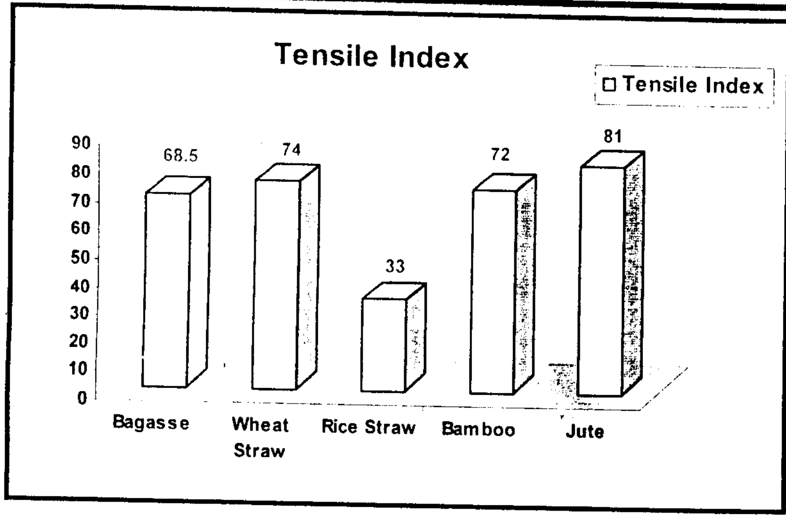
Bagasse

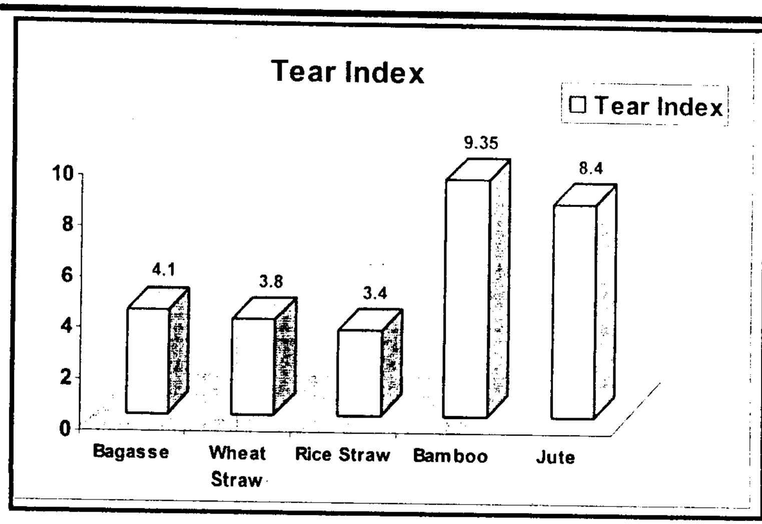
Fibre Dimensions of Agro-residues and Bamboo

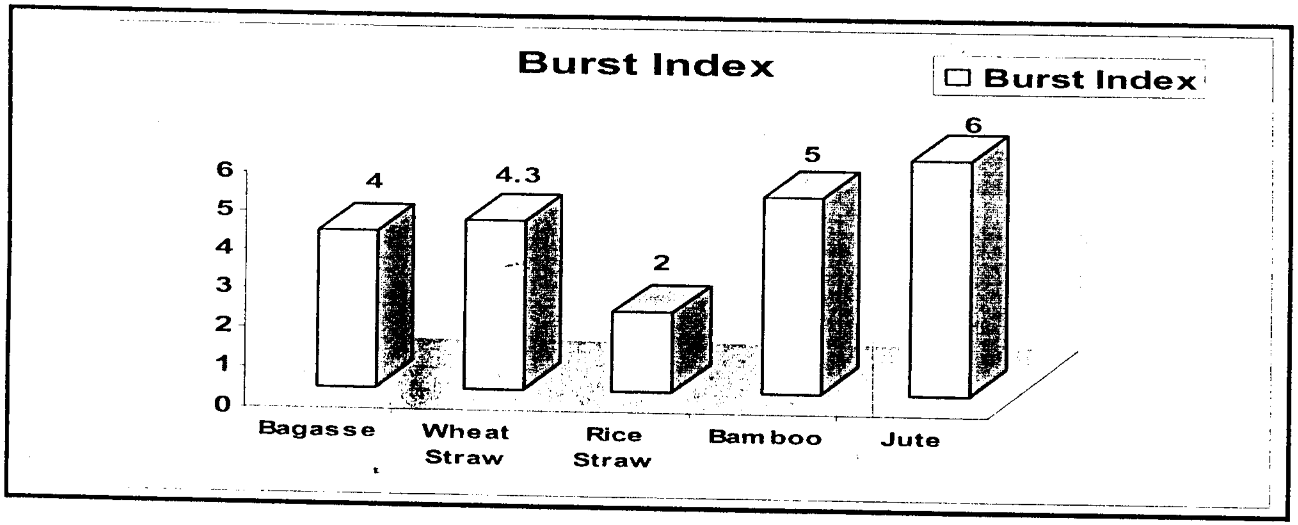


Weight weighted length measured by Fibre Quality Analyser LDA02

Comparison of Strength Properties of Non-Wood Raw Materials







Agro Based Paper Mills In India

Capacity	No. of Mills
Above 100 tpd	10
30 – 100 tpd	63
Upto 30 tpd	84

Agricultural Residues

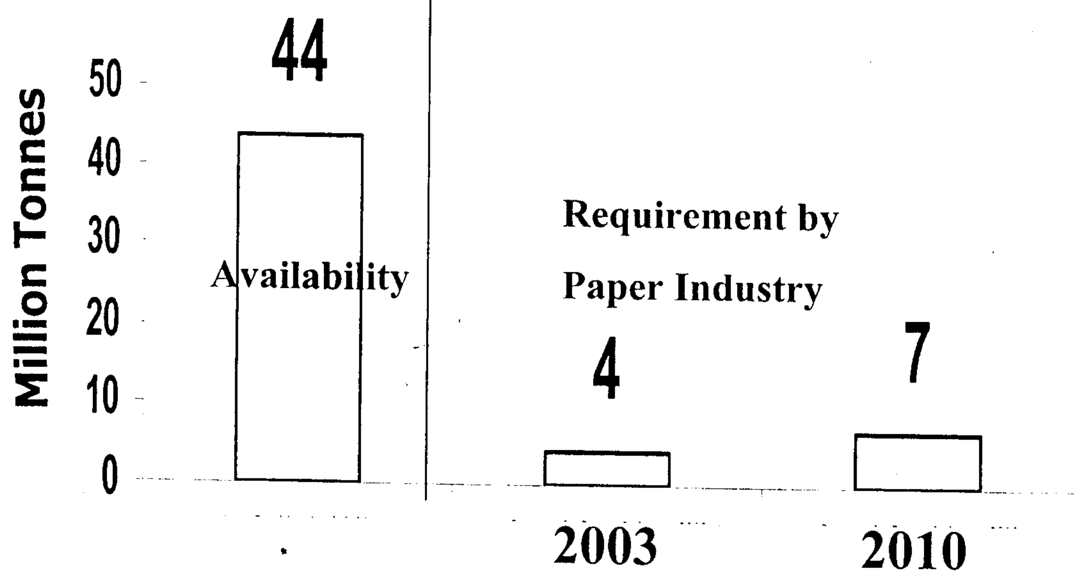
Current Situation

- Agricultural residues are emerging as a significant alternative raw material resource
- Agro based mills account for about one third of the paper capacity
- Today the agro-based paper mills use mainly bagasse and straw as raw material.
- Even if the theoretical availability of bagasse and straw is high there are limitations in their use

Availability of Agricultural Residues In India

Availability of agricultural residues is good, but there are many limitations to their use

- Since 1970 agricultural residues have emerged as significant alternate raw material with total fiber use share of about 29%.
- The main agricultural residues utilized by the paper industry include bagasse, straws (wheat and rice) and grasses.



Annual Potential of Agro Based Fibers in India 2004

Agro residue	Availability Mill.tons	Tons needed for 1 ton of pulp	Pulp potential (Theo.) Mill. tons	Wood required for same Qty of pulp Mill. tons	Total forest cover conserved (Mill.Hect.)	Total Tree in Million
Wheat straw	**22**	**2.5–3.5**	**7**	**15.4**	**1.54**	**289**
Rice straw	**15**	**2.5-3.5**	**5**	**11.0**	**1.10**	**206**
Bagasse	**10**	**5.0-6.0**	**2**	**4.4**	**0.44**	**83**
Total	**47**		**14**	**30.8**	**3.08**	**578**

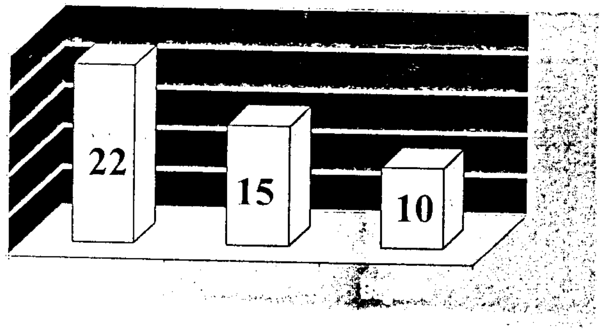
* Eucalyptus plantation growth @ 10 Tons wood/Hectare/Year

** Eucalyptus stands @ 1500 trees /hectare (3 x 2 meter distance)

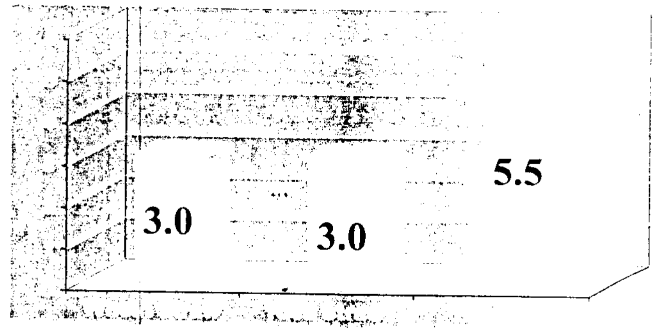
(IAPMA estimate)

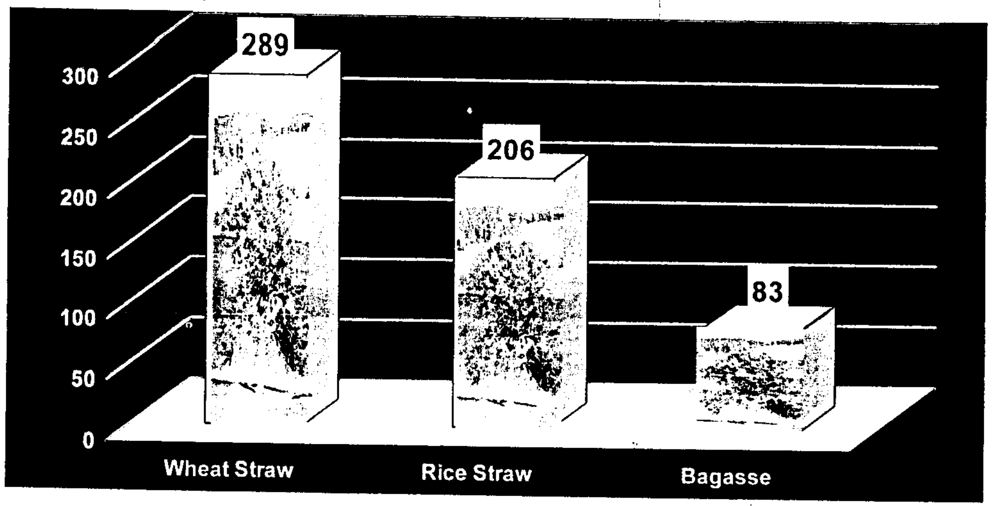
Annual Potential of Agro Based Fibers in India 2004

Availability in Million tons



Tons required for 1 tone of pulp





Total Trees in Millions Saved

* Eucalyptus plantation growth @ 10 Tons wood/Hectare/Year

** Eucalyptus stands @ 1500 trees /hectare (3 x 2 meter distance)

Bagasse

- The surplus bagasse produced by sugar industry is being utilized by the paper industry,
- Products from bagasse :-
  - Newsprint
  - cream- wove and
  - maplitho grades.
- The energy use of bagasse is currently subsidised, which limits the availability of bagasse for paper industry.

SWOT Analysis for Bagasse

Bagasse is not a competitive basic but an additional fibre. New projects should be based on wood or RCF. Investments are not viable in smallest bagasse based mills.

Strength

- Low raw material cost
- Tree free raw material
- Longer fibres than with straw
- Low refining energy consumption
- Good formation and smoothness

Opportunities

- Fibre for corrugating medium
- Twin wire machines & shoe presses
- Supported web run in dryer section
- Soft calender and shoe nip calender
- Only additional fibre (less than 25%
- New digesting and silicate removal methods

Conti...

SWOT Analysis for Bagasse

Weaknesses

- Seasonal and variable raw material- high storage cost and quality variation(pith)
- Low brightness and yield
- Quite short fibre- low wet strength and tear
- Very easy lumen collapse – optical properties, bulk and stiffness problems
- Slow drainage, low press dryness- high drying steam consumption

Threats

- Mill size must be small – not competitive
- PM speed must be slow- not competitive
- Effluent treatment is too costly
- Fibre can not be tailored for paper making by refining
- Runnability problems – low fibre content

Straws

- The total consumption of rice and wheat straws for pulp and paper production is 0.4-0.5 million t/a.
- Rice straw accounts for 70 % of the total straw consumption.
- Though straw is strongly encouraged for papermaking, its use has been restricted due to:
  - Scattered nature of the resource, which increases the cost of collection
  - Bulky nature, poses difficulties in transport and handling
  - Seasonal availability and elaborate storage
  - High silica content

Contd….

- **Disadvantages of straw pulp** - poor strength and drainage properties
- **Favourable features** - formation and easy beatability.

The uncertainties related to the raw material supply will, however, limit major capacity expansions despite the available surplus supply.

SWOT Analysis for Wheat Straw

Straw is not a competitive basic fibre but an additional fibre. New projects should be based on wood or RCF. Investments are not viable in smallest straw based mills.

Strength

- Low raw material cost
- Tree free raw material
- Includes also some long fibres (2 mm)
- Low refining energy consumption and good bonding
- Good formation and smoothness
- Suitable for corrugating medium

Opportunities

- Twin wire machines & shoe presses
- Supported web run in dryer section
- Soft calender and shoe nip calender
- Only additional fibre (less than 25%
- New digesting and silicate removal methods

Conti...

SWOT Analysis for Wheat Straw

Weaknesses

- Bulky, seasonal raw material – high transport and storage cost, low yield, high silicate content and variable quality
- Contains short and sticky fibres, low wet strength and tea, runnability problems
- Low brightness, lumen collapse if refined – lower optical properties and bulk
- Drainage problems and high drying steam consumption

Threats

- Mill size must be small – not competitive
- PM speed must be slow- not competitive
- Chemical Recovery / Effluent treatment is too costly
- Fibre can not be tailored for paper making
- Runnability probems – low fibre content

TECHNOLOGICAL BARRIERS OF AGRO MILLS

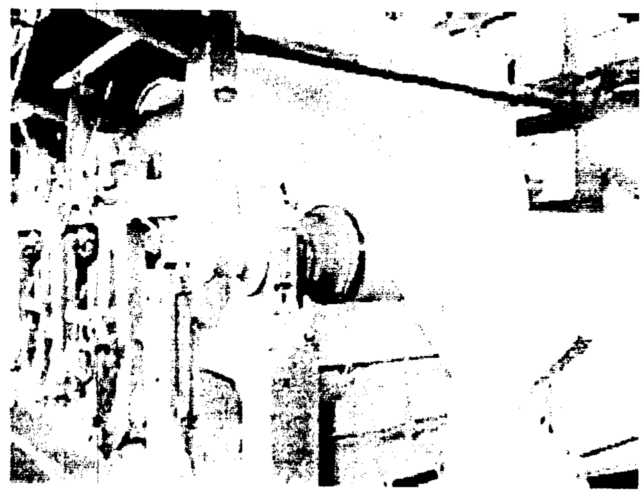
- Uneconomic scale of operation.
- Obsolescence of technology in most cases.
- High cost of purchased power.
- Lack of eco friendly state of the art processing technologies.
- It is not possible to have very high speed paper machine, i.e. >1500 mpm for type of raw material available in India
- For adoption of new papermaking technology limitations are mill size and quality of raw material.

PM CAPACITY AND SPEED – ECONOMY OF SCALE

Mills and machines are relatively small in Agro sector, technology is out dated and quality of raw material and end products is low.

Mills require-

- **High speed machines (about 50% of International size).**
- **Better automation – QCS and DCS**
- **Focus on few grades with efficient marketing and distribution channels.**



ENVIRONMENTAL ISSUES

Solid Wastes – Disposal of lime sludge and

Fly ash

Liquid effluents – Suspended solids

Discharge of coloured effluents and

AOX

Air Pollutants -- Mercaptans

Suspended particulate matter

Corporate responsibility for environment protection (CREP) has been enforced from 2003 to be complied by 2005 to 2008.

CREP – Agro based Pulp Mills

Environmental issues	Implementation Schedule (from April 2003)
Compliance of standard of BOD, COD & AOX	Either achieve the discharge Standards of BOD, COD & AOX by installation of chemical recovery system or utilization of black liquor with no discharge from pulp mill within 3 years or shift to waste paper
Up gradation of ETPs so as to meet discharge standards	Upgrade the ETP within one year so as to achieve the discharge standards
Waste water discharge/ tonne of paper	< 150 m^3/t_{paper} within 3 years
Utilization of treated effluent for irrigation	Wherever possible
Colour Removal from the effluent	IPMA to take up project with CPPRI

Conclusions

- Agro fibres will continue to be an important part of Indian paper mills fibre mix in the future
- Technology improvement of agro fibre processing will support the use of agro fibres together with virgin fibre and waste paper

ROLE OF NON-WOOD PLANT FIBRE IN INDIAN PAPER INDUSTRY

Dr. A.R. K. Rao,
Consultant,
Ex. Chairman cum Managing Director,
H.P.C. Ltd.(A Govt. of India Enterprises)

About The Author

Dr. A,R.K. Rao, Ex Chairman cum Managing Director, Hindustan Paper Corporation Ltd. (A Govt. of India Enterprise) with a brilliant academic career is an engineering graduate (B.Tech. Chemical) from Osmania University, Hyderabad (A.P.) and a post graduate in engineering from Indian Institute of Science, Bangalore. He stood Second in B.Tech. Chemical Engineering exam in the year 1963 in University of Osmania, Hyderabad. He has the distinction of holding merit scholarship of the same university during the academic year 1962-63 and of Indian Institute of Science, Bangalore for three consecutive years from 1963-1966. He holds a Ph. D degree in Chemical Engineering from University of Ottawa, Canada (1970). He was Chairman cum Managing Director ,H.P.C. Ltd., from April, 1996 to January, 2001.

During his tenure as CMD he also functioned as Chairman of Hindustan Newsprint Ltd., Newsprint Nagar, Kerala and Mandya National Paper Mills Ltd., Belagula, Karnataka subsidiary companies of H.P.C. Ltd. Prior to joining as CMD he was with The Mysore Paper Mills Ltd., Bhadravati, Karnataka from June, 1993 to March, 1996.

As an young Engineer he joined The Andhra Paper Mills Ltd., Rajahmundry (A.P.) as Chief Chemist in February, 1973 and held this position till December, 1975 and was subsequently promoted to the post of Superintending Engineer (Planning & Development) in January, 1976 . Prior to attaining the highest position in a Govt., Enterprise he held various important positions

- Project Coordinator (UNDP/FAO-GOI Project), New Delhi, February, 1977 to June, 1981

- Director (Acting), Central Pulp & Paper Research Institute, Saharanpur, U.P. December, 1980 to June, 1981.

- During his tenure in Seshasayee Paper & Boards Ltd., Erode (TN) from June, 1981 to March, 1993 from the post of Manger (R&D) he rose to the level of Vice President (Technical).
- Asstt. General Manager (Research & Development & Technical Control), December, 1985 to June, 1986.
- Asstt. General Manager (Technical), June, 1986 to March, 1990
- Vice President (Technical), April, 1990 to March, 1993.

He has more than 45 technical articles to his credit, which have been published in various National & International journals of high reputation like TAPPI, APPITA, IPPTA, Pulp & Paper Chemical Engineering Sc., Canadian Journal of Chemical Engineering etc. He has the distinction of holding important position in various technical associations. He was President (IPPTA), 1998-1999, Vice President (IPPTA in 1996-1997 & President (INMA) in 1997-98 & 1998-99. He was the member of Technical association of Pulp & Paper Industry, U.S.A. and Technical Association of Australia and New Zealand.

Served as National Editor for the technical journal "Pulp & Paper International" from 1990 to 1998. Was the Chairman of "Paper & Its Products" (excluding packaging material) Sectional Committee, CHD 15, of BIS, Govt. of India from 1991 to 2001. Was member of Indian Delegation to hold discussions regarding Technical Cooperation in the field of Pulp & Paper Technology with Russian delegation in the year 1980. Was sponsored by Govt. of India and FAO of United Nations to visit Pulp & Paper Research Centers in eight European Countries.

Was honored by IPPTA on October 13, 2000 in the Zonal Seminar at Jaipur for significant contribution and was presented with a memento.. Was also facilitated for technical contributions to Indian Pulp & Paper Industry with a memento by "The Indian Paper Mills association" on February 21, 1992 at Kolkata on the occasion of Golden Jubilee Celebrations. Participated as faculty in the UNEP workshops on " Environmental aspects of non-wood fibre pulp & paper manufacturing" in China, India & Philippines. He has four best paper awards of IPPTA for the years 1979, 1980, 1981 & 1985 to his credit.

ROLE OF NON-WOOD PLANT FIBRES IN INDIAN PAPER INDUSTRY

Dr.A.R.K.Rao

1.0 INTRODUCTION

- Predominant role of Bamboo in the growth of paper industry in India.
- The spurt in growth in 1980's based on agro-residues.
- The increase in production capacity from 1.56 million tonnes in 1980-1981 to 5.63 million tonnes in 1999-2000.
- The present contribution of 29 to 30% of Indian paper production by agro-residues is significant.

2.0 MAIN AGRI-RESIDUES UTILISED BY PAPER INDUSTRY

1. Bagasse
2. Wheat straw
3. Rice Straw
4. Jute
5. Mesta
6. Grasses
7. Cotton Stalks
8. Cotton Linters
9. Sunn Hemp.

In this presentation, we focus on utilization of bagasse by Indian paper industry.

3.0 BAGASSE

- Sugarcane residue.
- India is world's largest producer of sugarcane close to 280 million tonnes.
- Sugarcane development department's spade work to ensure growing of sugarcane by farmers.
- Bagasse can also be considered as industrial by-product.
- Ready availability.

- Easy accessibility.
- Surplus bagasse in sugar mills is expected to be available between 6 to 10% of bagasse, depending upon the thermal efficiencies of bagasse-fired boilers.
- Substitute bagasse will be available by replacing the bagasse with coal or lignite.
- Can be stored in the form of bales, stacked to acceptable heights.
- Steps need to be taken to avoid auto combustion. Techniques are developed.
- Alternately, wet bulk storage is practiced. However, yard losses need to be controlled and environmental aspects need to be taken care.

4.0 ANALYTICAL ASPECTS

- Bagasse constitutes about 32-34% of cane
- Contains about 50% moisture at the time of generation
- Contains small quantities of residual sugars depending upon the efficiency of cane crushing mills.
- Contains 30 to 32% pith, which has no fibre value, therefore, needs to be removed to an optimum level.
- Rind fiber contains considerable amount of silica, which hampers chemical recovery operations.

5.0 DEPITHING

1. Dry depithing
2. Moist depithing
3. Wet depithing
4. Biological depithing

Fiber loss in depithing operation restricts the complete removal of pith, therefore, undesirable effects of pith can not be totally avoided.

Pith separated from bagasse can be conveniently burnt in boilers, once moisture is reduced.

6.0 DIGESTION

- Pandya continuous digesters are used by the large integrated paper mills for pulping purposes.

- Small mills use spherical digesters with special chemical and raw material mixing arrangement.

7.0 WASHING, SCREENING AND BLEACHING

- These operations are carried out in a similar way done with bamboo and wood pulps, improvising the equipment and operating conditions to suit the poor drainability of the pulps and responses to bleaching sequences.

- Stock preparation, papermaking and chemical recovery operations are not covered here, as they will be dealt in detail by other technical presentations. However, some unique features of the large integrated mills, practicing bagasse pulping are given comprehensively.

8.0 SESHASAYEE PAPER AND BOARDS LTD.

1. Installation of a sugar mill, namely "Ponni Sugars and Chemicals ", with coal fired boilers, adjacent to the paper mill to supply bagasse.

2. To encourage formation of lift irrigation societies, sparing paper mills liquid effluent for irrigation and growing sugar cane in the adjacent fields.

3. Facilitating "NABARD" to give necessary financial support in the form of loans for laying pipelines and installing pumping facilities.

4. To install depithing and baling equipment in the premises of sugar mill and to transport the bagasse to paper mill.

5. To carry out research by sponsoring projects to Tamil Nadu agricultural university to study the effect of irrigating lands with paper mill effluent and to suggest amendments to soil, if necessary.

6. Conducting innovative research, jointly with sugarcane breeding research Institute, Coimbatore, to develop cane varieties to yield high fiber content to result in bagasse with higher pulp yields.

7. Successfully evolved system to monitor stack temperature to avoid auto combustion.

8. Using sulphate white liquors for digesting bagasse also.

9. Practicing chemical recovery with combined kraft black liquors of wood and bagasse.

10. Making provision for separate washing screening, bleaching and refining lines for bagasse and wood pulps.

11. Made provision for blending bagasse and wood pulps in different proportions suiting the product requirements.

12. Treated combined liquid effluent is supplied to lift irrigation societies for rising sugarcane.

9.0 THE MYSORE PAPER MILLS LTD. (MPM)

1. MPM installed a sugar mill in its own premises under the same management.

2. Erected necessary equipment to blow bagasse from sugar mill directly to paper mill's depithing section.

3. Made provision to divert the bagasse to the baling plant, which is installed in sugar mill, to meet with the exigencies arising out of failures in the blowing operations.

4. Special area is allotted to stack bagasse bales in the yard

5. Arrangements are made to blow pith to adjacent boiler house for burning.

6. Depithed bagasse is pumped to the wet bulk storage yard in the form of slurry; piling operations are carried out using a bull dozer and a pay loader.

7. Provision has been made to retrieve the bagasse to feed to the continuous digester of Japanese make.

8. Subsequent operations of washing, screening and bleaching are carried out separately in the old pulp mill section of the plant.

9. Chemical recovery operations are carried out with combined black liquors of wood and bagasse pulping.

10. Bagasse pulps are mostly used in the manufacture of cultural varieties on the old machines. In emergent situations, it is used to the extent of 5% in manufacture of newsprint.

11. Required power, water and steam are supplied to sugar mill by the utility sections of the paper mills.

12. Combined sugar mill and paper mill liquid effluents are treated in a common treatment plant.

10.0 TAMIL NADU NEWSPRINT AND PAPERS LTD. (TNPL)

1. TNPL procures bagasse from sugar mill with an arrangement to supply steam to them by installing and operation coal fired boilers at sugar mill sites.

2. Bagasse from sugar mills is transported using large tipper trucks in loose form.

3. Bagasse is stored in the wet bulk storage form in a large yard.

4. Depithing arrangement is also made at the paper mill.

5. Depithed bagasse is stacked using boom stackers.

6. Retrieving of bagasse is done using belt conveyer systems to feed to the digester

7. TNPL makes chemical and mechanical pulps from bagasse

8. Wood and bagasse pulps are processed separately in washing, screening and bleaching operations.

9. TNPL has the credit to be the first mill to produce successfully mechanical pulps from bagasse to be used in newsprint.

10. Bagasse mechanical pulps are used in manufacturing newsprints, whereas chemical pulps are used for both cultural varieties and newsprint.

11. TNPL practices combined chemical recovery for bagasse and wood black liquor.

12. Common liquid effluent treatment system is used for the whole mill.

13. It has been reliably learnt that efforts are made by TNPL also to use the treated effluents for land irrigation.

Other mills may be having different practices. They could not be cover here.

It is expected that bagasse and straws will play very important role in Indian paper industry in future also.

RELEVANCE OF NONWOOD FIBRES FOR PAPER MAKING - THE CHALLENGES AHEAD

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About The Author

Dr.S.L.Keswani has been in consulting profession ever since his return from Europe in 1968. He has been one the initiators of consultancy concept in India for pulp and paper industry. Since 1974, He heads well established consulting company, Chemprojects Consulting Pvt. Ltd.(formally know as Chemprojects design and Engineering Pvt. Ltd.) who provide engineering services from concept to commissioning the pulp, paper and other Chemical and Process industries, After obtaining Doctor's degree in Cellulose Technology from Technical University, Darmstadt (Germany) in 1960, he worked in a well know Swiss consulting company in Berne (Switzerland) primarily in the field of Cellulose based regenerated fibres and subsequently joined as Head of Research and Development of M/s O. Derrioes A.G Dueren (Germany) , a Voith group company. Subsequently, he worked as Sr. Process Engineer in a Greek mill, where he got interested in utilization of agro residue for pulp and papermaking. From there, he returned to India to be of service to Indian Pulp and Paper Industry.

RELEVANCE OF NON-WOOD FIBERS FOR PAPER MAKING – THE CHALLENGES AHEAD

DR.S.L. KESWANI

1.0 INTRODUCTION

- Paper can be made from any cellulose containing fiber resource.
- Predominant source is forest based raw material which provides substantial biomass/hectare. It however, requires long time to grow. Man made plantations are in vogue worldwide including in India.
- In Indian subcontinent, forest based raw-material is scarce and substantial quantities of raw-material is not easily available to have sustainable capacity for operating an optimum size of wood based pulp and paper mill - currently in range of 500 tpd – 1000 tpd. Higher capacities are coming up in other parts of world where wood based raw material is available on sustained basis.
- Keeping this in view, our country had to look at alternate cellulose raw materials.
- Per capita consumption, which currently is, only 5.5 to 6.0 kg is also low that own waste paper generation is not sufficient to meet substantial requirements. Waste paper has also alternate usages.
- Paper being demand – driven, it becomes an essential commodity / product for a country of our size to create a sustainable and globally competitive industry – alternate raw material sources have to be worked into.
- Viewing the above background, it was early seventies that we started looking at non-wood fibers, which are mostly annual crops in nature (except bamboo) as a source of cellulose for making paper.
- At the initial stage of its development, the slogan became " wealth out of waste" unfortunately, today it is considered as "environmental burden" and unfriendly and unable to obtain green rating.
- Derived from above situation, despite certain negative issues - non-wood fibers have created substantial capacity which is almost 30 – 35% of overall paper production.

- Since these raw materials are bulky and seasonal - capacities of mills is determined on fiber retrievable distance also considering the competing demands for alternate uses.

- Some non-wood fibers are regional in nature namely;

Jute	-	Bengal / Assam
Bagasse	-	Sugarcane growing areas such as U.P, Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh.
Rice straw	-	Punjab & Haryana, Chattisgarh, Uttaranchal, Andhra Pradesh.
Wheat straw	-	U.P. , Punjab & Haryana, M.P. Gujarat etc.
Sabai grass	-	Foot hills of Himalayas, H.P., Terai etc.

- Today, with improved irrigation and agricultural practices, almost all kinds of crops grow in various states thus an additional fiber has become available round the year, resulting into enforced development and usage of multi-fiber application of paper making and accordingly technical and technological development.

- Given the above background - role of non-wood fibers would continue to be very important to meet our requirements of paper and our economy.

- It is quite clear that the likes of TNPL would be an exception but movement from 10 – 30 tpd range can certainly go up to 100 – 200 tpd level or may be even more subject to logistics of availability, collection and storage of fiber resource.

2.0 CHALLENGES AHEAD

- The industry will have to accept some risks and be innovative.

- Substantial development work has been done by research institutes such as CPPRI and also in-house by industry based on in-house floor experience of their process engineers.

- Consultants and suppliers have also made attempts to develop technologies and suitable equipments but there are substantial gaps in incorporation by the industry particularly an element of scare and fear of risk factors.

- No development can take place if industry does not show confidence in scientists and engineers.

- A few companies have developed installations for solving their pollution problems though partially but very little has been done on delignification and bleaching side thus many have preferred opting for waste paper base.

- Our effort is to miniaturize i.e., downsize latest technologies being applicable to larger mill to our requirements. for example;

  A. Small oxygen delignification for non-wood fiber – 50 tpd

  B. Small alkali/oxygen stage which is now successfully working at a couple of mills.

- Similarly, small i.e., smaller than even 100 tpd non-wood fiber pulping recovery systems, can be designed economically.

- Price of caustic soda would continue to rise as it is directly related to energy cost. Please understand recovery is indirectly a caustic soda plant and also source of steam i.e., power - therefore, a useful model can be developed.

- There will be costs involved; and also risks factors but we do not see any major pitfall.

- It is encouraging to note that industry is fast expanding and therefore, must take advantage of <u>technological knowledge</u> & confidence in scientists and engineers in solving their problems.

- Concluding mindset of the gentlemen who matter and manage the destiny of their enterprises <u>must change</u> and be flexible.

- This is the right time as so far it is good going but one never knows in changing global competitivity and economic scenario.

MORPHOLOGY OF NON WOOD FIBRES

STRUCTURE OF NON-WOOD RAW MATERIALS

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About The Author

Dr. Subrahmanyam has a Masters degree in Botany with specialization in Wood Science and obtained his Doctoral degree in Botany from Sardar Patel University, Gujarat.

He joined Hindustan Paper Corporation in 1981 in their R & D group in the Kerala unit and worked in the area of biotechnological application in Pulp & Paper industry and evaluation of various fibrous raw materials for their suitability in Paper industry.

Subsequently in 1990, he joined Central Pulp & Paper Research Institute, Saharanpur as a Scientist. He has worked in the areas of refining of wood and non-wood fibers. He has obtained training in the area of fiber morphology and quality control from PAPRO, New Zealand. He is currently working in area of Pulping & Bleaching.

STRUCTURE OF NON-WOOD RAW MATERIALS

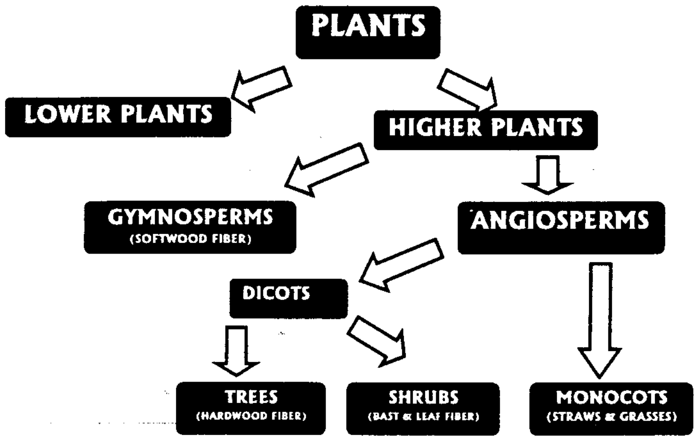
S.V.Subrahmanyam, R.D.Godiyal & A.K.Sharma

Current Global pulp and paper scenario shows that most paper is made from wood fibers. Of the total pulp and paper production, wood pulp accounts for about 90% and the rest is derived from vegetable fibers such as seed hairs, bast fibers, grasses and even animal and mineral fibers. Many specialty paper production demands the fibers other than wood. In areas where the wood supply is constraint, the pulp and paper mills use locally available raw materials such as straw, bamboo, bagasse, kenaf, jute etc.

Indian pulp and paper scenario shows that it uses 39% of forest based fiber, 31% agro residue based fiber and 30% fiber is derived from waste paper. The fibrous raw materials used for the production of different varieties of paper comes from different sources like wood, bast, leaf of trees, shrubs, and grasses. The Indian paper industry produces mostly two types of virgin pulps from the fiber sources i.e Chemical pulps through either soda process or Kraft process and chemi-mechanical pulps. Each material has distinct morphological characteristics and chemical composition. Morphological features of pulp fiber are the key factor controlling the quality of products during papermaking. The fundamental properties of any pulp fiber are length, diameter/width, and cell wall thickness lumen diameter/width. Pulps contain different types of cell types depending on the source.

1.0 Classification of fibrous raw materials:

The vegetable fiber sources are classified as wood fibers and non-wood fibers. The wood fibers are further classified as softwood fibers those are derived from gymnosperm trees and hardwood fibers, which are derived



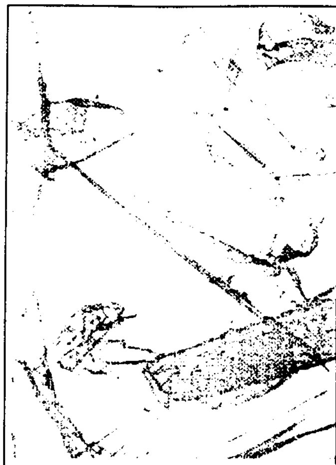
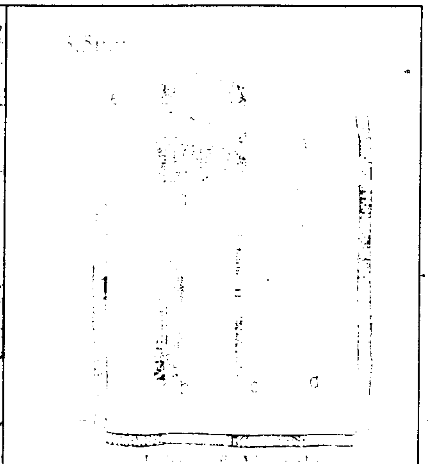
from angiosperm trees.

The non-wood plant (shrubs and grasses) fibers can be grouped into four types based on the botanical part used in making the paper pulp.

1.	Stalk or culms fiber:	Cereal straws, Grasses, Reed, Bamboo, Sugarcane (Bagasse).
2.	Bast fibers:	Flax, Jute, Kenaf, Hemp
3.	Leaf fibers:	Sisal, Abaca
4.	Seed hull fibers:	Cotton

2.0 Morphology of papermaking cells

The fibrous raw materials have different tissue composition based on the botanical source. The cells normally found in the paper pulps are fiber tracheids (normally present in softwoods) or fibers (found in all other fibrous raw materials), parenchyma, vessels (found in raw materials other than softwoods and bast fibers) and epidermal cells (mostly found in agro residues). The composition and structure of these different cells determines the papermaking quality of and acceptability of the fiber source.

	
Fibers and Parenchyma in non-woods	**a, b, c – Vessel elements in Hardwood pulps; d – fibers in hardwood pulps; e – tracheids in softwood pulps**

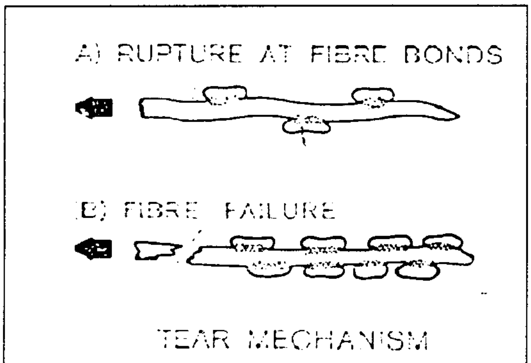
2.1 Fibers

Fibers are the most useful cellulose material in the pulp. These are normally long, flexible and form the basic network (web) in the paper. Fibers contribute to the basic strength of the paper. Fiber is long narrow cell with tapering ends and a central canal known as lumen. The fibers depending upon origin differ significantly. The average fiber length varies from 3.5 mm in softwoods, 0.8-1.2mm in hardwoods, 2-5mm in bast and leafy fibers and 1.0mm to 2.5mm in straws, bagasse and bamboo. Weight proportion of fibers in pulp varies from 95% in softwoods, 65-75% hardwoods and 55-65% in agricultural residues. The papermaking properties of the fiber are attributed to the various parameters of the fibers such as fiber length, fiber width, fiber wall thickness, and fiber lumen diameter. These primary parameters influence the derived parameters like slenderness ratio, coarseness and Runkel's ratio of the fibers. The submicroscopic parameters of the fibers such as microfibrillar orientation in various layers of fibers have also significant influence on the papermaking.

2.2 Fiber length

The papermaking pulps have fiber population with varying lengths. The heterogeneity of the fiber population influences the papermaking and the knowledge and understanding of the fiber length distribution is highly essential in predicting the behaviour of a raw material in the papermaking process. Generally, the fiber length is averaged for a source, which is a relatively easy expression and gives a broad idea for comparison purpose. The average fiber length varies from 3.5 mm in softwoods, 0.8-1.2 mm in hardwoods, 2-5 mm in bast and leafy fibers and 1.0 mm to 2.5mm in straws, bagasse and bamboo. The fibers in a paper web are randomly distributed and depending on the length of the fiber, the number of fiber crossings increase or decrease. If the number of fiber crossings increase due to longer fibers, the web is stronger, thereby having higher wet web strength of the sheet as well as the dry paper strength. The wet web strength is very critical in high-speed machines.

2.3 Fiber width



Strength (Tensile, tear and burst) of paper depends on the number of crossings per fiber (Courtesy: Dr.R.P.Kibblewhite)

The terms width and diameter of the fibers are normally used for all the practical purposes for the same dimension. In a two-dimensional view of the light microscope, it is not possible to distinguish between width and diameter. The unrefined fibers are normally tubular structures, which become flattened on refining. In the paper web when the fibers cross over randomly, the area of fiber cross over (area of bonding) is influenced by fiber width. If the fibers are wide, then the area per cross over increases where the fibers are held together that contributes to the strength of paper web. For a given fiber length, the fibers with higher fiber width gives higher paper strength due to increased cross over area per fiber.

2.3 Fiber lumen

The central cavity in the fiber is known is fiber lumen, which is void. Depending on the extent of void space, the fiber may flatten (collapsibility) to different extents, as the fiber is refined. Higher the extent of collapsibility then higher is the bonded (contact) area. The fiber lumen is different for different species. The fibers in the same source have different fiber lumen due to seasonal variations in the wood formation. For example the late (winter) wood fibers are have narrower fiber lumen compared to the early (spring) wood fibers. Rind fibers have thicker wall compared to the fibers in vascular bundles as in bagasse and straws.

2.4 Fiber wall thickness

Fiber wall is specific to a given fiber source. Depending on the fiber wall thickness the fibers' response to refining varies. Fibers with thin cell

Parenchyma cell of bagasse

2.6 Parenchyma: It is also called as nonfibrous parenchyma cells are cellulosic. The dimensions of parenchyma vary with source raw material. They do not contribute to the strength of the paper and often create serious drainage problems affecting the productivity especially in the agricultural residues. The weight percent of parenchyma (nonfibrous) cells is about 5% in softwoods, 25-35% in hardwoods and 30 to 45% agriculture residue pulps. The parenchyma is the source of primary fines in virgin chemical pulp. Reduction of this nonfibrous tissue especially in nonwoods is a big challenge and wherever it could be effectively reduced, resulted in chemical savings and improved quality of pulp. Raw material pretreatment methods in agro based paper industry are principally targeted to reduce the nonfibrous tissue.

2.7 Vessels

The vessel elements are the single units of the vessels. They are spiral shaped in straws, long, narrow and cylindrical in bagasse and bamboo, short, wide and cylindrical with short tail in the hardwoods. Wherever they are present, they help in the mobility of pulping liquor (penetration) in longitudinal direction of chips.

2.8 Epidermal cells: The epidermal cells are significantly small cells with serrated margins. They appear either in groups or as singles. Their presence is noticeable in straws and bagasse. The dimensions of the epidermal cells vary with the type of straw.

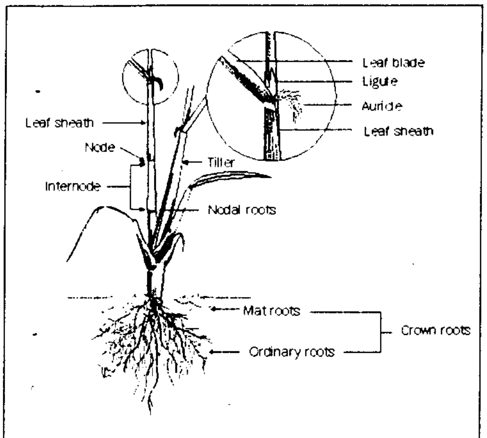

Epidermal cells of wheat straw

3.0 RICE STRAW

Oriza sativa

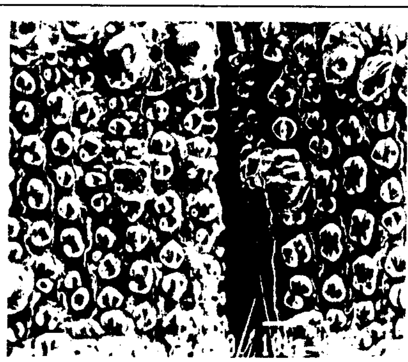
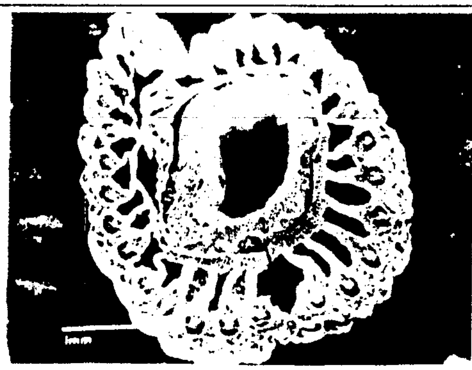
Rice is a member of the grass family (Gramineae) and belongs to the genus oryza under tribe oryzeae. The small and medium size paper mills in India make writing and printing paper from rice straw. The random estimates suggest that 4.0 tons of rice straw is produced per ton of rice. The annual production of rice straw is about 80 million tones as Crop production and about 180 million tones is the residue generation as waste. Rice straw is used for fodder and thatching and therefore less quantity was available for paper industry for paper and board production. The crop to residue ratio of the Rice straw is about 2.50, out of which, less than 1% is being used by paper industry.

3.1 Morphology

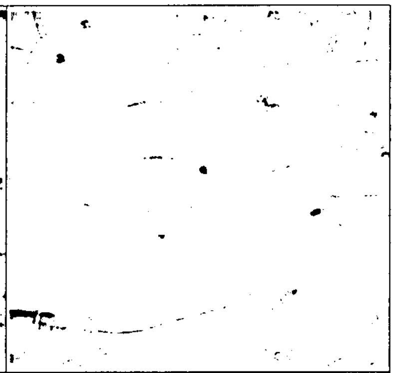


Rice Straw Plant

Rice Straw is a heterogeneous in nature when compared with wood. Straw consists of stem and leaves. The internodes section is called stalk. It is a hollow tube with an annulus thickness of about 0.5 mm. Typically a stem has 5-7 nodes. The stalk length increases from base to head. It carries the grain. Stem length greatly varies from species to species, genetic mutation within a species, soil condition and climate. The stem is separated at intervals by nodes. At the nodes, a sheath that ends in a leaf blade is formed around the stem. Seed hulls and foreign material is found in straw bales. The agricultural waste after extracting the grains is used in papermaking. It is used in straw boards, cheap grade corrugating, writing and printing paper in admixture with long fiberdpulp.

	
Surface view of rice straw	**Sectional view of rice straw**

Magnified view of ground tissue



Rice straw pulp

3.2 Pulp components

Under Scanning Electron Microscope, the stem surface shows spiny structures and silica mapping using X – rays indicate that silica is concentrated in the surface area. The fibers appear cylindrical, having vitreous silica spread all over its surface thereby giving coarse surface appearance under low magnification. Under the high magnification, the fibers show characteristic striations on the longitudinal direction. As separation of individual epidermal cell is difficult, and epidermal peels are observed. The rice straw fiber varies from 0.26- to 3.1 in length with an average of 1.1 mm and 7-14μm in width (average 11.1 μm). The pulp consists of fibers, parenchyma, vessel epidermal cells and spicules. The fibers are thick walled and pointed ends. The fibers are small than bamboo and bagasse. The parenchyma cells are short or long and rectangular. The vessels are long and narrow. The epidermal cells are conspicuous and abundant with serrated margins often not separated with epidermal peel and have distinct papillae on them. Small-oppressed spicules are present, difficult to observe.

4.0

S. No.	Dimensions	Unit	MPM	Punjab
A	**Properties of fiber**			
1	Fiber Length (Weight weighted)(L = 0.20 – 4.0mm)	mm	1.07	0.90
2	Minimum Fiber Length,	mm	0.40	0.26
3	Maximum Fiber Length,	mm	2.7	3.1
4	Mean Fiber width (μ= 7 – 45)	μm	11.1	13.1
5	Lumen Diameter	μm	2.38	2.8
6	Cell wall thickness	μm	5.36	4.14
B	**Properties of non-fibrous tissue**			
7	Length of vessel	μm	198.6	227.1
8	Width of vessel	μm	36.6	36.6
9	Length of Parenchyma	μm	83.8	93.6
1	Width of Parenchyma	μm	28.0	26.7
1	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	64.0	66.6
1	Length weighted Fines (L = 0.01 – 0.20 mm)	%	25.3	27.7

4.0 WHEAT STRAW

Triticum vulgare

The small and medium size paper mills in India make writing and printing paper from wheat straw. The random estimates suggest that 3.0 tons of wheat straw is produced per ton of wheat. The annual production of Wheat straw is about 60 million tones as Crop production and about 90 million tones is the residue generation as waste. Wheat straw is used for fodder and thatching and there fore less quantity was available for paper industry for paper and board production. The crop residue ratio of the wheat straw is about 1.50. Out of this less than 1% is being used by paper industry.

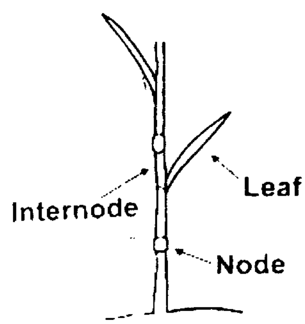
4.1 Morphology of wheat straw

Wheat Straw is a heterogenous in nature when compared with wood. Straw consist of stem and leaves. The internodal section is called stalk. It is a hollow tube with an annulus thickness of about 0.5 mm. Typically a stem has 5-7 nodes. The stalk length increases from base to head. It carries the grain. Stem length greatly varies from species to species, genetic mutation within a species, soil condition and climate. The stem is separated at intervals by nodes. At the nodes, a sheath that ends in a leaf blade is formed around the stem. Seed hulls and foreign material is found in straw bales.

4.2 Tissue composition

Like any botanical tissue, straw consists of cells. A cell has has a multi-corner cross-section. It has a cell wall; inside void portion of cell wall called lumen. The cell wall consist of 80 to 90 % substance on dry basis. The rest 10 to 20 % is deposited within the lumen and consist of silica (5-10 %) and extractives (5-15 %).

S.No.	Botanical part	Wt %
1.	Internodes	46.7
2.	Blades and sheaths	39.9
3.	Nodes	6.9
4.	Glumes	4.1
5.	Grains	0.2
6.	Foreign matter	2.2



When viewed under the Scanning Electron Microscope the most of the useful fibers located at the outer part of the stem i.e. near the skin with a little area of the fibers being present in the vascular bundle. The parenchyma cells, which constitute mainly fines, occupy about 75 % of the total area. The fibers originating from the out part of internode are thick walled and those coming from the inner part are called thin walled. However, the bulk of the fibers (80%) are from the outer part of stem. The cross section of wheat straw stem will differentiate in to different categories of cell types, where fiber is 25%, Parenchyma is 75% and vessel proportion is 3%.

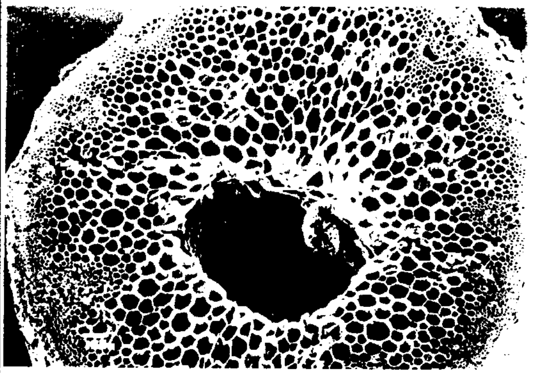
4.3 Pulp Components

The wheat straw is normally converted to chemical pulp using soda process in the Indian paper industry. The pulp contains fibers, parenchyma, vessels, and epidermal cells. The fibers are slender and long and the ends are pointed. The fiber lumen varies from broad to narrow. The fibers have an average length of 1.22 mm and the range is from 0.52 to 2.37 mm. The average fiber width is 14.9 microns. The parenchyma is abundant and barrel-shaped. The epidermal cells vary in size and form, sparsely pitted, have more or less serrated margins and appear in either groups or singles. The vessel elements are slender and long.

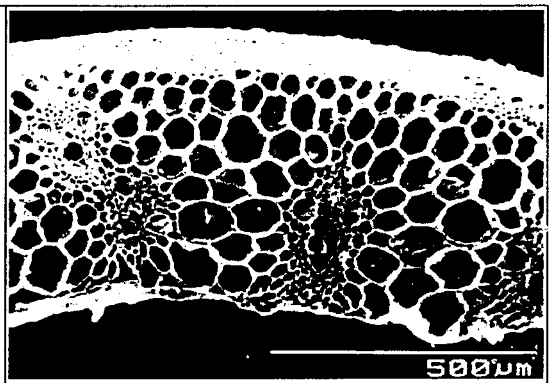
Dimensions of wheat straw pulp components:

S. No	Dimensions	Unit	Wheat Straw
A	***Properties of fiber:***		
1.	Fiber Length (Weight weighted)(L = 0.20 – 4.0mm)	mm	1.15
2.	Minimum Fiber Length,	mm	0.26
3.	Maximum Fiber Length,	mm	3.84
4.	Mean Fiber width (μ= 7 – 45)	μm	15.2
5.	Lumen Diameter	μm	3.31
6.	Cell wall thickness	μm	5.95
B	***Properties of non-fibrous tissue***		
7.	Length of vessel	μm	195
8.	Width of vessel	μm	27.2
9.	Length of Parenchyma	μm	193
10.	Width of Parenchyma	μm	44.2
11.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	56.9
12.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	15.9

5.0 WHEAT STRAW

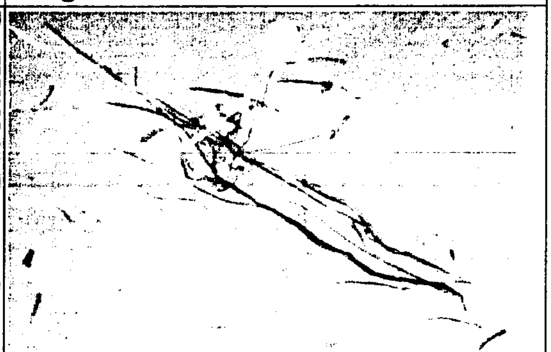


Cross section of wheat straw

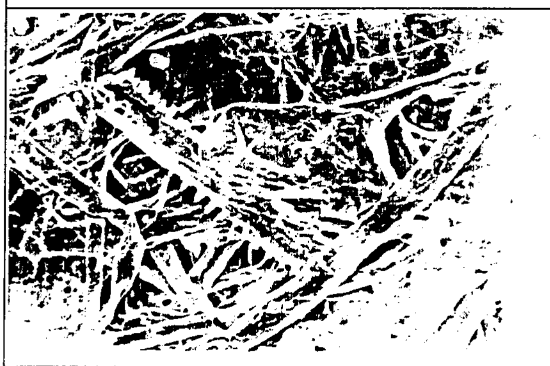


Magnified view of XS of wheat straw

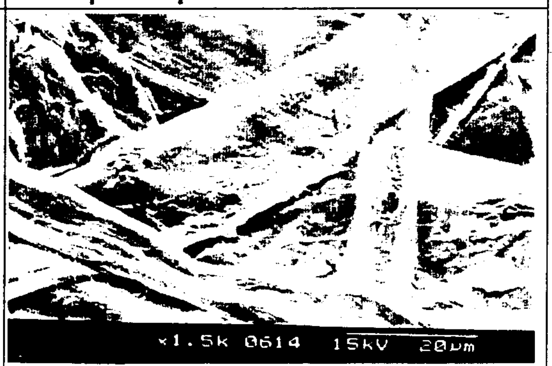
Cross section of fibers



Pulp composition of wheat straw



Paper surface showing various cells



Magnified view of fiber crossings

6.0 BAGASSE

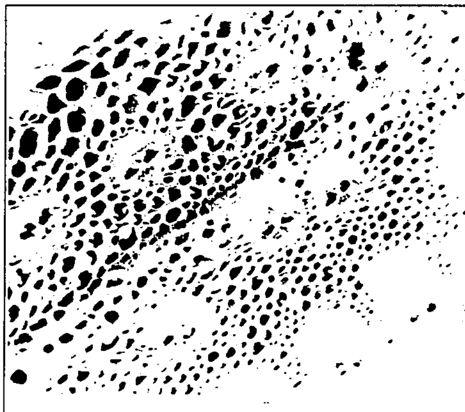
Saccharum officinarum

Sugar cane (Saccharum officinarum) residue, commonly known as bagasse is one of the prime papermaking fiber source. About 7.2 million tonnes of bagasse is produced per annum in India. Sugar cane is cultivated in about 4.25 million hectare of agriculture land in India at a yield rate of 70 ton/hectare. Sugar factories crush about 180 million tons of sugar cane per year and the season lasts for 150 to 180 days. Major sugarcane growing states are Utter Pradesh, Maharashtra, Tamilnadu and Karnataka. Bagasse constitutes about 30% of cane processed for production of sugar, which is used as a fuel for cogeneration of steam and power to meet the process requirements. Depending upon the energy efficiency, sugar mills also save bagasse, ranging from 4% to 10% on cane. This spare bagasse is used for production of pulp, paper and particleboard.

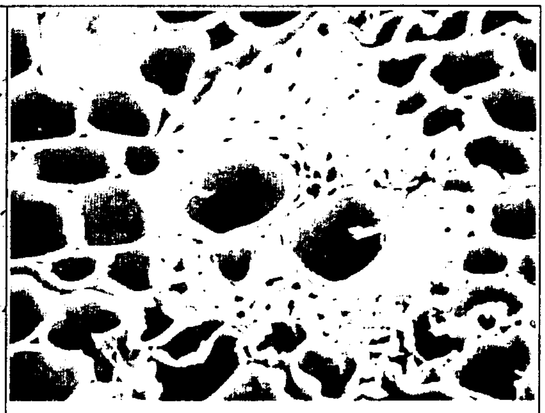
Bagasse is highly bulky and its transportation to the paper mills poses serious problems. Hence, the paper plants, which are situated near the sugar mills, are only able to partly utilize bagasse as a raw material for production of paper. Bagasse is generated from the renewable agriculture source its use in paper industry reduce the dependency of paper industry on forest based fiber and conservation of forests preventing global warming. As per the Development council India (APFSOS/WP/10) the total bagasse production in 1990 was 7.2 million tons of which 15% was supplies (1.08) million tones) which is equivalent to 0.18 million tons /year paper.

The fibers are obtained from the stem of sugarcane plant after extracting the juice. The fibers in admixtures with some long fibers are used for the manufacture of all types of cheap grade Cultural and industrial paper. The fiber varies 0.3 to 4.0 mm in length and width varies from 10 to 40μm. The wider fibers are thick to thin walled, with straight, pointed tapering ends and relatively more numerous slit like or lenticular pits than in bamboo. Transverse markings similar to those of bamboo are quite common. The wider fibers are usually shorter and comparatively thin walled not frequently with blunt, oblique or forked ends. Parenchyma cells are very abundant, usually appreciably larger than those of bamboo. They are up to 900 μm in length with an average of 358 μm and up to 180 μm in width with an average of 78 μm and serve to distinguish bagasse from bamboo. The parenchyma cells are small to medium sized narrow rectangular and numerous. Vessels are similar to those of bamboo, ranging from 180 to 1600 μm and 30 to 220 μm long and narrow. The epidermal cells somewhat narrow and rectangular with undulating margins are always present. Stomata may be rarely present.

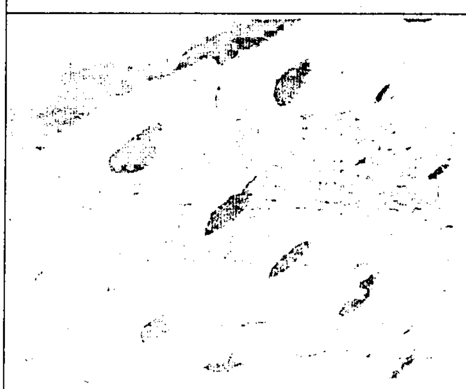
BAGASSE



Cross section of bagasse

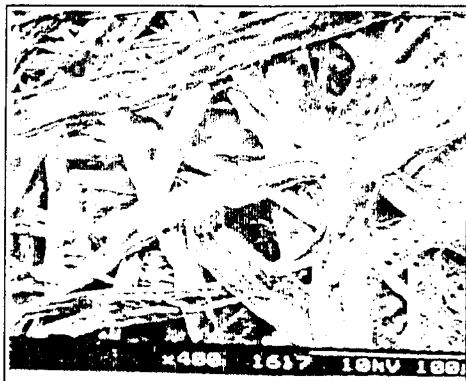


Magnified view of vascular bundle

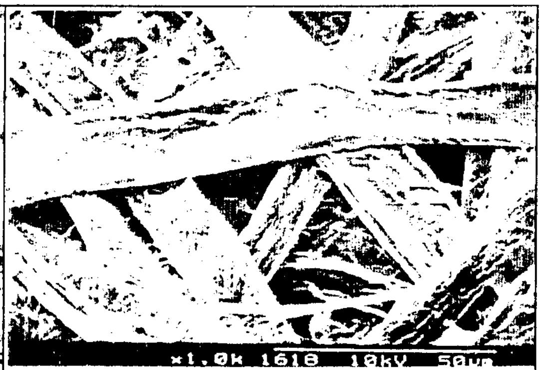


Cross section of fibers

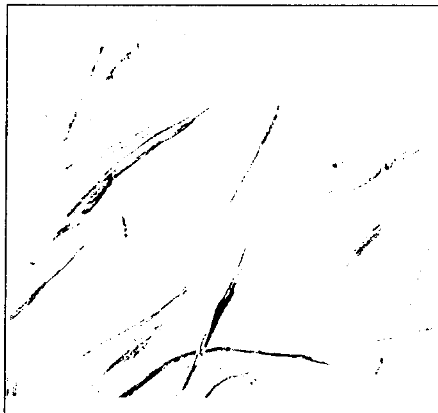
Section showing ground tissue



Surface view of paper



Magnified view of fiber crossings



Bagasse pulp components

Magnified view of vessel element

Prominent parenchyma cells

Enlarged view of fiber, note bright wall and fiber lumen

S.No.	Dimensions	Unit	Bagasse (Punjab)	Bagasse (Chenni)
A	***Properties of fiber:***			
1.	Fiber Length (Weight weighted)(L = 0.20 – 4.0mm)	mm	1.24	1.52

2.	Minimum Fiber Length,	mm	0.35	0.32
3.	Maximum Fiber Length,	mm	3.62	3.9
4.	Mean Fiber width (μ= 7 – 45)	μm	19.3	21.8
5.	Lumen Diameter	μm	4.07	6.29
6.	Cell wall thickness	μm	7.65	7.76
B	***Properties of non-fibrous tissue***			
7.	Length of vessel	μm	287.5	151.6
8.	Width of vessel	μm	101.4	27.8
9.	Length of Parenchyma	μm	358.5	327.7
10.	Width of Parenchyma	μm	78.2	53.2
11.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	61.9	58.3
12.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	20.5	17.0

7.0 SARKANDA GRASS

Saccharum bengalense

It is very large erect grass, growing in clumps with following clumps upto 6 meter tall found mainly in Punjab, Uttar Pradesh, Bihar, Bangal and orissa, growing well on alluvial sandy banks of streams not subjected to water logging. Culms biennial, pale soild, pithy smooth with an inconspicuous growth ring and root zone. Leaves 1-2 meter long and upto 3 cm broad. The fiber obtained from sarkanda grass is quite strong and elastic and not affected by moisture.

7.1 MORPHOLOGY

The fiber varies from 0.2- to 3.5 in length (an average of 1.3 mm) and 7 to 40 μm in width (average 15.7 μm). The pulp consists of fibers, parenchyma, and vessel and epidermal cells. The fibers are narrow, long, straight and thick walls and pointed tapering ends and occasional transverse markings. The fibers are narrow than bamboo and bagasse. The parenchyma cells are small to medium sized narrow rectangular and numerous. The vessels are fairly long and narrow. The epidermal cells are numerous, rectangular and conspicuous with serrated margins.

S.No.	Dimensions	Unit	Sarkanda
A	**Properties of fiber:**		
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.3
2.	Minimum Fiber Length,	mm	0.50
3.	Maximum Fiber Length,	mm	4.48
4.	Mean Fiber width (μ= 7 – 45)	μm	15.7
5.	Lumen Diameter	μm	4.24
6.	Cell wall thickness	μm	5.72
B	***Properties of non-fibrous tissue***		
12.	Length of vessel	μm	79.9
13.	Width of vessel	μm	30.1
14.	Length of Parenchyma	μm	141
15.	Width of Parenchyma	μm	31.8

16.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	60.5
17.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	16.5

8.0 SABAI GRASS

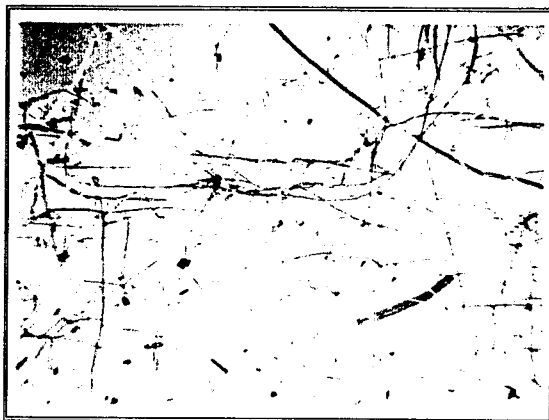
Eulaliopsis binata

Eulaliopsis binata SYN. *Ischaemum angustifolium* commonly called Sabai, Babui or bhabar, is an important grass species having lot of commercial value. It is a tufted perennial grass of family Gramineae. Sabai grass is grown in large quantities out side forest area. Sabai grass is perennial grass, 2-5 ft. high erect, slender culms, shiny and woolly at the base. Leaves narrow, linear, 3-4 fit long. The grass flowers during the cold weather and for purposes of paper manufacture, the grass is cut prior to or during the flowering stage. The yield of the grass varies from 20-75md per acre according to locality, rainfall and intensity of management. Sabai grass when carefully collected free from weeds and foreign matter, forms an excellent material for the production of printing and medium quality writing paper.

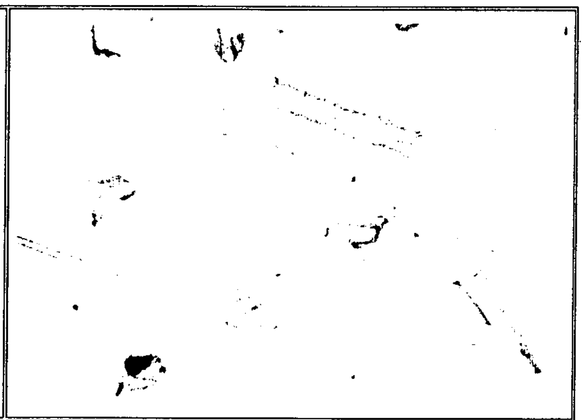
8.1 MORPHOLOGY

The fibers are derived from the vascular bundles of leaves. The pulp is used for the manufacture of all types of cultural and industrial paper. The fiber varies from 0.4 to 4.4 in length with an average of 1.6 mm and 5-15μm in width (average 13.7 μm). The pulp consists of fibers, parenchyma, and vessel and epidermal cells. The fibers are narrow, long, straight and thick walls and pointed tapering ends and occasional transverse markings. The fibers are narrower than those of bamboo and bagasse. The parenchyma cells are small to medium sized narrow rectangular and numerous. The vessels are fairly long and narrow. The epidermal cells are numerous, rectangular in shape and conspicuous with serrated margins.

SABAI GRASS PULP



Sabai grass pulp



Magnified view of pulp fiber

S.No.	Dimensions	Unit	Sabai Grass
A	***Properties of fiber:***		
1.	Fiber Length (Weight weighted)(L = 0.20 – 4.0mm)	mm	1.57
2.	Minimum Fiber Length,	mm	0.35
3.	Maximum Fiber Length,	mm	4.4
4.	Mean Fiber width (μ= 7 – 45)	μm	13.5
5.	Lumen Diameter	μm	1.11
6	Cell wall thickness	μm	6.3
B	**Properties of non-fibrous tissue**		
7.	Length of vessel	μm	43
8.	Width of vessel	μm	30
9.	Length of Parenchyma	μm	70
10.	Width of Parenchyma	μm	15
11.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	59.7
12.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	14.0

9.0 KANS GRASS

(Saccharum spontaneum)

Kans Grass (*Saccharum spontaneum*) popularly known as north Indian canes is a perennial grass with slender culms green gray, ivory or white, hard , but very pithy. Kans Grass is mainly found in Himalayas of northern India and extends up to the equatorial regions of java. Kans Grass is a coarse grass normally not relished by cattle and is generally used as fodder only in times of scarcity. Kans Grass is often hollow in the center, varying in diameter from 5 to15 mm, often rooting at the node, internodes usually long and nodes always thicker than the internodes. Leaves are long, linear, narrow or very narrow, the leaf module or ratio of breadth to length varying from 1:24 to 1:300 or more in the different forms of the species. Culms biennial, pale solid, pithy smooth with an inconspicuous growth ring and root zone. Leaves 1-2 meter long and up to 3 cm broad. This species is of great value for fiber extracted from the upper leaf sheaths of the flowering culms. The leaves are also used for thatching and for purpose of pulp manufacturing. Keeping its availability and existing utility in view, pulping and papermaking properties of Kans Grass have been evaluated so that it can be exploited for pulp and paper manufacture. Kans Pulps suitable for production of wrapping, writing printing and greaseproof papers. It is also used for hardboard making. The grass can be used in admixture with other grasses.

9.1 MORPHOLOGY

Kans Grass shows the same diversity of cell type as sarkanda and sabai grass. The fibers are uniform, long and slender with pointed ends. The fiber length ranges from 0.20 mm to 3.90 mm with average length of 1.40 mm. Parenchyma cells are numerous small to large, rectangular to rounded and somewhat larger than sabai grass and their length varies from 22.0 to 312 microns (average 91 μm) and 12 to 98 μm (average 35 μm) in width. Vessels vary from very short to long from 104 μm to 1265 μm (average 489μm) and width various 25 micron to 92 micron (average 38 micron). Epidermal cells are narrow and cylindrical with toothed margins. Epidermal cells' length varies from 57 to 163 μm (average 81 μm) and width from 8 to 16.3 μm (average 13.5 μm).

S.No.	Dimensions	Unit	Kans Grass
A	***Properties of fiber:***		
1.	Fiber Length (Weight weighted) (L = 0.20 – 5.0mm)	mm	1.4
2.	Minimum Fiber Length,	mm	0.43
3.	Maximum Fiber Length,	mm	3.57
4.	Mean Fiber width (μ= 7 – 35)	μm	15.4
5.	Lumen Diameter	μm	1.14
6.	Cell wall thickness	μm	6.38
B	***Properties of non-fibrous tissue***		
7. B	Length of vessel	μm	489.0
8.	Width of vessel	μm	38.0
9.	Length of Parenchyma	μm	91.1
10.	Width of Parenchyma	μm	35.0
11.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	55.71
12.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	13.59

10.0 BAMBOO

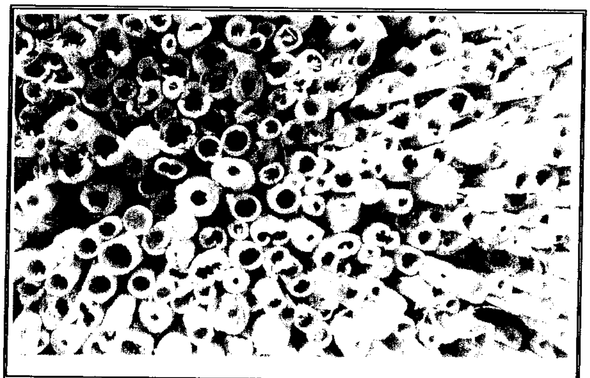
Bamboo is a perennial, giant, woody grass belonging to the tribe Bambuseae of the well-known family of Gramineae in group angiosperms and the order monocotyledon. The grass family Poaceae (or Gramineae) can be divided into one small subfamily, Centothecoideae, and five large subfamilies, Arundinoideae, Pooideae, Chloridodeae, Panicoideae, and Bambusoideae. In distinction to its name, bamboos are classified under the sub-family Bambusoideae. About 1200-1500 species of 60-70 genera of bamboo are known to exist in the world. More than half of these species grow in Asia, most of them within Japan and Indo-Burmese region, which is considered their area of origin. In India out of 136 species identified, 30 – 40 species are extensively available for economic exploitation. Some examples of bamboo genera are *Bambusa, Chusquea, Dendrocalamus, Phyllostachys, Gigantochloa* and *Schizostachyum*.

10.1 MORPHOLOGY AND GROWTH

Many species of bamboo exist but the morphology of the cell tissue is almost similar. Bamboo species flower at regular interval but various species have different flowering periods. Some flower sporadically and some gregariously. The life cycle of different species various from 30 to 60 years. After periodic flowering, seeding and death of bamboo, there will be an interruption of supplies for a period of 8 to 12 years. It is always advisable to have a bamboo crop of different species flowering at different periods. The flowering cycle (in years) in bamboo varies with species viz. *Bambusa bamboo*, (30-40); *Arundinacea falcate, (28-30); Ochlandra travancorica , (28-30); Bambusa polymurpha*, (55-60); *Dendracalmus strictus*, (30-40); *Melocanna bambusoides*, (45); *Bambusa arundinacea*, (32-34); *Bambusa tulda*, (40) represents the general structure of bamboo. Rhizomes and culms are the two important portion of Bamboo. The rhizome is the underground part of the stem and is mostly sympodial or, to a much lesser degree, monopodial. The upper part of stem is known as culms and is used for papermaking. Culm portion of the bamboo tree contains most of the woody material. Most of bamboo culms are cylindrical and hollow, with diameters ranging from 0.25 inch to 12 inches, and height ranging from 1 foot to 120 feet. It is without any bark and has a hard smooth outer skin due to the presence of silica.

Species	**Average Height (m)**	**Internodes, (cm)**	**Diameter, (cm)**
Bambusa arundinacea	26-30	30-40	15-18
Dendracalamus strictus	6-16	30-40	2.5-7.5
Ochlandra species	2-6	60-120	2.5-5.0

Bamboo is a fast growing species and a high yield renewable resource. Bamboo growth depends on species, but generally, all bamboo matures quickly. Bamboo may have 40 to 50 stems in one clump, which adds 10 to 20 culms yearly. Bamboo can reach its maximum height in 4 to 6 months with a daily increment of 15 to 18 cm (5 to 7 inches). Culms take 2 to 6 years to mature, which depends on the species. Bamboo mature in about 3 to 5 years and with a good management of the bamboo resource, the cutting cycle is normally 3 years as its growth is more rapid than any other plant on the plant. Some bamboo species have been observed to surge skyward as fast as 48 inches in one-day. The fast growth characteristic of bamboo is an important incentive for its utilization. The current Bamboo consumption rate by pulp & paper industry in India is in the range of 0.8 to 1.0 million A.D. tons.



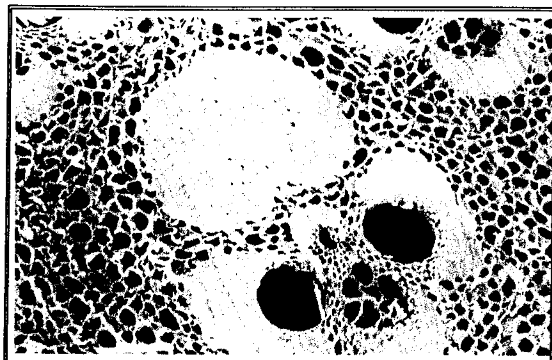
Thick and thin wall bamboo in stack

General morphology of bamboo remains the same for all species. Rhizomes and culms are the two important botanical parts in bamboo structure, where the former is underground part of the stem and later is the surface part of the stem. The culms those are apparent stem parts have the papermaking potential. The bamboo culms are cylindrical and hollow, with diameters ranging from 1 cm to 30 cm having height ranging from 0.5 meter to 40 meters. The culms have no bark like the other wood trees, which is an advantage in processing. Bamboo culms can reach its maximum height in 4 to 6 months, but require 2 to 6 years to mature. Tropical climatic conditions influence the extraction of bamboo from forests and its transportation to mill site. As the felling stops for 4 to 5 months, proper storage and preservation of bamboo are important for smooth running of the mills. The extraction of immature culms results in financial losses and the pulp and papermaking characteristics are adversely affected.

Bamboo culms are extracted from the forests, cut to about two meter length pieces, bundled and stacked, which in turn transported to the interim depots. The freshly extracted bamboos have moisture content ranging from 75% to 50%. From these interim depots, the material is moved by road or rail route to the mill sites. The prolonged storage at the extraction sites leads to serious damage due biological infestations and microbial attack and adversely affects the quality of pulp. It is suggested that there should be concrete paved yards in the mills and the bamboo bundles should be stacked in criss-cross fashion to improve ventilation and drainage of rainwater. The inventory of bamboo storage in a mill should be decided keeping in view the location, infrastructure and production capacities, such that it should not interrupt the sustained supply of bamboo to the mill.

10.2 MORPHOLOGY OF BAMBOO CULMS:

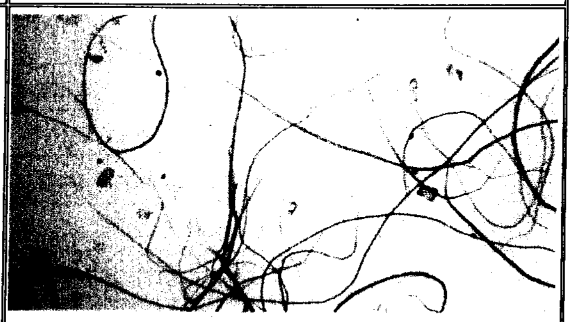
The bamboo culms are divided in to segments by nodes. The segments between tow nodes are known as nodes. Outermost cellular layer of bamboo cum is epidermis upon which a waxy layer exists, which gives the smoothness to surface. The fibers appear in layers below the epidermis followed by ground tissue. The vascular bundles, which also contain fibers, are distributed in the ground tissue, which are more closely packed towards the periphery of the stem and scattered towards the inner side in the ground tissue, which causes the differential density of in concentric layers of bamboo. This differential density of bamboo poses biggest challenge to the chip quality management in the chipper house. The bulk density of bamboo chips range between 180 to 250 kg/m3. The bulk density of bamboo chips can be as low as 120 kg/m3 in case of immature bamboo. The bamboo fibers are slender and long. The average lengths of the fibers vary between 1.8 mm to 2.5 mm depending upon the species. Similarly, the fiber width varies between 8 μm to 12 μm



Vascular bundle in ground tissue

Magnified view of fiber cross section

Bamboo chips



Bamboo pulp fibers

Bamboo pulp is capable of fine writing and printing paper standards, offering similar strength, brightness and printability of comparable wood pulp-based papers. Bamboo has it's own papermaking potential, which can hardly be substituted by other raw materials. Bamboo has its maximum resistance to mechanical forces in transverse direction and the smooth surface of the culms; differential density of the culms in concentric layers makes it difficult to achieve clean chipping process. These factors, when the bamboo is not seasoned properly causes more slivers (large chips) and pin chips (botanically vascular strands) and dust (parenchyma cells). This non-uniformity in the chip quality is not a serious problem in batch digestion, but poses serious operational problems when processed in continues digesters due to chocking of the digester screens leading to interruptions in pulping liquor circulation. Nodes in the chips are difficult to pulp as the grain (fibers) and other tissues are intertwined in them causing tightly packing and hinder the pulping liquor penetration. Bamboo has capillary structures (vessels) running vertically throughout the length in regular distances in the internodes help in pulping liquor movement. These capillaries have air, if the chips are dry and expulsion of air necessary prior pulping process. Steaming of chips would help in expulsion of the entrapped air in the capillaries.

Dimensions and properties of tissues in pulp

S.No.	Dimensions	Unit	*tulda*	*hamiltonii*	*balcooa*
A	***Properties of fiber:***				
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.82	1.96	2.12
2.	Minimum Fiber Length,	mm	0.58	0.47	0.39
3.	Maximum Fiber Length,	mm	5.01	3.5	3.4
4.	Mean Fiber width (μ= 7 – 45)	μm	17.8	17.2	17.2
5.	Lumen Diameter	μm	3.20	3.42	3.67
6.	Cell wall thickness	μm	7.30	6.89	6.76

7.	**Properties of non-fibrous tissue**				
8.	Length of vessel	μm	286.3	270.2	162.9
9.	Width of vessel	μm	33.5	38.5	58.0
10.	Length of Parenchyma	μm	55.3	69.4	88.0
11.	Width of Parenchyma	μm	30.7	35.5	33.0
12.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	41.7	53.33	32.3
13.	Length weighted Fines (L = 0.01 – 0.20 mm)	%	4.55	6.52	3.09

11.0 JUTE

Corchorus olitorius

India is the world's largest producer of jute and allied fibers (1.941 million Metric tons), which accounts for about two third of the world's production (3.092 million Metric tons). The area under jute cultivation is 0.817 million hectares and mesta cultivation is 0.184 million hectares in the year 2001-2002 in India (Source: Ministry of Agriculture, Govt. of India). Jute plants are classified into two broad groups i.e. Corchorus capsularis (White jute) and Corchorus olitorius (Tossa jute). Mesta / Kenaf yielding fibers of commerce are similar to jute, constitute a third group. All these four varieties can be considered as one, although it is known that there are marginal variations in their pulping characteristics.

11.1 RAW MATERIAL

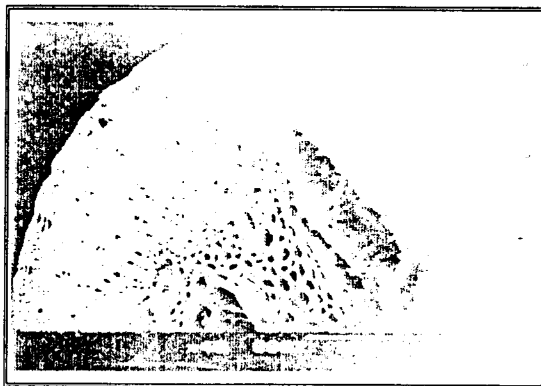
The jute plant is an annual plant and grows to a height of 5– 16 feet in height and normally do not have significant branches. Diameter of the stem may reach up to 10 to 20 mm on maturity. The stem portion has two distinct zones viz. bark and core. The bark portion becomes loosely attached to core when the plant is dry. The dry bark is dark brown in color and the core (wood) is pale yellow or cream colored. Bast fiber constitutes 36% of the weight in the whole jute, and the balance 64 % is core wood. Bulk density of the whole jute is very low compared to the hardwood and softwood. Bulk density of jute bast fiber is very low compared to core wood. Bulkiness of the raw jute fiber has disadvantages in terms of volumetric loading, throughput etc. Impregnation of chips with liquor is affected due to high bulkiness, as chips tend to float.

Sl. No.	Particulars	Whole Jute	Bast	Core
1.	Ratio of Bast and Core, %	-	36	64
2.	Bulk Density, kg/m^3	93.4	69.2	110.5

11.1 MORPHOLOGY

The outer layers (sheath) of stalk are of bast and the fiber from which is used as cordage etc. after retting. The central most core portion is filled with parenchyma tissue, which is termed as pith. The woody tissue located between pith and bast. The fibers from this woody tissue are short and are normally discarded as waste or used as domestic fuel.

The jute fibers have different dimensions based on the tissue source. The fibers from the bast are long with thick fiber walls, whereas the fibers from core (wood) are short and relatively thin walled. The average length of the whole jute fiber is 1.01 mm and average width is 18.4 μm.

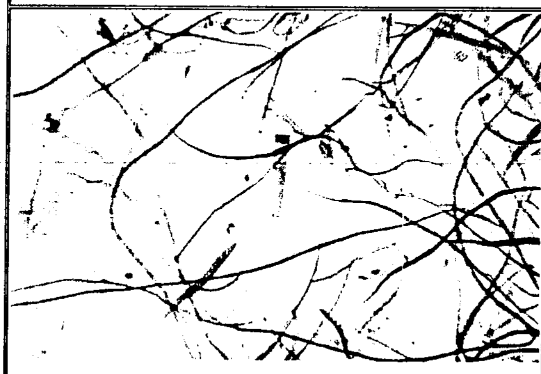


Cross section of Jute stem

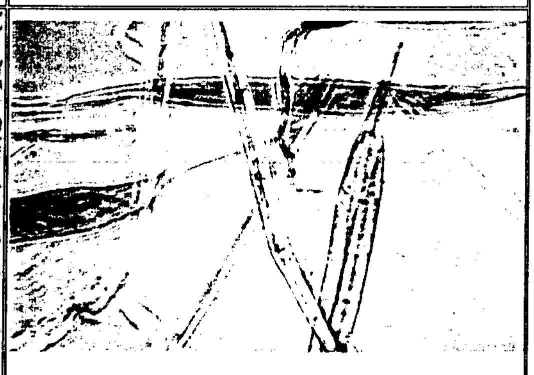
Magnified view of cross section

Magnified view of bast fibers

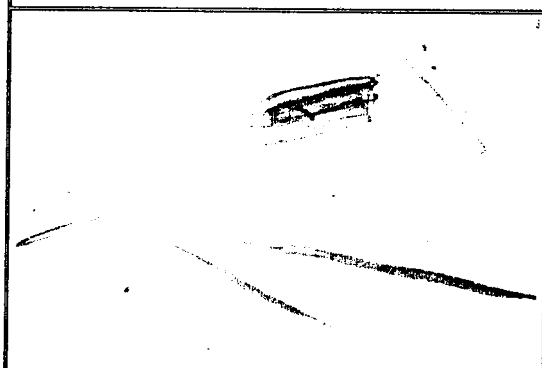
Bast fibers in sectional view



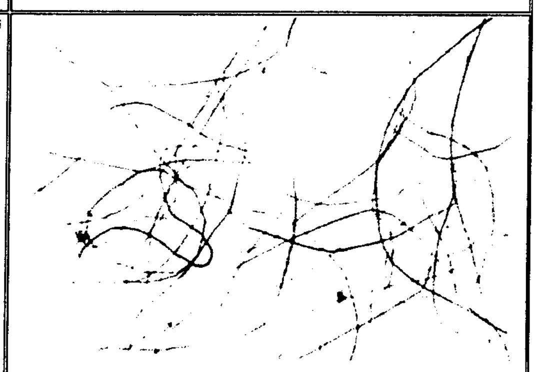
Whole Jute Pulp Fibers



Magnified view of Whole Jute Pulp



Jute Core wood Pulp Fibers



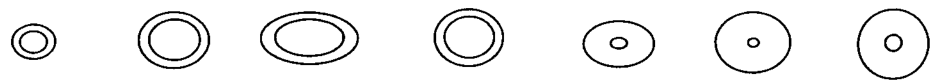
Jute Bast Pulp Fibers

The diagnostic feature of the jute bast fiber is the irregular width of the broad and well-defined lumen. Sometimes the lumen closes up and is entirely missing for a short distance. The individual fiber is cylindrical with little variation in diameter. The fiber walls are thick and generally smooth, having more or less numerous nodes and cross markings depending upon the mechanical they have received. The fiber ends are slender and pointed. The cross section of the fiber is of polygonal shape with sharply defined angles and a round or oval lumen. The comparative fiber dimensions and properties are recorded in table and Photomicrograph of different fiber of Whole jute; Central core wood (stick) and bast fibers (skin) are given below.

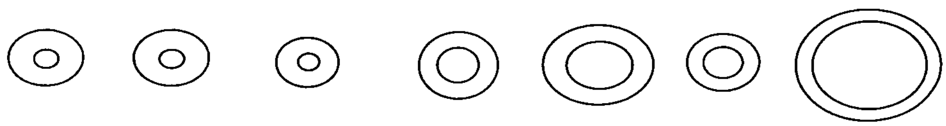
Dimensions and properties of Jute pulp components:

No.	Dimensions	Unit	Whole Jute	Core Fiber	Bast Fiber
A	*Properties of fiber:*				
1.	Fiber Length (Weight weighted) (L = 0.20 – 4.0mm)	mm	1.39	0.69	1.95
2.	Minimum Fiber Length,	mm	0.2	0.2	1.0
3.	Maximum Fiber Length,	mm	4.20	1.0	4.60
4.	Mean Fiber width (μ= 7 – 45)	μm	20.1	21.9	16.4
5.	Lumen Diameter	μm	9.00	-	-
6.	Cell wall thickness	μm	5.35	-	-
B	*Properties of non-fibrous tissue*				
7.	Length of vessel	μm	387	-	-
8.	Width of vessel	μm	43.1	-	-
9.	Length of Parenchyma	μm	348.8	-	-
10.	Width of Parenchyma	μm	74.8	-	-
11.	Arithmetic Fines (L = 0.01 – 0.20 mm)	%	32.07	33.58	20.87
12.	Length weighted Fines(L = 0.01 – 0.20 mm)	%	5.10	6.86	1.56

COMPARATIVE CROSS SECTIONAL DIMENSIONS OF DIFFERENT FIBERS



	Rice Straw	Wheat Straw	Bagasse	Sarkanda Grass	Sabai Grass	Kans Grass	Jati Bamboo
Fiber diameter, μm	11.1	15.2	21.8	15.7	13.5	15.4	17.8
Fiber Lumen, μm	2.3	3.3	6.3	4.2	1.1	1.1	1.2
Wall Thickness, μm	5.4	6.0	7.8	5.7	6.3	6.4	7.3



	Kako Bamboo	Bhulka Bamboo	Casuraina	Mango	Subabul	E.Hybrid	Softwood
Fiber diameter, μm	17.2	17.2	14.5	15.0	20.1	14.2	40.0
Fiber Lumen, μm	3.4	3.7	2.8	4.2	9.2	3.4	28.0
Wall Thickness, μm	6.9	6.8	5.8	5.4	5.5	5.4	6.0

The coarseness was found to influence the bulk with an exponent of –0.3, burst with – 1.0, tensile strength with – 0.6, and tearing strength with – 0.3 (Rydholm)

RAW MATERIAL HANDLING, STORAGE & UP-GRADATION OF NON-WOOD FIBRES

RAW MATERIAL HANDLING & STORAGE PRACTICES IN AGRO BASED MILLS

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Dr. M.C. Bansal graduated in Chemical Engineering from University of Roorkee in 1967 and obtained Master in Chemical Engineering from Indian Institute of Science , Bangalore in 1969. He is a Ph. D in Chemical Engineering from University of Roorkee. He joined University of Roorkee as lecturer in July 1969 in the Chemical Engineering Deptt. In Jan. 1981 joined Institute of Paper Technology , Saharanpur as Reader and since 1988 he is working as Professor in the same Institute.

He visited NTH, Trondheim, Norway as a guest faculty for a period of three months and is widely traveled in Norway , Sweden & Denmark. He had been actively associated with two NIEM (UNEP) projects and had been to China & Thailand in connection with the activities of these projects. Co-ordinated 12 HRD programmes for mill personnel /traders/technocrats . Contributed a chapter in "History of Technology in India" on " Paper making in India" 1801 to 1947.

Was the Editor -in Chief of IPPTA Journal for six years. Is on the Editoirial Advisor Board of IPPTA for the last twelve years. He is a member of many technical committees at National level. He is Co-ordinator of BIS committee for proposing the grades of waste paper. He is actively engaged in the activities of various social organizations. Had been instrumental in getting " Sarswati Temple" constructed at IPT, Saharanpur.

He is author of a monograph on " Non-wood Fibre Pulping" . Is Co-ordinator of a UGC Project on "Waste Paper Processing & Deinking at Deptt. of Paper Technology, IIT Roorkee Campus , Saharanpur. Has more than 30 research papers to his credit & has attended many National & International seminars .

RAW - MATERIAL HANDLING AND STORAGE PRACTICES IN AGRO BASED MILLS

Dr. M.C.Bansal

1.0 INTRODUCTION

Non – wood plant fibers are classified in three main categories, in terms of their source, availability and fiber characteristics:

- Agricultural and agro – industrial waste, which includes wheat and rice straws, and bagasse.
- Natural growing plants which include bamboo, reeds, esparto, sabai, and other grasses.
- Cultivated fiber crops, which include sisal, jute, hemp etc.

BAGASSE:

Sugarcane is considered to be the best synthesizer of solar energy into biomass, like sugar, cellulose and lignin. Considering the good yield per hectare and the fact that every part of sugarcane can be used, its utilization has increased substantially in most of the countries. The approximate production of bone-dry bagasse is one - third (~33%) on the total sugarcane crushed in the sugar factories, though it varies to some extent from state to state, depending upon the variety of sugarcane crushed and other factors. A peculiar feature of the Indian sugar industry is that out of the total sugarcane grown in the country, only about one - third (~33%) is crushed in sugar factories to produce sugar and as much as 55% of the cane is used for the manufacture of gur and khandsari, and the balance 12% is used for seed, chewing and cane- juice drinking.

As it comes out of the milling plant, bagasse contains about 50% moisture and hence, it is generally known as "Mill Wet Bagasse" or "Green Bagasse". Bagasse is composed of two distinct cellular components- fiber and pith. The fiber fraction consists of the long, strong fiber bundles from the rind and pith from fibro-vascular bundles within the cane stalk. The strong fibrous fraction known as bagasse, is an excellent raw material for the production of pulp and paper. The pith fraction consists of thin walled non-fibrous parenchyma cells that contains the sugar juice. In addition to pith cells, there is dense non-fibrous waxy epidermal material which is also of no value for paper mills.

Bagasse as obtained from the sugar mills is first depithed and then proper care is taken to store the depithed bagasse by following the wet bulk storage of bagasse or by storage of bagasse bales in properly covered piles

Bagasse can be used either as fuel for sugar mills or as fibrous raw material for pulp and paper industry. At present, in India, most of the sugar mills are burning bagasse to produce energy for their own use. (one tonne of bagasse gives 2-2.3 tons of steam and in terms of fuel value, it is equivalent to 0.3 -0.35 tons of coal) .The calorific value of mill wet bagasse is approximately 1900 kcal per kg and with 35% moisture its calorific value increases to about 2200 kcal per kg.

We have 3 categories of mills in India:

- Some of the paper mills have assured sugar mills to arrange for their coal requirement, and in return sugar mills give bagasse to paper mills.
- In some other sugar mills, the bagasse fired boilers have been improved which result in saving of 6 to 10% of the bagasse produced, and this saved mill wet bagasse is available for paper mills.
- In some cases, sugar mill and paper mill complexes have been developed, where the paper mill supplies steam to the sugar mill and the sugar mill in turn supplies depithed bagasse and pith to the paper mill.

As the bagasse is available during a shorter period (November to April), the collection, transportation and storage problems need proper consideration at the mills.

2.0 COLLECTION, HANDLING AND TRANSPORTATION OF BAGASSE :

The handling of bagasse is to be considered at two places separately-

(a) At the sugar factories
(b) At the paper mills

2.1.1 AT THE SUGAR FACTORIES

Normally the mill wet bagasse received from the milling plant of the sugar mill is used in the boilers directly. Arrangements are usually made to carry the excess bagasse outside the mill and bale it out before storing it. The conveyor systems are so designed that it can bring back the dried bagasse to the sugar mill if the partially dried bagasse is used in the boilers, to get better heat values. The use of pre-heaters, economizers, and de-aerators etc. help in achieving better thermal efficiencies in the sugar mill boilers, which in return shall also help them to save more bagasse. The sugar mills should also gradually try to go for high, pressure boilers with extraction type of turbines to generate power for internal use and steam at required pressures. The use of dried pith shall further help them to save more bagasse..

2 .1.2 AT THE PAPER MILLS

The bagasse is usually transported by trucks or tractor trollies, but being low in bulk density (160 kg per cubic meter), the transportation cost is very high. As the mill, wet bagasse is usually contains 50% moisture and 20% pith, its transportation means only 30% of the real value of the useful raw material. This thus envisages that, if possible, the bagasse must be depithed at the sugar factory and the pith so obtained be burnt in the sugar factory boilers itself. Depithed bagasse shall now carry even less moisture content then before due to atmospheric exposure. Presently in India, however, most of the sugar mills are supplying the whole mill wet bagasse either in the loose form or in the baled form to the paper mills. This is causing exorbitant costs to the paper mills only on transportation. The bales are tied up by mild steel wire. The rope of jute, Hessian etc., if used in place of wire can get digested in the digester itself, eliminating the danger of wire getting into the digesters.

The bagasse bales are normally stored in the paper mills, for different periods, as per the need. Similarly, if whole bagasse is received in the paper mill in bales form, it may first be stored for some time before finally used after depithing. It is observed that after 4 to 6 weeks of storage, the moisture content goes down to nearly 30%, resulting in easy handling and transport. Further, it is also observed in some of the mills that the alkali consumption is high, the foaming problem in washers is more and the runnability is poor on paper machines with fresh mill wet whole bagasse, and they prefer bagasse with 4 to 6 weeks storage only.

2.3. DEPITHING OF BAGASSE

The bagasse must be depithed for better operation and good paper production as the pulping of whole bagasse leads. to higher chemical consumption, problems in washing, and paper making due to the pith present. Depithed bagasse increases yield, and improves brightness and strength properties of the paper. Some mills are still using the whole bagasse, which is not a properly recommended practice. Some of the reasons are as given below:

1. The presence of pith in the bagasse increases the requirement of chemicals d during cooking, thereby increasing the cost of production.

2. Pith occludes large quantities of dirt and as a result requires more bleaching chemicals. In spite of this, pith particles appear on the white paper as dark spots.

3. The presence of pith in the cooked pulp reduces the drainage of water on the pulp washers and on the paper machine subsequently, thereby resulting in reducing the speed of the paper machine, which affects paper production rate.

4. The presence of pith in the pulp causes press stickiness on the paper machine.

5. Pith reduces the strength and brightness of the paper.

There are many types of depithing equipments like Horkel, Peadco, Gunkel, Rietz, SPM, Revinco, Kimberlay-Clark, Belloits etc.; but the principle of working of all these depithers is more or less the same and are some sort of hammer mills. Some Indian manufacturers have started manufacturing good depithers based on the same principle. Due to severe beating of bagasse, the adhering pith is loosened and removed either by screening or by washing with large quantities of water. As the pith particles are smaller than fiber particles and are also lighter, and hence pith can be separated by screening and washing/flotation. The depithing of bagasse may be carried by any of the following main depithing methods –

i) Dry depithing
ii) Moist depithing
iii) Wet depithing

2.3.1 . DRY DEPITHING

Dry depithing is carried out on stored bagasse at a moisture content of 20-30%. Hammer shredders, disk mills or the like are used in the separation of pith from bagasse. The disadvantages of this process are heavy wear and tear of the equipment, loss of valuable fiber along with the pith and production of lot of dust etc., causing problems to operators and environment. Some of the small bagasse-based paper mills are still continuing with it being simple and economical.

2.3.2 MOIST DEPITHING

This is generally done presently at the paper mills when the mill wet bagasse has about 50% moisture. The specially designed depithers break open the fiber bundles and dislodge the pith by mechanical rubbing and mild disintegration action. The units consist of a rotor having swing hammers attached to it. The hammers are enclosed fully or partially by perforated screen plates through which the pith fraction is discharged. The bagasse feeding to depithers is along either the horizontal or vertical axis of the unit, depending upon the construction. The depithed fiber is discharged at the end of the rotating axis. About 50% of the total pith present is removed by this method.

After breaking up of bales, the bagasse is passed through radar-disc screen to remove stones and other large non-fibrous materials which might damage the depithers. The bagasse is then fed to depither where it is hammered successively by a group of knives. The hammers are free to swing off the way. The resistance they meet accounts for the force which the hammers can exert on the fibers to separate them from pith. The pith by centrifugal force is forced through screen and fibers fall downward by gravity.

2.3.3 WET DEPITHING

This method is more applicable at the pulp mill for the final cleaning and depithing just before bagasse enters the digester. The process is suitable for either baled bagasse or bagasse delivered from bulk storage. A typical layout of wet depithing system feeding directly to the digester house is shown in Fig. 1. The bagasse is fed to the hydrapulper where it is wetted and broken up at a consistency of around 2 to 3% which is maintained by continuous recirculation of process water. The stock is passed through liquid cyclone to remove heavy impurities. Then it is passed through dewatering screens and wet depithers, to remove water and pith from fibers. Pith is removed at around 14% consistency and fiber around 20% consistency from the system.

2.4. STORAGE OF BAGASSE

Bagasse has a very low bulk density which makes it necessary that the material be either baled in dense bales or piled in high dense stacks in order to facilitate storage. Excessive fermentation and heat built-up during storage degrades the quality of the fiber. Therefore, a need for a better and less costly method of storage has become apparent.

Bagasse can be stored in the following forms -

1) Baled whole bagasse in stacks
2) Baled depithed bagasse in stacks.
3) Loose/Compacted bagasse in dry or moist piles.
4) Loose/compacted bagasse in wet piles.

Bagasse deteriorates during storage due to the action of undesirable microorganisms. Considerable amount of bagasse is rendered unsuitable for pulping due to biodegradation. The residual sugar content of bagasse, the heterogeneity of its tissues, the vast exposed surface and the congenial tropical environmental conditions facilitate the growth and colonization by microorganisms. Technically as well as economically, efficient utilization of bagasse for pulping process depends on the .way .of storing the bagasse during the off-season periods.

The type of damage to bagasse in storage can be classified into two categories viz. chemical degradation and discoloration. The chemical degradation is the consequence of bio-chemical alterations and depends on temperature, pH, amount of nutrients and the degree of aerobicity. This process affects yields and properties of pulp. The discoloration reaction is strongly related in its origin to chemical degradation reactions. However, in aerobic environment by the action of heat and light, the darkening effect is accelerated.

2.5 CONSERVATION OF STORED BAGASSE

Techniques involved for bagasse conservation are formulated to prevent or hinder the proliferation of cellulolytic microorganisms by the use of bactericides such as SO_2, formaldehyde, Sodium Carbonate etc. in a bagasse pile. However, the economic consideration makes these techniques unacceptable. As an alternative, the promotion of growth of non-cellulolytic microorganisms that may retard or prevent the proliferation of those that damage the fibers has been suggested. In this method, the non-cellulolytic microorganisms are promoted by enhancing the predominance of acid producing bacteria (Thermophilic) or by promoting the predominance of mesophilic micro -organisms.

2.5.1. RITTER'S PROCESS

Bagasse conservation method by promoting the growth of acid producing bacteria uses the natural evolution of fermentation in a closed system in the presence of fermentable sugars and absence of air. Under these conditions, the Lactic acid producing bacteria prevail over other micro-organisms and retards the degradation of fiber by slowing down the growth rate of cellulose attacking micro-organisms. Dr. Ritter's process of bio-liquor treatment is based on this concept.

2.5.2. CUSI 'S PROCESS

Bagasse conservation method by promoting the mesophilic non-cellulolytic microorganisms provides a process for preserving bagasse by controlling the flow of air through the pile to create a controlled temperature environment for mesophilic bacteria like yeast to grow and consume soluble sugars. The growth of other microorganisms that degrade the fibers is retarded by reducing the moisture content of the material below 28%. Dr.Cusi's process of conservation of bagasse by ventilation is based on this concept.

Many of the mills are using the dry depithed bagasse bales piling with due provision for air ventilation in the piles to take care for the heat generated by the various exothermic reactions and are able to use this properly stacked and covered bagasse for nearly a year with less than 5 % decay as reported by the mills.

3.0 BAMBOO

Bamboo is a grass, which grows in many parts of India and is used by many mills to supplement the need of long fibers. It takes 7 to 10 years for the full growth of the stem usable by the industry. Bamboo size varies according to the specie. Some species are small (0.5 to 1 inch in diameter and 12 to 20 ft in height), whereas other species are large (3 to 8 inches in diameter and up to 150 ft in height)

Chemically, bamboo contains four principal substances; starches, pectin, lignin, and cellulose. The bamboo stem consists of a woody portion or a hollow tube, referred to as the culms and the ground tissue or parenchyma. In the ground tissue, there are fibro vascular bundles. Bamboo fibers are good in length (2 mm to 4 mm). The woody portion or culms of the bamboo stem is joined at nodes along the length. These nodes create problem in the pulping, since they are denser than the rest of stalk and hence are penetrated by the liquor by great difficulty. The cooking of the bamboo is facilitated by the crushing of the bamboo stem during chipping by crushing the internodes and separating this makes the fibers more accessible to the cooking liquor. Which is an important factor in the pulping of the bamboo, as there is no horizontal ray parenchyma to conduct the liquor horizontally into the stems.

A series of operations like felling, collection, transportation and transportation are involved in bamboo utiiization.

3.1 STORAGE

Bamboo bundles are stacked in criss-cross fashion, with 6 to 10 layers. The moisture goes down to 10 to 12% from an initial moisture content of 40 to 50% within 70 to 90 days. If the fresh felled bamboo with higher moisture content is stacked in large stacks, then air circulation is not adequate and the bamboos are more prone to Bohr attack. The use of bamboo after nearly 90 days is preferred as the use of green bamboo creates operational problems like higher percentage of slivers during chipping and increase in black liquor viscosity during evaporation. Storage on raised platforms is preferred. The transportation cost is one of the major components of the cost of bamboo delivered at the mill. Due to its low bulk density its transportation cost is nearly 15 – 20 % more than the eucalyptus for the same distance by road-transportation. Density of bamboo stems and chips are on an average 130 to 200 and 260-280 kg/m3 respectively.

Storage of bamboo in open causes loss of substance due to bio degradation. The extent of damage shall depend upon the species, temperature, humidity, period of storage and the microbial population in the surrounding area. The major cell wall components – the cellulose, hemi cellulose and lignin are decomposed simultaneously. Decayed bamboo results in loss of extractives, hemicelluloses, cellulose and lignin. It also affects the degree of polymerization, pulp yield, pulp strength and its brightness. The losses can be reduced by the prophylactic treatment of the storage yard and the bamboo. The losses can also be reduced by systematic storage, good yard management and proper treatment. Some chemicals which have shown encouraging results are (a) benzene hexa-chloride (b) penta chlorophenol (c) sodium pentachlorophenate (d) methyl bromide and (e) kraft green liquor.

3.1.1 BAMBOO CHIPPING

As the bamboo stem is hollow, the wood chippers or modified versions of wood chippers have not proved very successful on bamboo. The bamboo chipping requires crushing of the stem along with chipping operation. The various chippers used by the Indian Paper Industry for chipping the bamboo are -

1} P N Bamboo Chipper   2} Pallman Chipper   3} Sumner Chipper
4} Voith Chipper   5} Wigger Chipper   6} KMW Chipper

The right kind of chipper will produce very little dust, pin chips and over-sized material. Here we are discussing only the PN chipper and Pallman chipper:

3.1.2 PN Bamboo Chipping System

This system incorporates a chipper with a positive horizontal feeder, with other ancillaries such as cyclone, screen and a chip washer. At the end of the systems screened and washed chips of uniform quality are delivered.

The feeder consists of three rollers, each having a different configuration to serve a specific purpose. The rollers are driven by a gear train and chain drive mechanism. The top roller is pneumatically loaded through a linkage with an air cylinder. When bamboo are fed to the feeder, they are carried between the top and bottom rollers at a pre - determined rate, proportional to the surface speed of the rollers. With air pressure, the front roller and pusher keep the bamboos pressed rigidly over the anvil knife for chipping. The trailing end of the bamboo is held by the front .roller after it has passed through the top and bottom rollers. This arrangement ensures that the whole length of the bamboo is chipped. The pusher is located close to the disc. It is designed for holding bamboos securely while chipping, thereby eliminating chattering or slipping of the bamboos. This feature, coupled with a special knife design provides good quality chips.

There are eight pairs of knives mounted on the chipper disc at an angle of 2° -40° to the vertical. The projection of knives over the disc is about 20 to 22 mm. Such an arrangement ensures almost right angle chipping of bamboo, producing predominantly chips that are 20 mm long. The acceptable portion on a chip classifier is 90 to 95% in the -28 mm to +4 mm range, with average chip thickness as 5 mm.

3.1.3 PALLMAN CHIPPER SYSTEM

Bamboo is fed through belt conveyors to positive feed device consisting of 4 top and 5 bottom toothed rolls, with decreasing spacing. These toothed rolls does not allow the material to go back and also give crushing action to bamboos. Both top and bottom rolls are rotated separately by suitable electrical motors. Before positive feed device, metal detector is installed above the belt conveyor, which stops the feed system, if any metal is present in the system feed. Pallman chipper consists of one drum with 4 moving and 1 stationary blade. The cutting action takes place between the moving and stationary blades. The blades are sharpened after every 5 hours of use, which requires 0.5 to 0.6 mm of length in each sharpening, and each blade is used for 160 mm of length. A chipper for 18 to 20 tons per hours of bamboo require a ~ 50 hp motor. The chipper has internal screening arrangement in order to control the product in a limited size range.

4.0 DUST FORMATION

A lot of dust is formed during the chipping operation, due to combined crushing and chipping operations. The various factors which affect the dust formation are –

- Age of Bamboo : Over matured bamboo is likely to create more dust.
- Storage of Bamboo: In the stored stack, the lowest layers are more prone to microbial and Bohr attack, than the upper layers. This leads to decayed bamboo with more dust associated with it. A bamboo stored for a longer time, shows more signs of decay than the other bamboo which has been stored for a shorter time. Similarly, the microbial attack is more, if the pile is on soil instead of on a cemented platform.
- Sharpness of knife: Blunt knife produces more dust than sharpened knife. The sharpening must be frequently carried out, as per need, for maintaining the desired production with little dust formation.

5.0 DUST POLLUTION

Once the dust is formed, it starts polluting the surroundings. Dust pollution in chipper house is mainly because of the following reasons:

- In the chipper section: Some amount of dust is formed in the chipper depending upon the condition of bamboo and blades. This dust is dispersed into atmosphere from chippers directly, during chipping operation.

- Free fall in conveyors and screens: When chips are carried from the chippers to conveyors or screens, .or from screens again to re-chippers by free fall, the smaller dust particles disperse into surroundings and cause atmospheric pollution.

- Screening operation: Shaking action on screens is also responsible for dust emission into surroundings. When the screened undersize material, with more dust drops on conveyors, then again some fraction of it is dispersed into atmosphere.

6.0 POSSIBLE MEASURES TO REDUCE DUST POLLUTION

From the above discussions, it is evident that the dust is formed in the chippers and then is transmitted to atmosphere during chipping, conveying and screening operations. Thus, the possible measures to reduce the dust pollution can be divided into two groups:
Measures to eliminate dust formation.

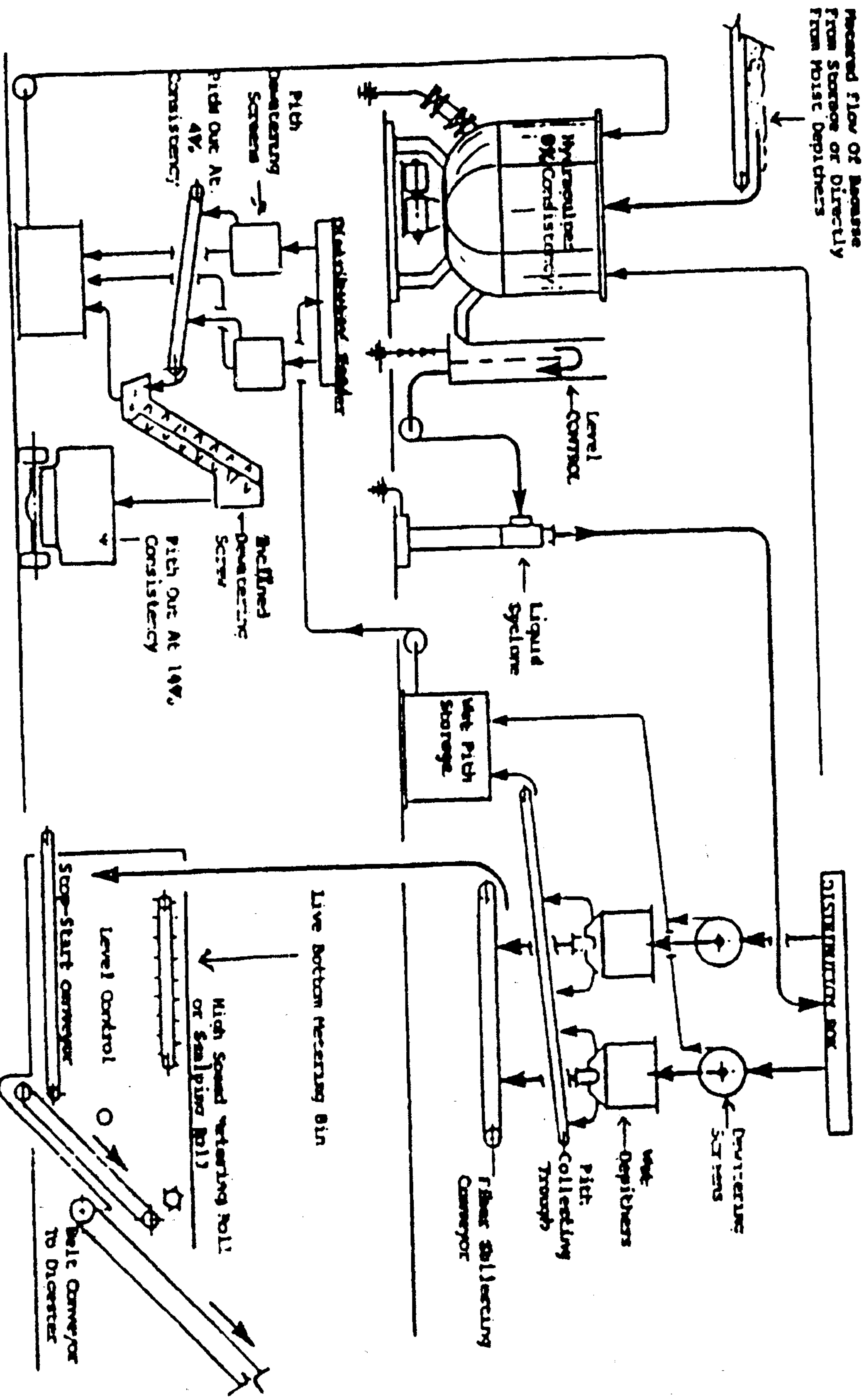

FIGURE 1 - WET SECONDARY PITH SEPARATION SYSTEM AT PULP MILL
(Joseph E. Atchison Consultance, Inc.)

RAW MATERIAL UP-GRADATION OF AGRO RESIDUE PULP

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He has 11 years of Industrial experience out of which 2 years in Orissa Cement Ltd. as Chemical-cum-Mechanical Engineer and Deputy Production Manager and 11 years in Titagarh Paper Mill as Incharge Pulp Mill and Laboratories. He has 2 years of teaching experience of teaching final year engineering students of BE Pulp & Paper and Post Graduate Diploma in Pulp & Paper of IPT, Rorkee University. He has 22 years of Research and Development (R&D) experience in CPPRI and is presently working as Scientific -F and Head, Consultancy and International Cooperation Division and Environmental Engineering Division. In connection with research has visited Germany, Austria, Finland, Swedan, Denmark, Nethrland, Myanmar and Bangladesh and has got number of research papers to his credit.

RAW MATERIAL UPGRADATION OF AGRO RESIDUES

V. K. Mohindru

1.0 INTRODUCTION

The present estimated total demand of paper & board including newsprint is about 55 lac tonnes & will increase to about 83 lac tonnes by 2010 A.D. Table -1 indicates the gap in paper production for which extra raw material is needed considering no extra growth of forest based raw material. So in future there will be more dependence on non-conventional raw materials like straw, bagasse etc. But there are certain drawbacks with these raw materials in addition to short fibers. Bagasse contains about 30.% pith which must be efficiently removed to make it more suitable for paper making. Similarly straw contain lot of silica & undesirable portion like leaves, grains, husk etc which create problems in the process of paper making and chemical recovery. So if this silica & other, undesirable materials can be separated in the raw material preparation then it will be much better from pulp and paper making point of view and will also improve the black liquor characteristics from chemical recovery point of view. The straw treatment plant is a set of equipment which can clean straw efficiently & can also depith bagasse by mechanical treatment this milling system converts non-homogeneous raw material into fractions that are chemically or physically homogeneous to improve the quality of these raw materials.

Preliminary trials to upgrade raw material for paper making were performed with rice straw & satisfactory results were obtained. Subsequent to this more trials will be performed on wheat straw, bagasse & rice straw & detailed study will be conducted from the point of view of improvement in paper and black liquor quality.

2.0 DESCRIPTION OF THE STRAW TREATMENT PLANT

The various components of the Disc Mill Plant which is shown in Fig. 1'are

1. Screw Feeder
2. Magnetic Separator
3. Disc Mill
4. Fan & cyclone separator

5. Universal separator

2.1 Screw Feeder

It is installed at top of Disc mill to provide constant volumetric feed rate to disc mill. Its speed can be regulated.

2.2 Magnetic Separator

This is fixed at the inlet of disc mill. It consists of permanent magnet to remove iron pieces which otherwise will damage the disc surface.

2.3 Disc Mill

This is a high quality grinding machine consisting of a pair of vertically mounted grinding and dehulling discs, one stationary and one rotating. The grinding discs are, exchangeable and made of steel, and the grinding surface is mounted with exchangeable grinding elements made in wolfram carbide. 'Each disc has 24 grinding elements, each fastened in a groove in only the outer periphery of the discs. The inside and outside diameter of circular grinding, surface are approximately 384 mm & 482 mm respectively and diameter of discs is 510 mm. The balanced rotating disc is mounted on the shaft with a friction bush assembly . The shaft is mounted in a cast iron housing on double spherical ball bearings. The grinding house is made of cast iron. The motor is with pulleys and V-belt drive and the motor sledge is enclosed by •sandwich constructed steel plates.

The grinding gap is adjustable by means of a dial hand wheel mounted on the basic house. All are mounted on a rigid welded steel profile frame.

3.0 Working principle

The grinding takes place between the grinding surface of a rotary and a stationary disc. The process involved is as described below and illustrated in Fig.2

The raw material enters the machine through the top positioned inlet and falls/slides directly into the centre of the milling chamber.

In here the raw material stream is met by a distributor mounted in the center of the rotating disc.

This distributor evenly feeds the material out between the whole peripheries of the inner most part of the circular grinding surface of the two discs.

Well caught between the grinding surfaces the raw material is gradually grinded while passing through the grinding areas by the centrifugal force created by the rotating disc.

Finally being thrown out from the grinding area the grinded material falls down by gravity.

The grade of grinding is dependent on the distance (adjustable) between the grinding surfaces of the rotating and the stationary disc, their angles and also on pattern of grinding elements; the narrower the distance, the finer the fractions and vice versa.

2.4 Blower and cyclone separator

It consists of high pressure centrifugal fan for pneumatic conveying of the grinded material. The grinded material is sucked through the high efficiency cyclone. Cyclone is used for elimination of fine grained particles & dust. The fine grained particles & dust are removed from top via fan & required material passes from bottom outlet through rotary valve to Universal separator.

2.5 Universal separator:

The universal separator is an advanced U-shaped trough with inlet and out let and supplied with a brush auger. It is used for~ the purpose of cleaning & separating different fractions (Fig 3).

The material to be separated is led past the screen area by the brush auger. On the way through the screen, materials with the same structure as the hole size are separated. The remaining materials leave the separator through the outlet at the end of the screen.

The screen area consists of 1 to 4 screens where the hole size gets bigger, the nearer you come to the outlet. Now it is fixed with 1.0 mm screen above first & second outlet & 1.6 mm screen above third & fourth outlet.

The separator is supplied with an independent outlet for each screened size.

The separated material can be bagged of directly or taken via a cell sluice for further conveyance. Otherwise it can be taken to a place for storage by means of the suction blower.

This separator is having following advantages.

- Can separate materials with nearly the same specific gravity.
- The screens are easy to replace as per the nature of materials & cleaning rates.
- Many adjustment and combination alternatives.
- Can separate up to 4 grading at a time.

3.0 Precautions

1. The raw material must not contain moisture above 15% otherwise efficiency of milling will be decreased due to jamming.

2. Raw material should be free from hard foreign particles otherwise they will damage the disk surface.

3. There must be no material between disks while starting the plant otherwise the friction thus added to the discs may be so high that the motor will be overloaded.

4.0 ADVANTAGES OF PRETREATING STRAW

Straw from various sources is a non-homogeneous raw material. It consists of three major botanical components (Fig 4).

1. Nodes.
2. Leaves
3. Internodes &

Also have wax on epidermal, rachis or pod at top consisting grind and also husk. The percentage of these components for particular rice straw of Indian variety are given in Table-2. The percentage silica and ash in these fractions is also given.

These components of straw have different physical strength properties. The leaves are fragile, the internodes on the other hand and are very tough and strong.

It is well known that the botanical components also differ in chemical composition. The inter node has a high content of cellulose while the leaves & nodes have a higher content of ash, protein & silica.

Thus, the inter-node fraction is the fraction of high quality as raw material for cellulose industry since it has a higher content of cellulose, relatively higher average fiber length, a lower content of ash and very important, a low content of silica as compared to other components of straw. The content of silica in straw is much higher than that in wood and so straw fractions obtained after pretreatment in disc mill with a low silica content would clearly be of high value from point of view of black liquor recovery and subsequent paper making process.

Secondly, the non-fibrous portion obtained after pretreatment has a higher mineral content (silica), coarser fiber, contain more protein, and has a high digestibility for animal feed.

Thus from technical point of view the value of straw as raw material for the industry can be increased by separating it into its botanical components and this job is done by straw treatment plant or disk mill by mechanical separation of straw material and thus will be suitable for paper making process including black liquor recovery & meal fraction can be converted to:

- Fuel
- Fodder

So, the main advantage which will be achieved by cleaning straw by Disk Mill can be summarized as

1. Less chemical consumption due to removal of non fibrous material.

2. Less solid waste generation during pulp and paper making process.

3. Improvement in paper properties.

4. Improvement in properties of black liquor.

5.0 RESULTS & DISCUSSION

Dried and chopped raw material was treated in a Disc Mill with different disk clearances between the discs. The milled mass was sieved first using 2 mm screen in separator into five fractions. The percentage yield as shown in Table 3 was very low (assuming 3rd , 4th & 5th fractions as accept) and so, no ash and silica determination was made for this lot, Of course, considering the internodes fraction which consist only 40 percent , this is alright but practically it is very low yield no mill will be interested. Then, sieve was changed to 1 mm screen over 1st & 2nd outlet and to 1.6 mm screen over 3rd and 4th outlet. Three trials were conducted under these conditions of screen but with variation in disc clearance and angle. The percentage of different fractions & ash & silica percentage on o.d. material basis is given in the table 4, 5 and 6 for different disk clearances.

The yield in 2nd trial is lower but %ash and %silica removal is higher than next two trials. From 2nd to 4th trial yield increases but silica & ash percentage removal decreases. In the 2 trial straw was cut by grinding mill which generates more dust and fine material so in the next two trials it was cut by conventional chopper.

Thus the results of trails conducted till now shown that there is about 30-50% reduction in total silica content and if we desire raw material totally free from leaves, grains etc. then yield will be very low and ash and silica removal will be high

5.0 CONCLUSION

Disk mill is machine which can be used for both straw cleaning & bagasse dry depithing. This will not only make straw more suitable for paper making considering consumption of chemicals during pulping, quality of paper and properties of black liquor due tc removal of undesirable components & silica but provides meal fraction which can be further used as fuel, fodder etc. Preliminary trials performed with rice straw gives satisfactory results about the silica removal, however, we hope to get still better results in silica and undesirable component removal & thus improvement in pulp & black liquor quality after making changes in discs & grinding elements combination.

TABLE NO.1

THE AMOUNT OF RAW MATERIAL THAT NEED TO BE MOBILISED IN FUTURE

(Lakh tonnes)

Year	Raw material available			Demand For paper, Paper Boards & Newsprint	Paper that can be produced	Gap in production for which extra raw material is needed
	Bamboo	Wood	Total			
1987	19.0	13.1	32.1	21.95	12.11	8.94
1990	19.0	13.1	32.1	24.45	12.11	12.34
1995	9.0	13.1	32.1	31.61	12.11	19.50
2000	19.0	13.1	32.1	41.12	12.11	29.01

TABLE NO. 2

AVERAGE BOTANICAL COMPONENTS (% W/W) OF RICE STRAW AND ASH & SILICA CONTENT IN COMPONENTS:

Components	% of components In straw (w/w)	%Ash in component	% Silica in component
Pods/Rachies	5.00	13.45	8.87
Leaf +Leaf Sheath	45.00	15.84	11.10
Internodes	40.00	12.87	4.80
Nodes	9.00	15.47	11.16

TABLE NO. 3

DISK MILL TRIAL NO. 1.

Disc Mill clearance	:	1.0 mm
Disk Mill angle		
Rotary	:	2.5^0
Stationary	:	2.5^0
% Ash in unprocessed straw	:	-
% Silica in unprocessed straw	:	-
Any other remarks	:	Chopped by conventional Chopper to about 1" length

Fraction	% Fraction (Wt %) on whole material processed.	% Ash in Fraction (o.d)	Silica in Fraction (o.d)
No. 1 (Reject -2 mm screen)	30.00	-	-
No.2 -2 mm screen	16.00	-	-
No.3 - 2 mm screen	6.00	-	-
No.4 - 2 mm screen	3.00	-	-
No. 5 Accept	46.00	-	-

TABLE NO. 4

DISK MILL TRIAL NO. 2

Disc Mill clearance : 0.65 mm

Disk Mill angle

Rotary : 4.0^0

Stationary : 4.0^0

% Ash in unprocessed straw : 14.84

% Silica in unprocessed straw : 08.49

Any other remarks : Chopped by grinding machine with 30 mm screen

Fraction	% fraction (Wt%) On whole material Processed.	% ash in fraction (o.d Material basis)	Silica in fraction (o.d material basis)
No. 1 (Reject -1.0 mm screen)	24.00	16.59	14.02
No.2 -1.0 mm screen	09.00	15.15	12.31
No.3 - 1.6 mm screen	10.00	14.62	07.08
No.4 - 1.6 mm screen	03.00	14.32	07.01
No. 5 Accept	54.00	13.30	05.48

TABLE NO.5
DISK MILL TRIAL NO. 3

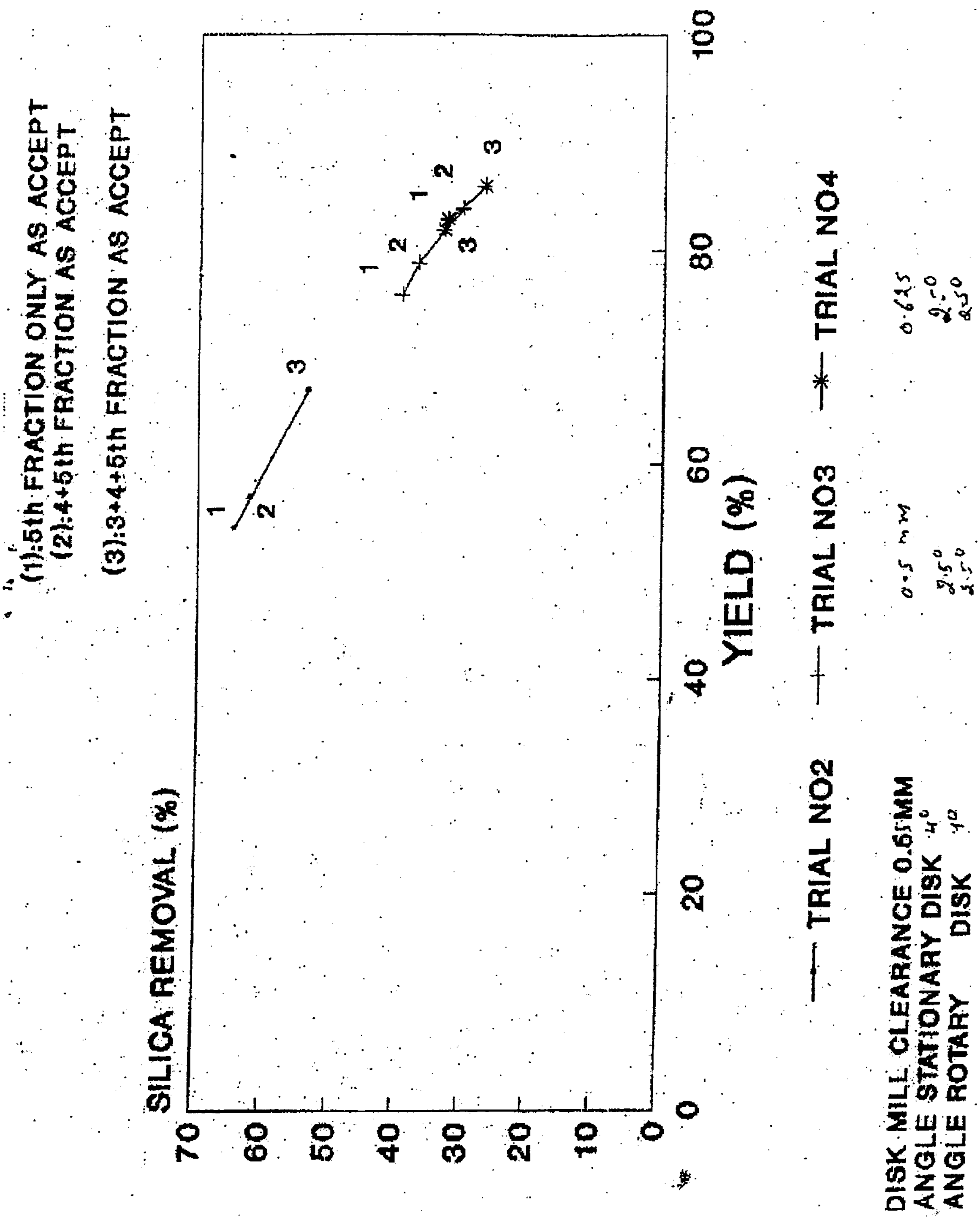
Disc Mill clearance	:	0.5 mm
Disk Mill angle		
Rotary	:	2.5^0
Stationary	:	2.5^0
% Ash in unprocessed straw	:	15.49
% Silica in unprocessed straw	:	08.11
Any other remarks	:	Chopped by conventional chopper to about 1"length

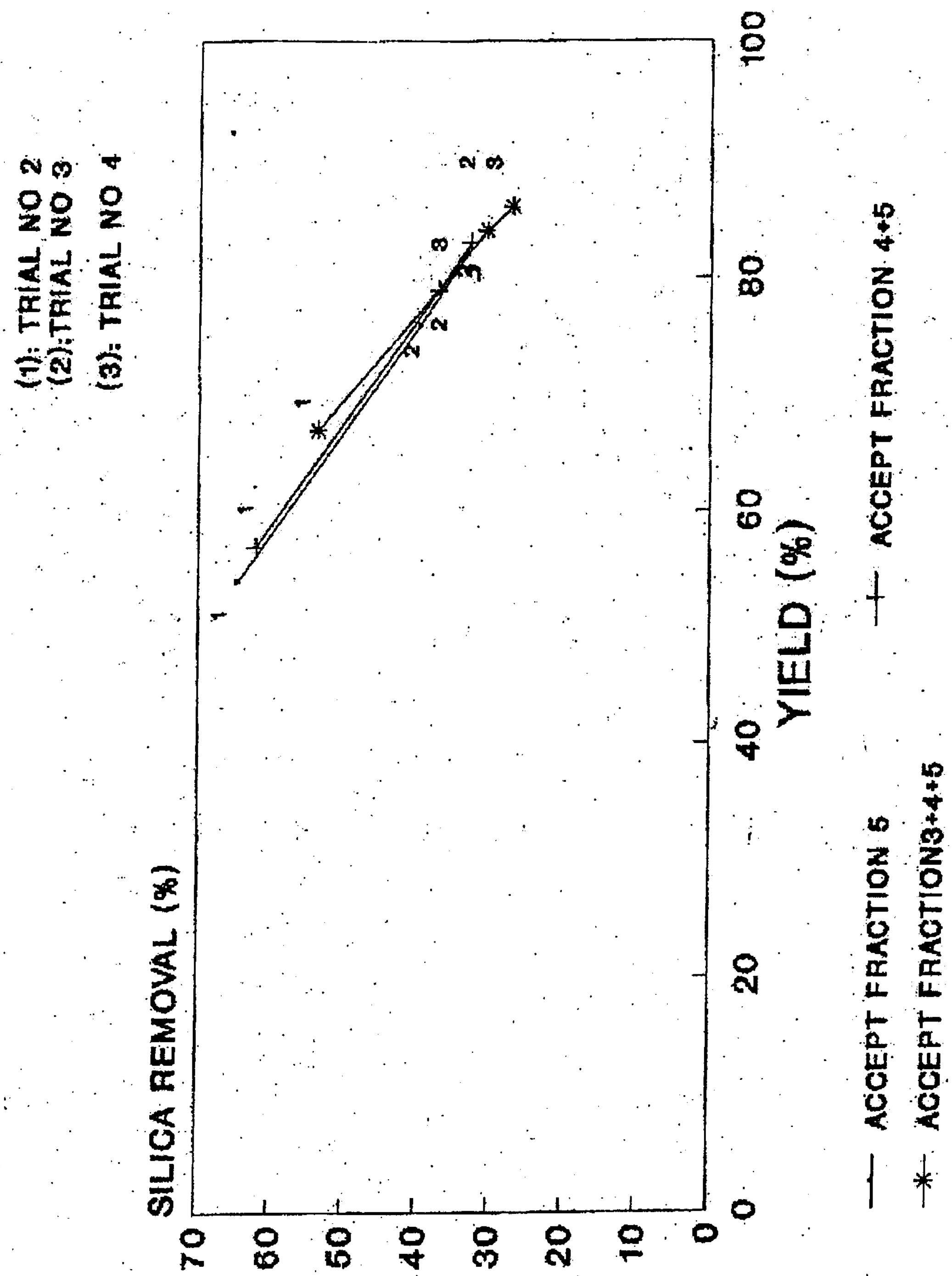
Fraction	Fraction (wt %) on whole material processed.	% Ash in fraction (o.d. material basis)	% silica in fraction (od. material basis)
No. 1 (Reject -1.0 mm screen	13.40	18.05	15.00
No. 2 -1.0 mm screen	02.80	15.14	12.33
No. 3 -1.6 mm screen	04.90	15.05	10.60
No. 4 -1.6 mm screen	02.60	14.98	07.66
No. 5 Accept	76.30	14.28	06.12

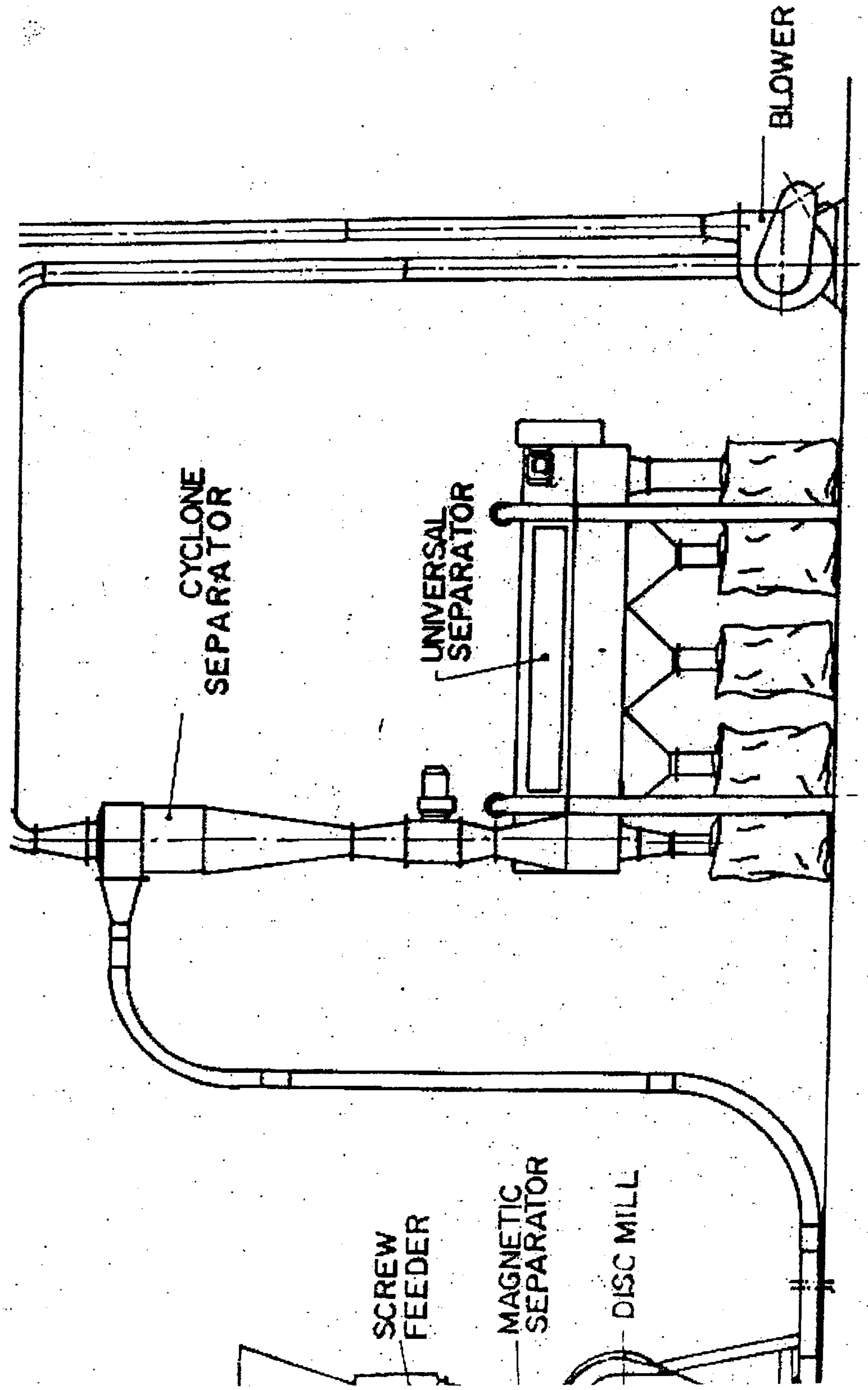
TABLE NO. 6
DISK MILL TRIAL NO. 4

Disc Mill clearance	:	0.625 mm
Disk Mill angle		
Rotary	:	2.5^0
	:	2.5^0
Stationary		
% Ash in unprocessed straw	:	16.00
% Silica in unprocessed straw	:	08.21
Any other remarks	:	Chopped by conventional chopper to about 1"length

Fraction	% Fraction (wt %) on whole material processed.	% Ash in fraction (o.d. material basis)	% silica in fraction (o.d. material basis)
No. 1 (Reject -1.0 mm screen	12.00	18.05	15.03
No. 2 -1.0 mm screen	02.00	16.36	13.21
No. 3 -1.6 mm screen	03.50	16.00	12.29
No. 4 -1.6 mm screen	00.50	14.09	08.00
No. 5 Accept	82.00	14.80	06.18

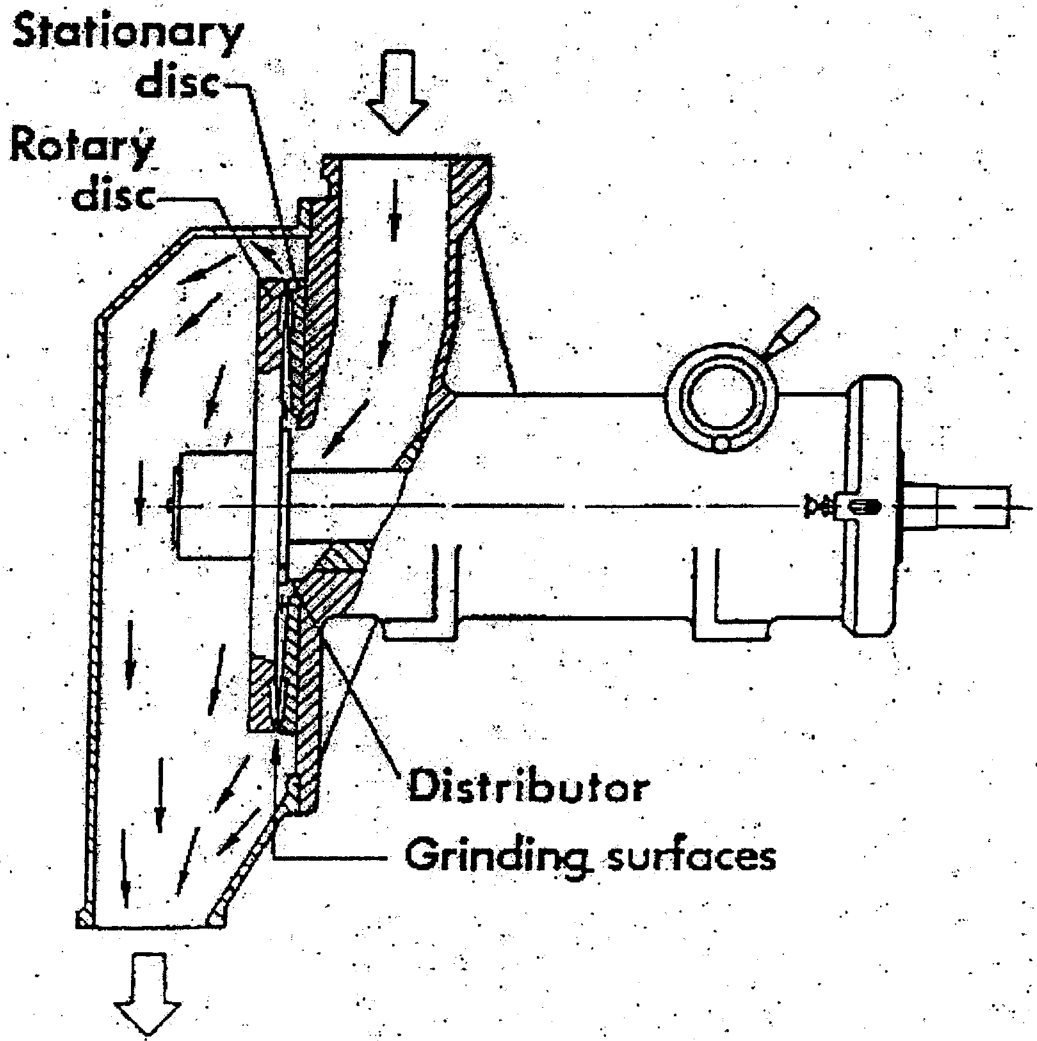

(1):5th FRACTION ONLY AS ACCEPT
(2):4+5th FRACTION AS ACCEPT
(3):3+4+5th FRACTION AS ACCEPT
SILICA REMOVAL (%)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
YIELD (%)
TRIAL NO2
TRIAL NO3
TRIAL NO4
DISK MILL CLEARANCE 0.65MM
ANGLE STATIONARY DISK
ANGLE ROTARY DISK


(1): TRIAL NO 2
(2): TRIAL NO 3
(3): TRIAL NO 4
SILICA REMOVAL (%)
YIELD (%)
ACCEPT FRACTION 5
ACCEPT FRACTION 4+5
ACCEPT FRACTION3+4+5



1. STRAW TREATMENT PLANT

FIGURE- 2


Stationary disc
Rotary disc
Distributor
Grinding surfaces

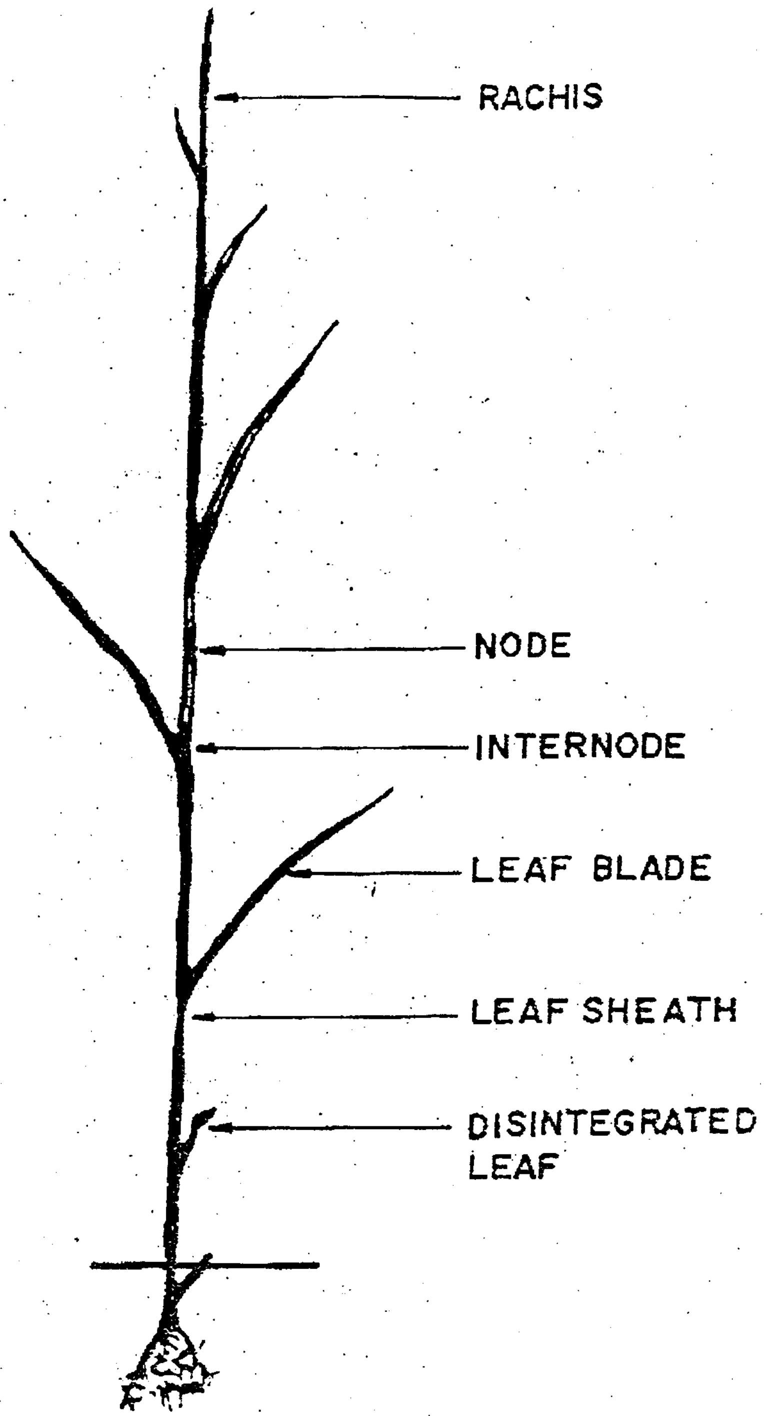
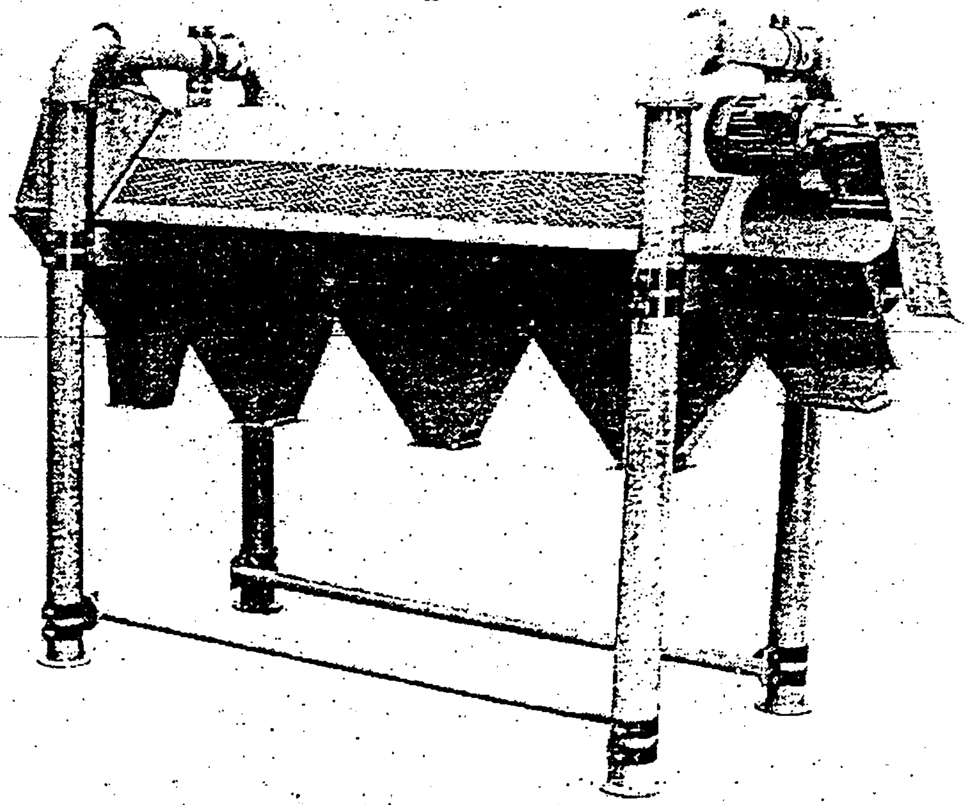

RACHIS
NODE
INTERNODE
LEAF BLADE
LEAF SHEATH
DISINTEGRATED
LEAF

FIGURE- 3

Universal Separator



for cleaning and separating purposes

STATUS OF TECHNOLOGIES IN AGRO BASED MILLS

STATUS OF TECHNOLOGIES IN AGRO BASED PULP & PAPER MILLS

Dr. A. G. Kulkarni,
Director,
CPPRI, Saharanpur

About The Author

Dr. A.G. Kulkarni, Director Central Pulp & Paper Research Institute (CPPRI) Saharanpur, Uttar Pradesh, India has been with the CPPRI since its inception. He holds a Master degree in Chemistry & Doctorate in Black Liquor and Lignin Chemistry.

Dr. Kulkarni has pioneered the research work on Desilication of black liquor with eventual development of mill scale plant, installed at Hindustan Newsprint Ltd., Kerala and High Rate Bio-methanation of black liquor rich effluent and a mill scale unit is successfully operating at Satia Paper Mills is another achievement of Dr. Kulkarni. His contribution in the area of physico chemical & thermal properties of agro - residue non-wood black liquors has now made it possible to process this liquor in chemical recovery boilers. He has published more than 300 scientific papers in Indian and International journals. He is widely traveled in Europe, S. E. Asia, and Australia and has been on several foreign missions as UNDP/UNIDO Consultant.

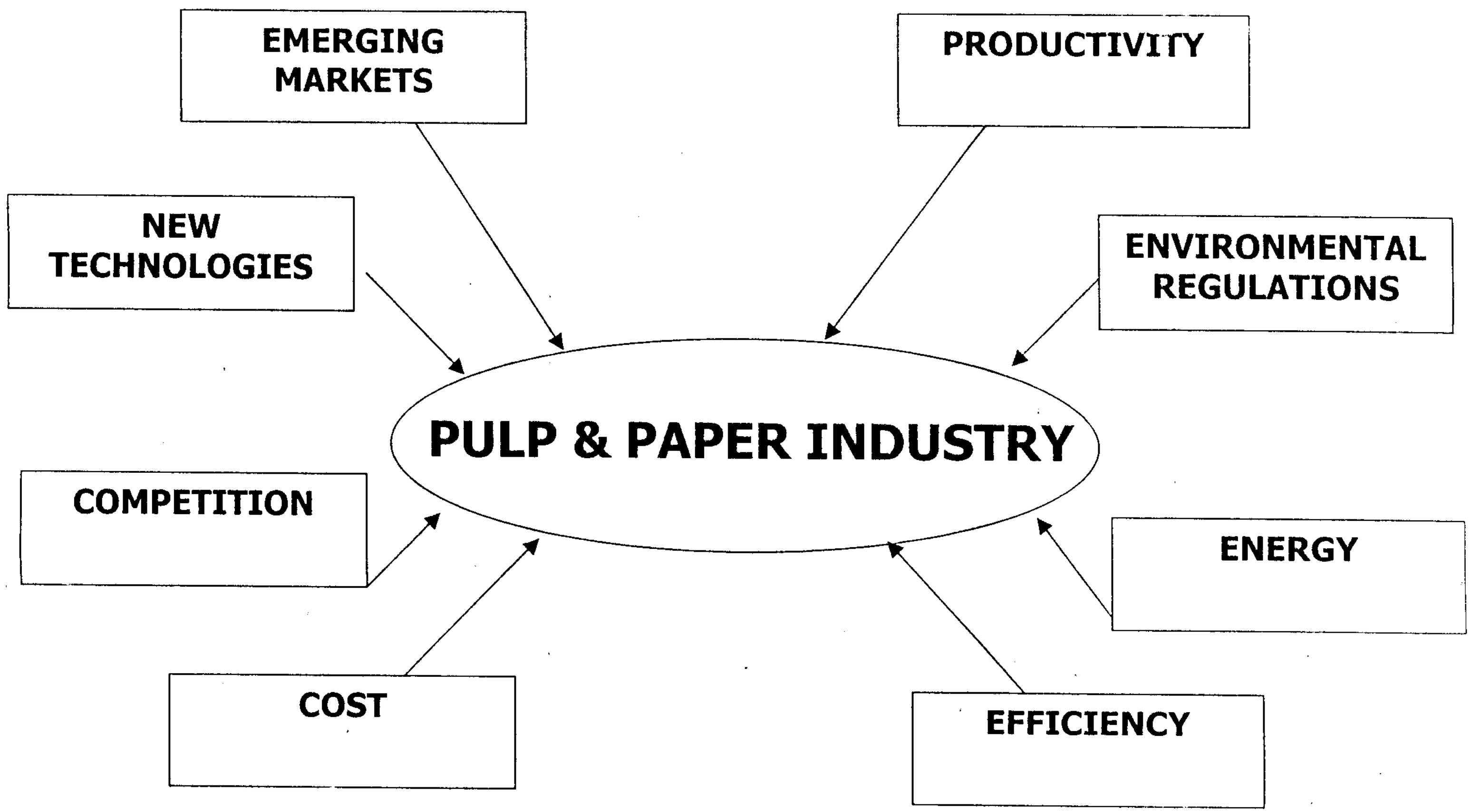
His areas of specialization include pulping and bleaching, black liquor-its chemistry & processing, environment and energy management. Dr. Kulkarni holds several patents-important ones being on desilication of black liquor, thermal treatment of black liquors and Direct Alkali Recovery System etc. He is a member of several National and International Scientific & Technical organizations and also on board of Directors of Paper Mills & Research organizations

STATUS OF TECHNOLOGY IN AGRO BASED MILLS

Dr.A.G.Kulkarni

The author has highlighted the latest developments, which have taken place in technology in various units operations in agro-based pulp & paper mills with particular reference to raw material handling, pulping, washing and bleaching. The article also focuses on various technology up-gradation schemes for agro-based mills.

FACTORS CONTROLLING GROWTH OF PULP & PAPER INDUSTRY WORLD WIDE



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PULP & PAPER INDUSTRY WORLD WIDE

- Fifth largest Industrial sector
- Accounts for 10% of industrial consumption of energy

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FACTS ABOUT INDIAN PAPER INDUSTRY

- A large no. of small paper mills have been installed during late 70's & 80's, with high priority to keep their capital costs low.
- These mills do not posses energy efficient equipments
- After the energy crisis of 70's & 80's, the paper industry had to think of technology upgradation and adoption of energy conservation for its future viability.

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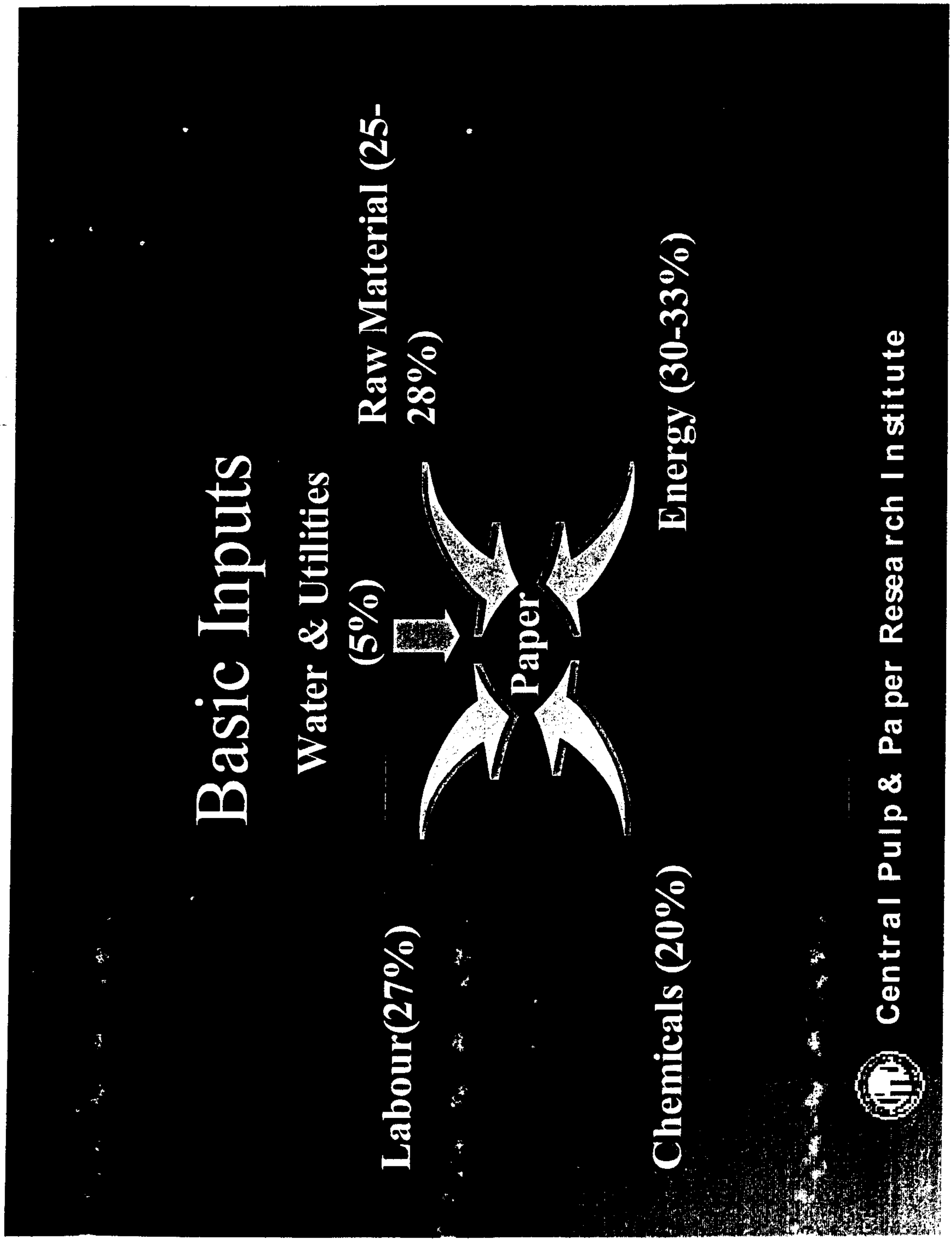
Basic Inputs
Water & Utilities (5%)
Raw Material (25-28%)
Labour(27%)
Paper
Chemicals (20%)
Energy (30-33%)
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COST COMPONENT FOR PAPER PRODUCTION IN 1973 & 2001

Basic inputs	2001	1973
Raw materials	25%-28%	25%
Chemical	20%	35%
Energy	30-33%	13%
Labour	20%	27%

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ENERGY CONSUMPTION PATTERNS

Particulars	Specific Energy Consumption, GJ/t p		
	1985	1990	1995
Mill I - Large	28	30	29
Mill II - Large	32	26	27
Mill III - Large	26	21	22
Mill IV - Large	28	34	29
Mill V - Large	*	*	45
Mill VI- Medium	25	20	16
Mill VII - Medium	*	23	20
Mill VIII - Medium	25	20	19
Mill in a developed country , Japan	28	21	17

*Information not available.

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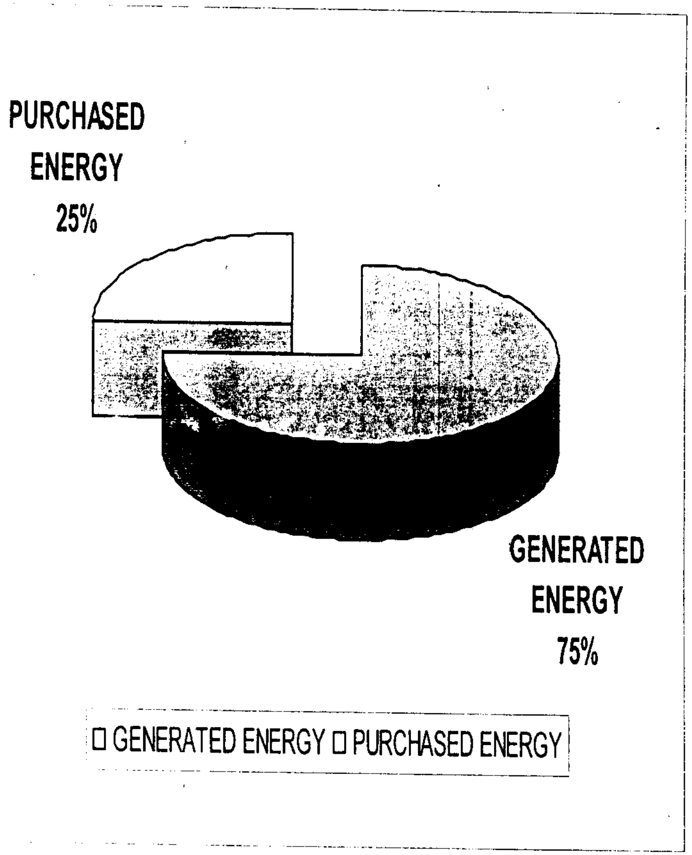
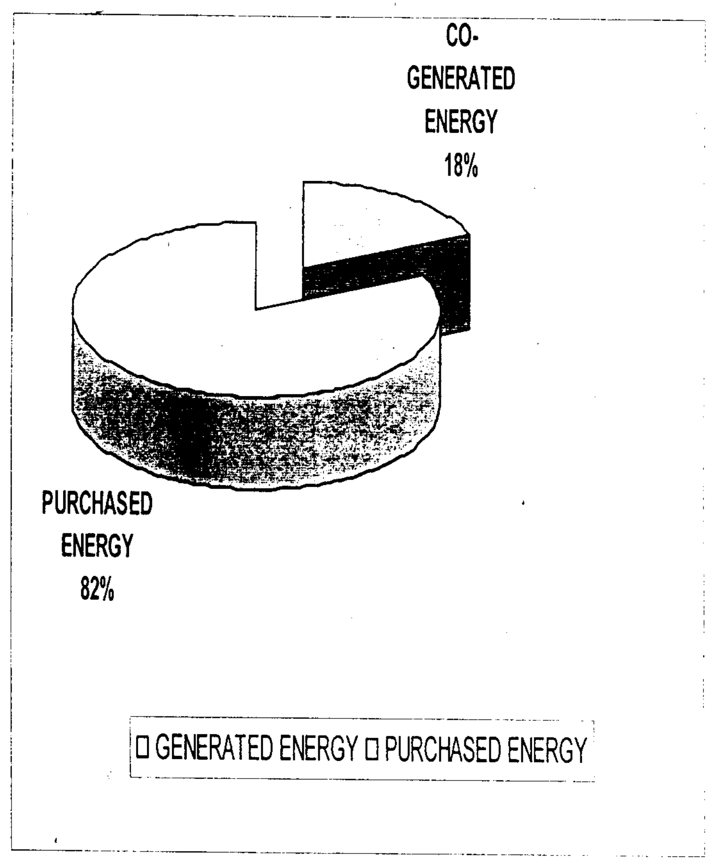
GENERATION OF ENERGY



DEVELOPED COUNTRIES



INDIAN MILLS

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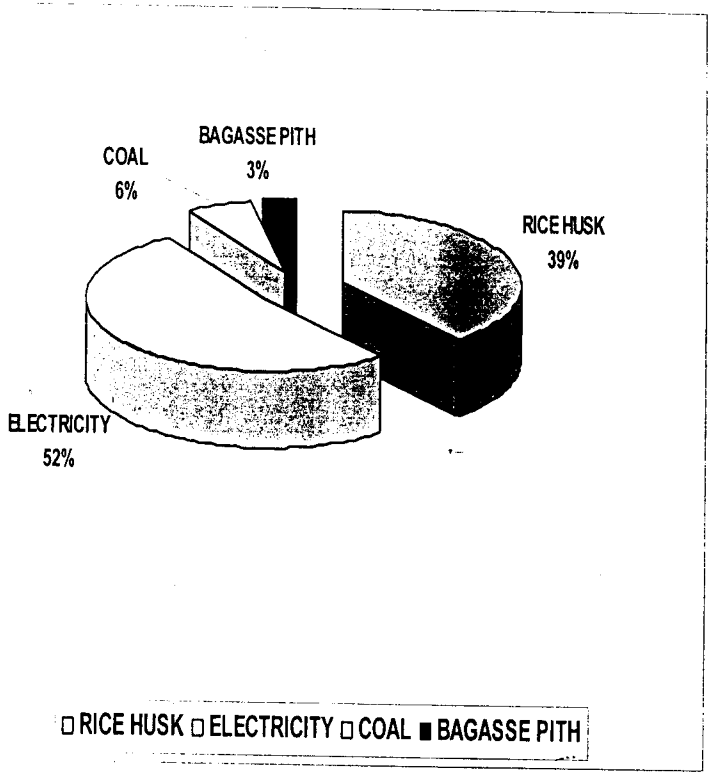
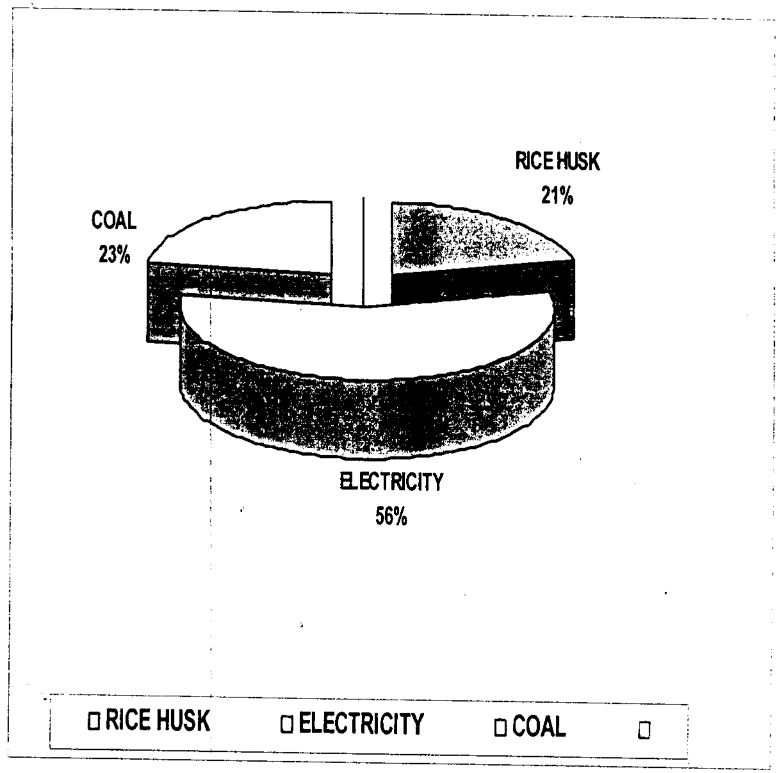
DISTRIBUTION OF ENERGY COST



Mill-1



Mill-2

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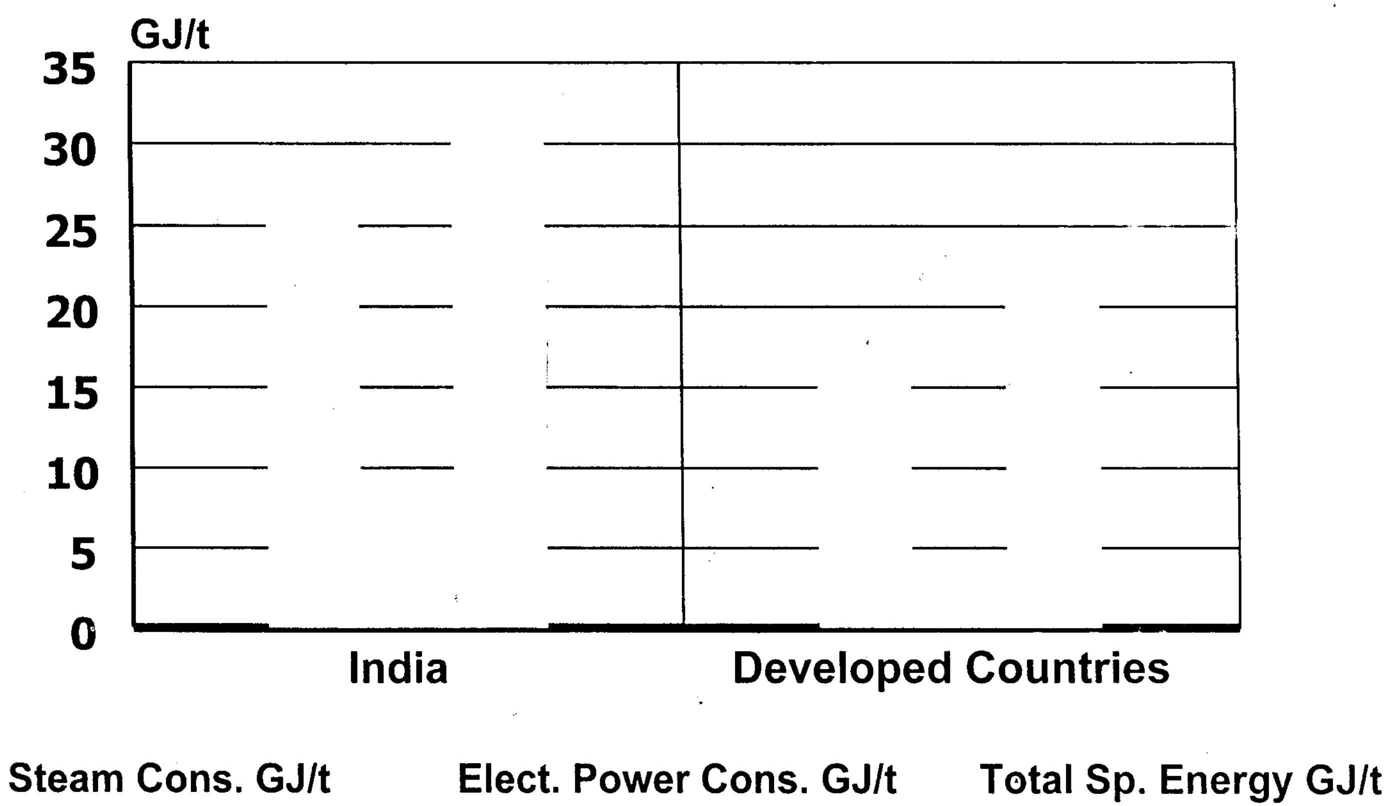
ENERGY CONSUMPTION IN INDIA & DEVELOPED COUNTRIES



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MAJOR FACTORS IDENTIFIED

- Lack of time to time modernization
- Need for general awareness & good house keeping
- Energy audit

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NEED FOR CLEANER PRODUCTION TECHNIQUES

- CONSERVATION OF RESOURCES (CHEMICAL, WATER, ENERGY & RAW MATERIAL)
- COST EFFECTIVE PRODUCTION AND QUALITY STADARDS
- ENVIRONMENTAL COMPATIBILITY

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Raw Material Handling:

- Compact baling of loose materials
- Efficient cleaning of raw material
- Installation of belt conveyors for conveying system.

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STRAW QUALITY IMPROVEMENTS WITH EFFICIENT CLEANING SYSTEM

PARTICULARS	BEFORE CLEANING %	AFTER CLEANING %
Ash /Dust	18	10.0
Fibre	78	88.0
Grain / Husk	5.0	2.0
Chemical Charge as NaOH	12.0	10.0
Screen Rejects	1.5	1.0
Kappa No.	18.6	14.5

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Pulp Mill Operation:

- Separate cooking of raw materials
- Short cycle pulping of non-wood raw materials
- Indirect steaming in digesters
- Vapour phase pulping
- Hot stock refining
- Blow heat recovery

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- Screw press installation for non-wood raw material
- Low kappa no. pulping
- Improved washing system.

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OTHER PULPING PROCESS

- ORGANOSOLV
- AMMONIA
- AQ. ADDITIVE
- SULFITE
- BIOPULPING
- KRAFT PULPING
- LIME PULPING

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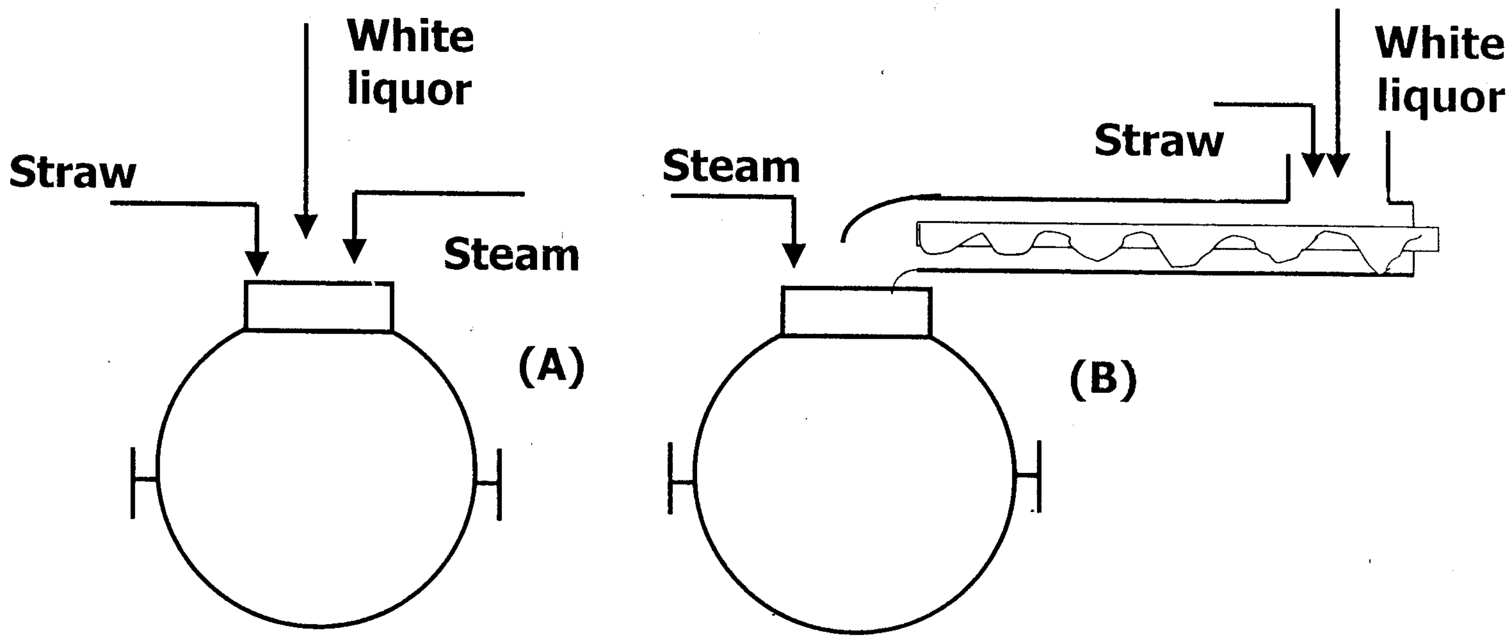
ILLUSTRATION OF CONVENTIONAL (A) & MODIFIED DIGESTERS(B) WITH CHEMICAL PREMIXING ARRANGEMENT



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STRAW PULPING AT LOW MATERIAL TO LIQUOR RATIO

PARTICULARS	HIGH BATH RATIO	LOW BATH RATIO
Material to liquor ratio	1:5	1:3.5
Active alkali, g/l as NaOH	20	29.0
Steam consumption, T/t O.D. Pulp	4.8	1.7
Black liquor solids, % w/w at blow tank	12.0	17.0
Rejects, % w/w	5.0	3.0

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SALIENT FEATURES OF EXTENDED DELIGNIFI CATION IN MODIFIED BATCH DIGESTERS AS COMPARED TO CONVENTIONAL BATCH PULPING

- AIR REMOVAL IS ENSURED BEFORE PULPING STARTS.
- DIGESTER IS ALWAYS FULL.
- EXTENSIVE CLOSED CIRCUIT RECYCLING OF ENERGY & BLACK LIQUOR.
- PULP IS QUENCHED & PUMPED BUT NOT BLOWN.
- MOST BLACK LIQUOR REMOVED FROM DIGESTER- VERY LITTLE CAN REACH WASHER.
- DISPLACEMENT PHASE CONTINUED TILL WATER DILUTION FACTOR HAS PASSED.

*

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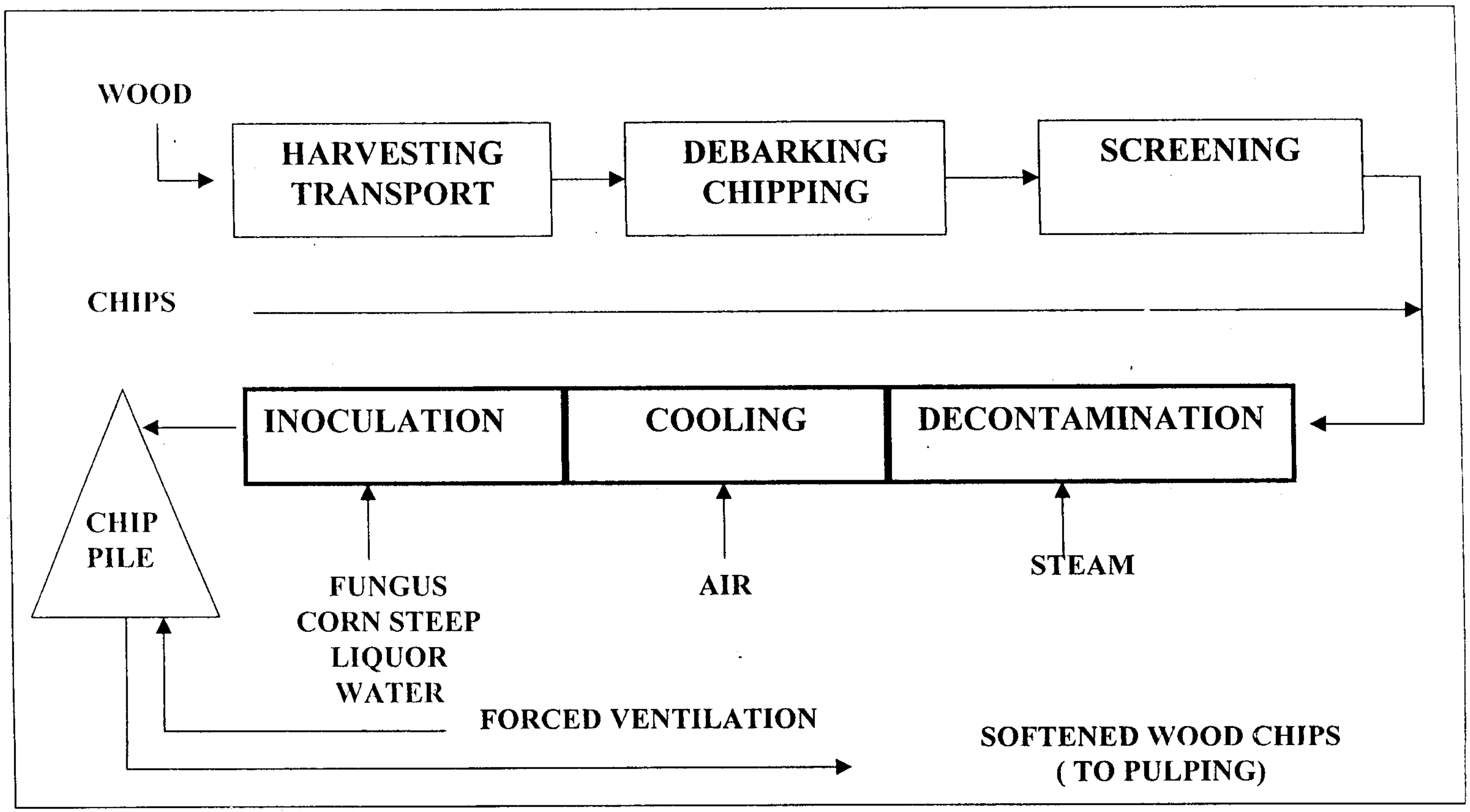
OVERVIEW OF BIOPULPING PROCESS



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PREVAILING WASHING PRACTICES

Raw material Processed	Washing System Adopted	Soda Losses During Washing	Soluble COD in Pulp Kg/t	Total Chlorine Demand Kg/t	Initial Black Liquor Conc. %
Straw/ bagasse	2-4 rotary Vaccum Washers	30-60	15-20	150-200	5-7
Bamboo	4 vaccum Drum Washers	25-35	10	80	12-14
Wood	Do	20	7	60	14-16

ROTARY VACUUM WASHERS

- Directly connected to vacuum pumps
- Washers working with barometric leg
- Washers fitted with drop leg pipes inside the drum (valve less)
- New generation of washers
- Rotary pressure filter
- Diffusion washers
- Belt washer .{black – clawson – sunds defibrator. (Ultra washer)}
- Double wire washers.

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OPERATING CONDITIONS

Particulars	Inlet cy.	Discharge %	Efficiency %
Rotary vacuum	0.8-1.0	10-14	90
Rotary pressure	1.0-1.5	12-14	90
Belt washers	2.5-3.0	12-14	99
Double wire washers	2-3	30-40	95

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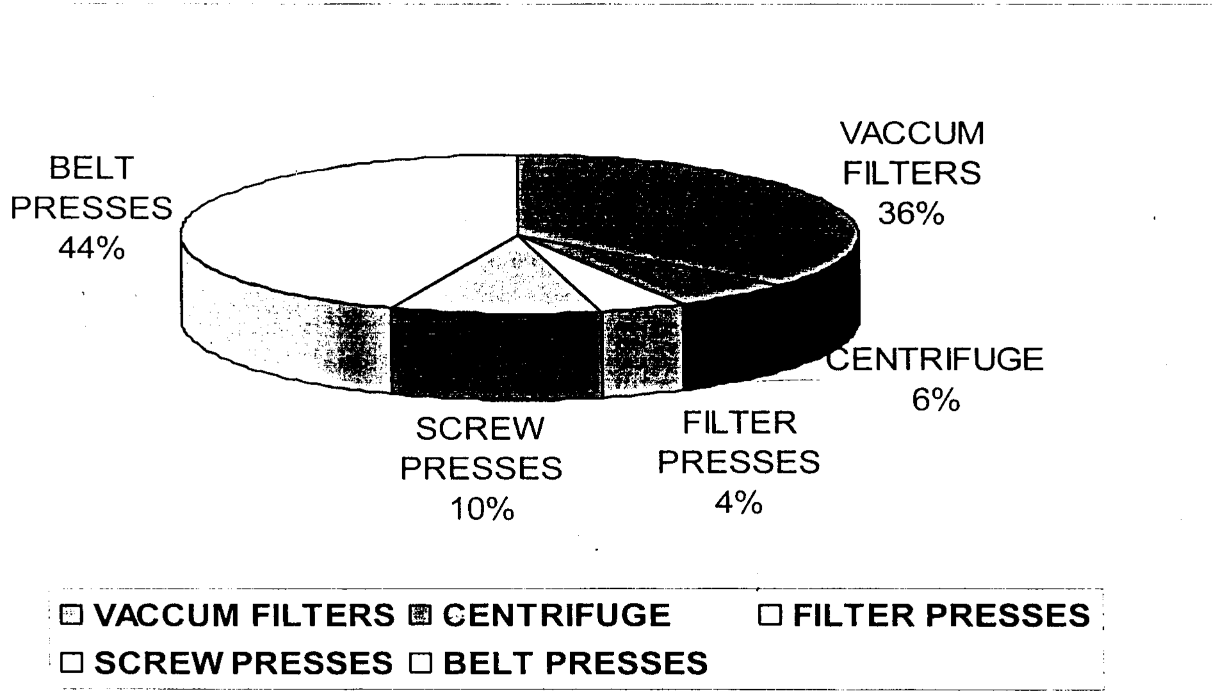
MECHANICAL DEWATERING DEVICES- RELATIVE USES IN PULP AND PAPER INDUSTRY



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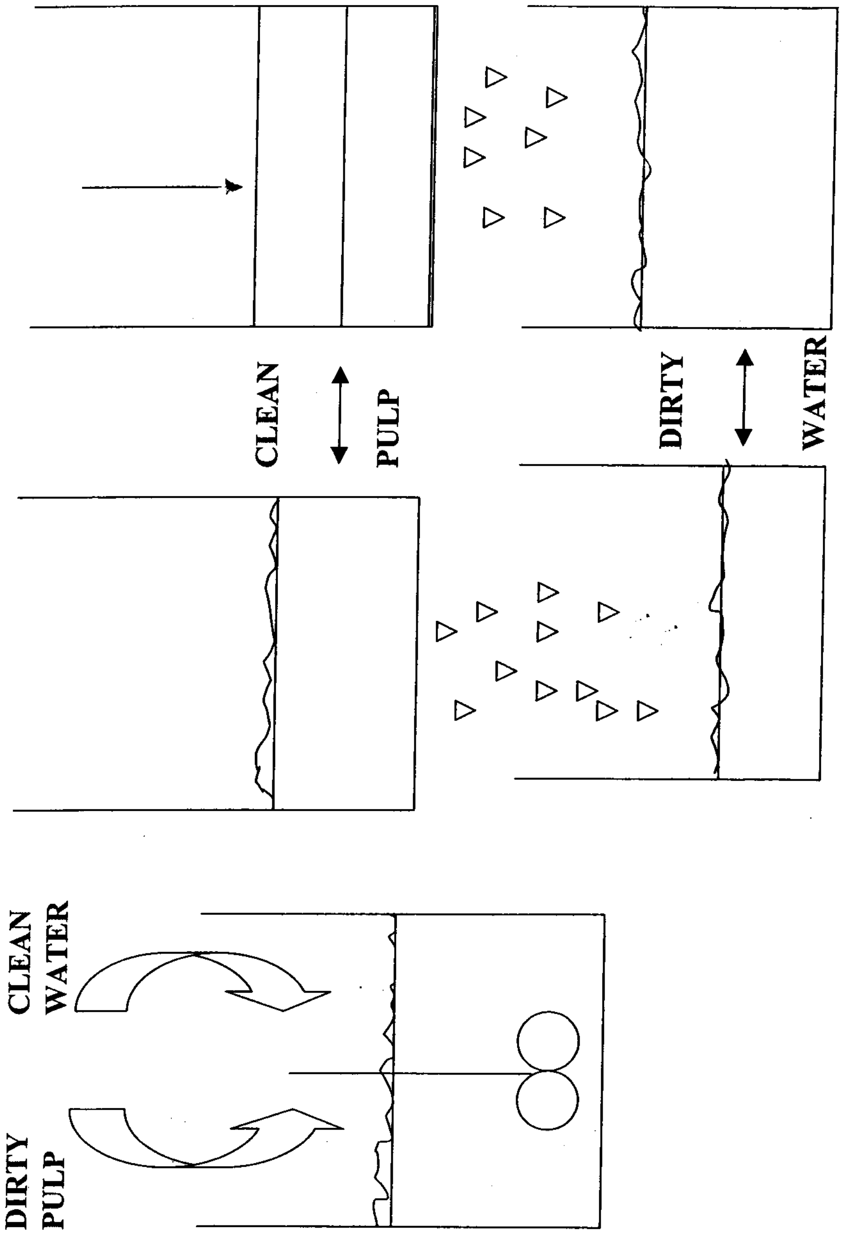
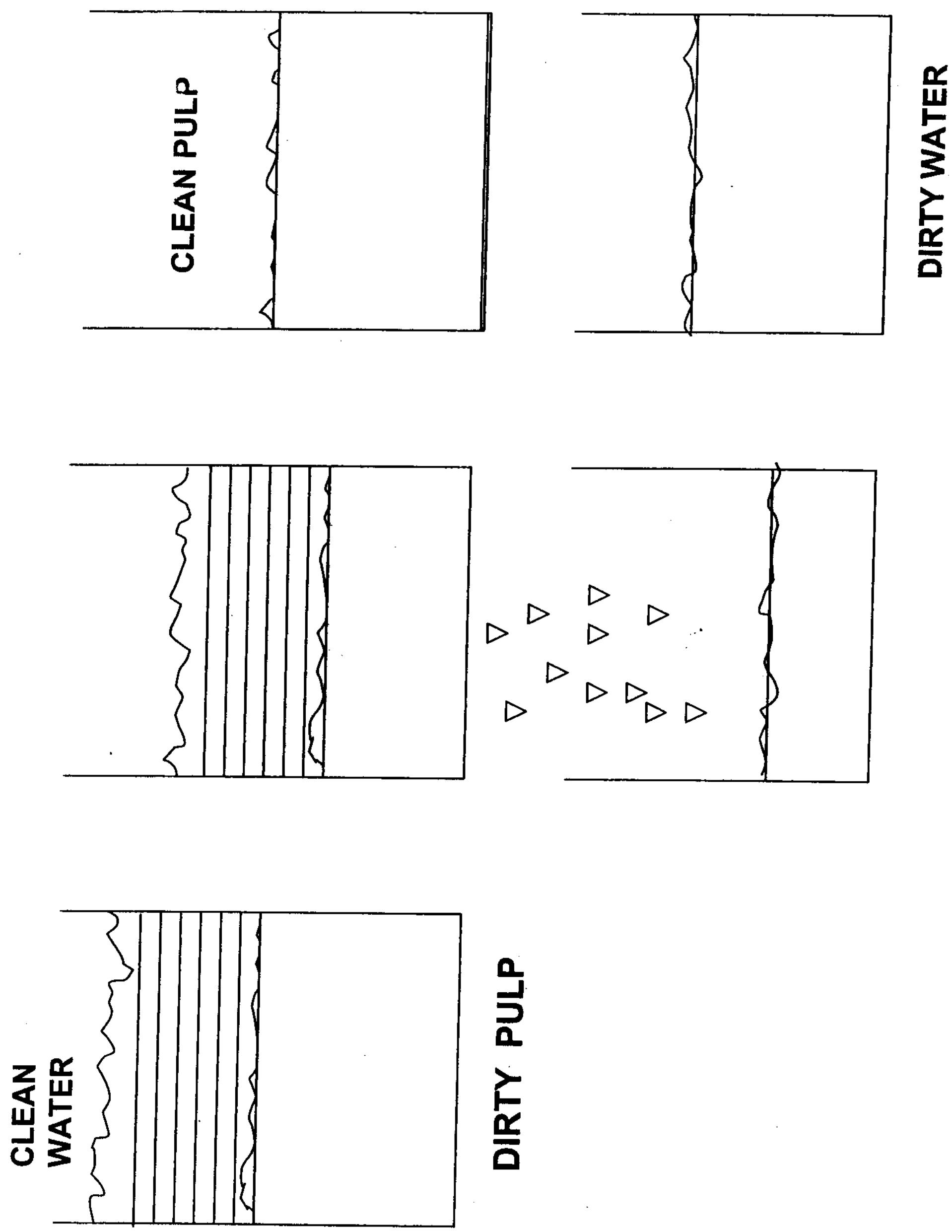
DILUTION WASHING



DISPLACEMENT WASHING



BENEFIT OF IMPROVED WASHING SYSTEM

Raw material Processed	Saving in Chlorine consumption, kg/t	Steam saving in evaporation to achieve 50% conc. T/t PULP
Straw/ bagasse	75-100	(Raising conc. From 6-10%)
Bamboo	40	(Raising conc. From 13-16%)
Wood	30	(Raising conc. From 15-18%)

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PRODUCTIVITY OF VACUUM WASHER FOR DIFFERENT TYPE OF PULP

PULP TYPE	VACUUM WASHER SPECIFIC LOADING	DOUBLE WIRE WASHER SPECIFIC PRODUCTION t/m/d
BAMBOO	3.1-4.8	
BAGASSE	2-4	31.1
RICE STRAW	1-2	22.4
WHEAT STRAW	1-2	22.5

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COMPARISON OF CONVENTIONAL VACUUM WASHER & HORIZONTAL BELT WASHER

(BASIS 30 TPD PULP MILL)

WASHER TYPE / PARTICULARS	BELT WASHER HORIZONTAL	3 – STAGE VACUUM WASHER
DILUTION FACTOR	AROUND 2	MORE THAN 3
WASHING EFFICIENCY	90 – 95 %	AROUND 80 %
ELECTRIC ENERGY, KWH /DAY	1200	3600
% W/W DISSOLVED SOLIDS GOING TO RECOVERY	MORE THAN 12.0	AROUND 6.0
STEAM REQUIREMENT FOR EVAPORATION TO ACHIEVE 40% CONCENTRATION,TONS	263	450

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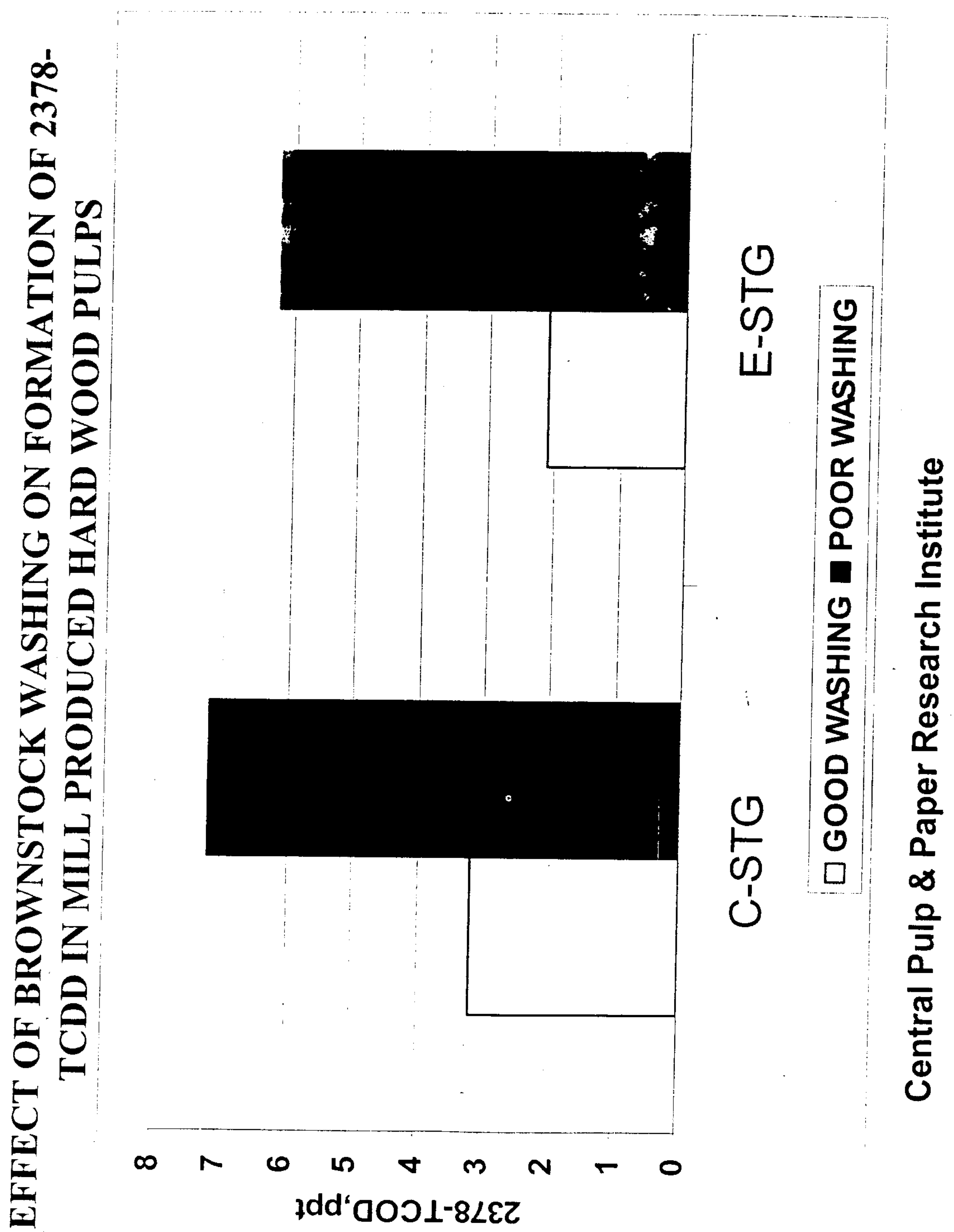
EFFECT OF BROWNSTOCK WASHING ON FORMATION OF 2378-TCDD IN MILL PRODUCED HARD WOOD PULPS
2378-TCOD,ppt
0
1
2
3
4
5
6
7
8
C-STG
E-STG
GOOD WASHING
POOR WASHING
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EFFECT OF PULP QUALITY & BLEACH SEQUENCES ON AOX LEVEL

		BLEACHING SEQUENCE			
		CEH		OCEH	
RAW MATERIAL	KAPPA NO.	CL2 DEMAND KG/T PULP	AOX KG/T PULP	CHLORINE DEMAND KG/T PULP	AOX, KG/T PULP
EUCALYPTUS	19.2	60.0	4.18	30.0	1.27
BAMBOO	18.2	80.0	4.63	30.0	1.32
BAGASSE	14.6	45.0	2.93	17.0	0.86

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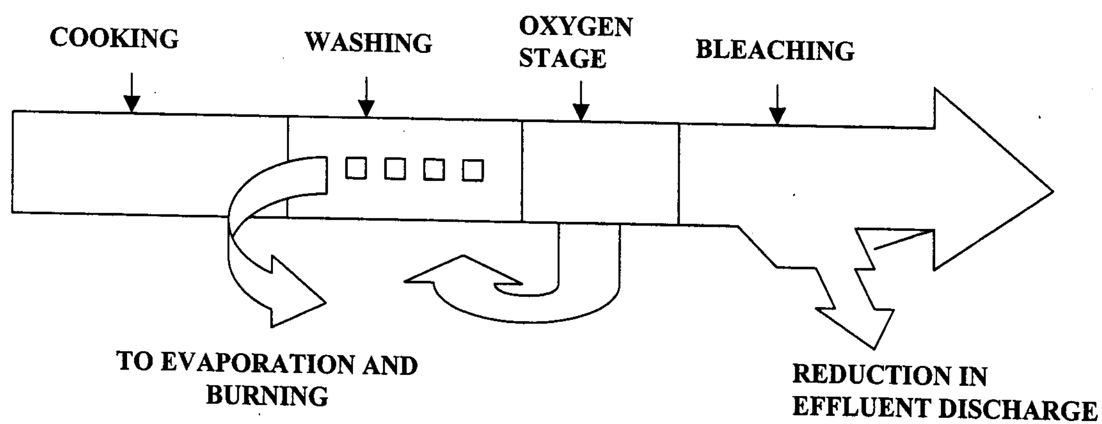
INCENTIVES OF OXYGEN DELIGNIFICATION



BOD	COD	COLOR
-50%	-60%	-70%

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Papermaking:

- Installation of disc refiners
- Cascade system for efficient condensate removal
- Pocket ventilation for dryers
- Installation of pressurized closed hoods on paper machin
- Use of Thyrister drive in place of line shaft drive
- Use of double dilution system

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Chemical Recovery:

- Increasing number of evaporator bodies for better steam economy
- High solids black liquor firing
- Installation of high pressure boilers with efficient control system

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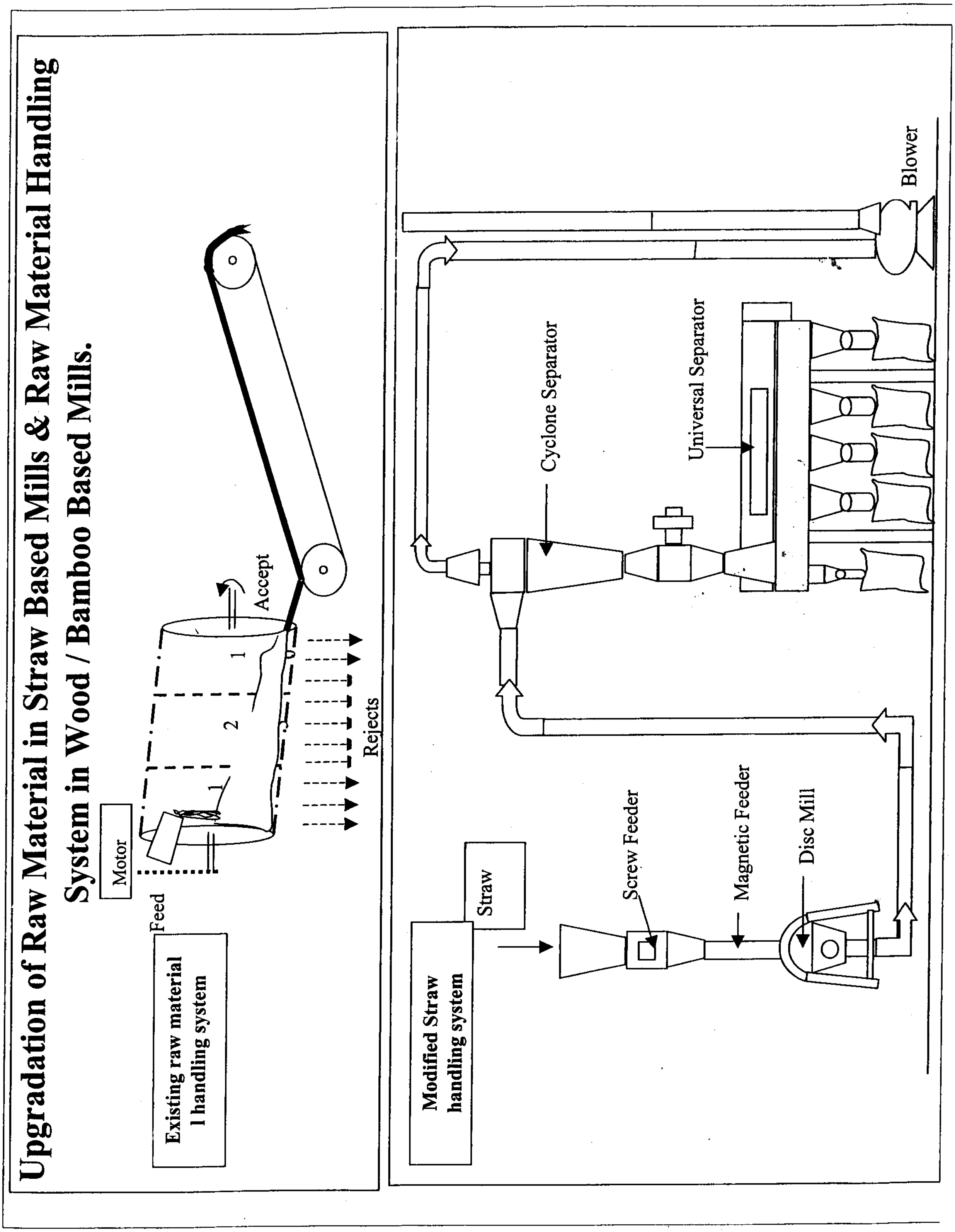
EXTERNAL EFFLUENT TREATMENT METHODS IN PULP & PAPER INDUSTRY.

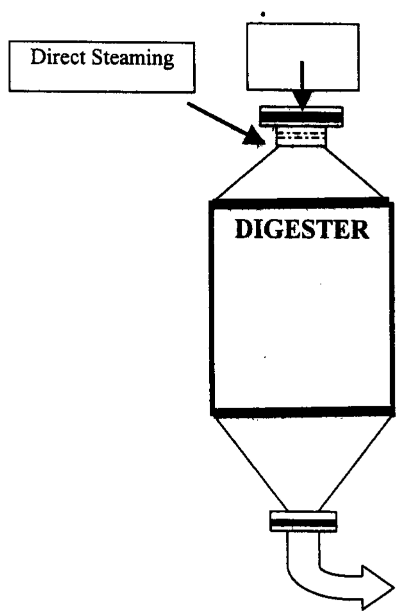
PRETREATMENT	SCREENING EQUALIZATION
PRIMARY TREATMENT	OIL SEPARATION SEDIMENTATION ALUM & LIME TREATMENT FLOATATION SCREENING
SECONDARY TREATMENT	MEDIA FILTRATION STABILIZATION PONDS AERATED STABILIZATION OXYGEN ACTIVATED SLUDGE TRICKLING FILTER AIR ACTIVATED SLUDGE UPFLOW ANAEROBIC SLUDGE BLANKET SYSTEM IRRIGATION AND LAND APPLICATION
COLOUR REMOVAL	MASSIVE AND MINIMUM LIME TREATMENT ALUM COAGULATION POLYMERIC ADSORBANTS & ION EXCHANGE RESINS EXCHANGE RESINS ACTIVATED CARBON ADSORBTION MEMBRANE PROCESSES OZONATION

TECHNOLOGY UPGRADATION SCHEMES FOR AGRO BASED MILLS

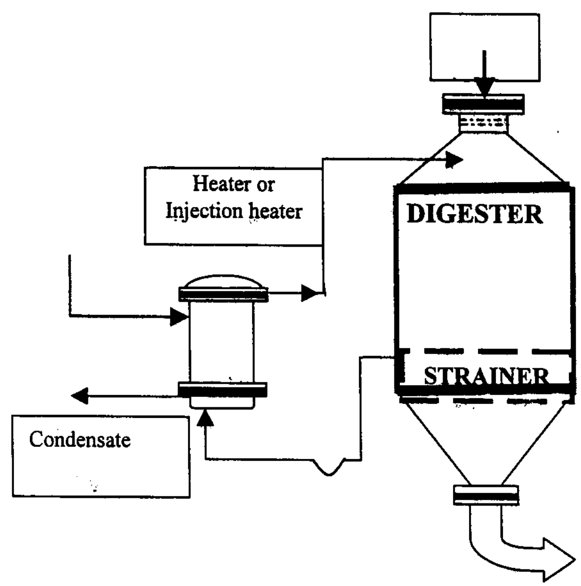

Upgradation of Raw Material in Straw Based Mills & Raw Material Handling System in Wood / Bamboo Based Mills.
Existing raw material handling system
Feed
Motor
1
2
1
Accept
Rejects
Modified Straw handling system
Straw
Screw Feeder
Magnetic Feeder
Disc Mill
Cyclone Separator
Universal Separator
Blower

Provision for indirect heating arrangement for batch digesters.

Existing Direct steaming System

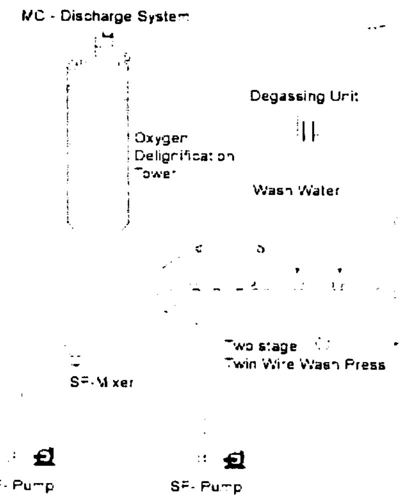


Modified In-direct steaming System

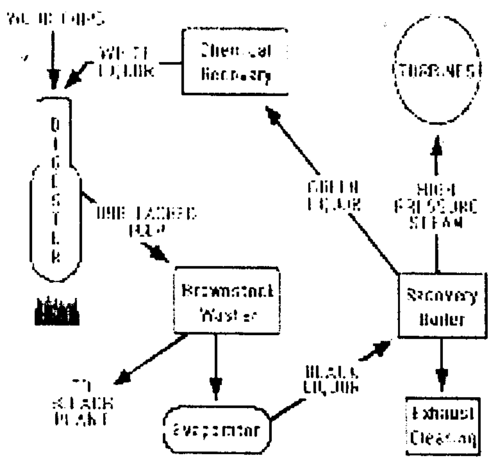


Adoption of Oxygen delignification for low kappa pulping

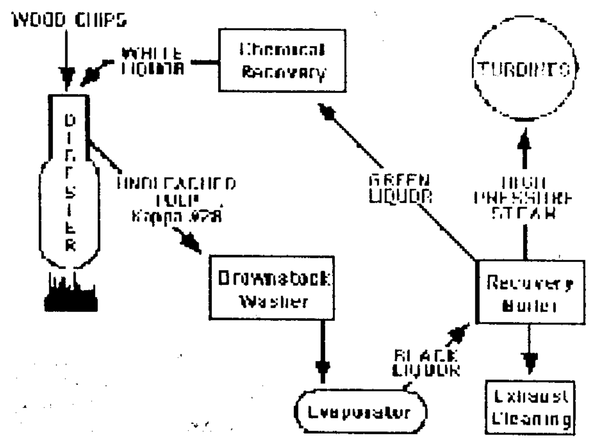
Oxygen delignification system



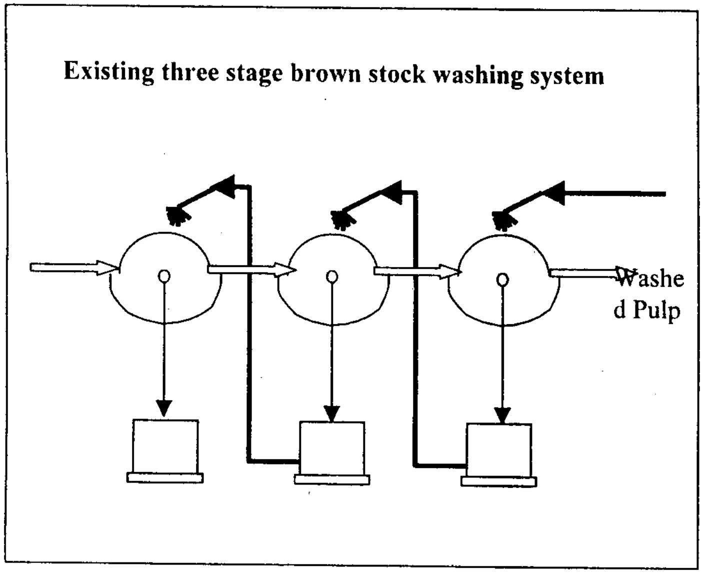
Existing System

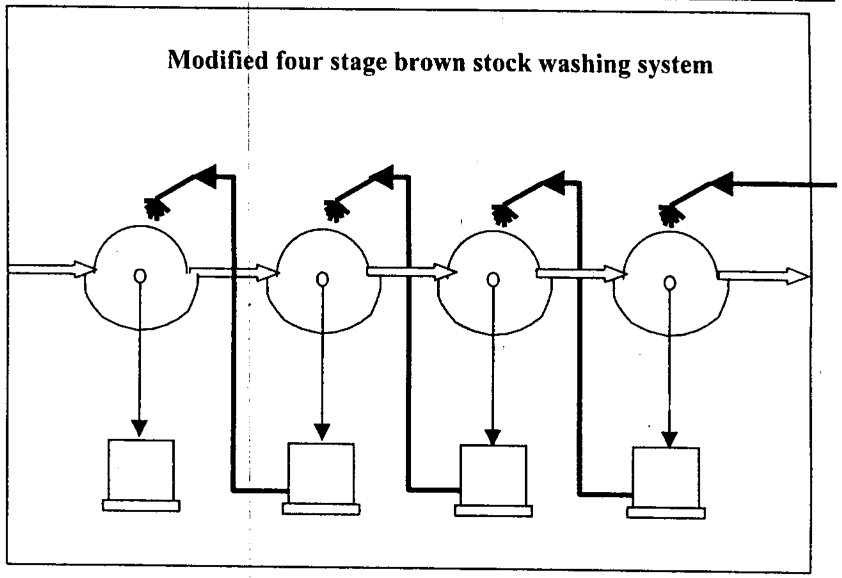


Proposed System

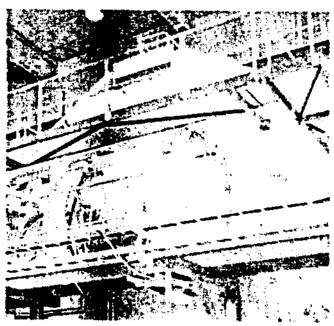


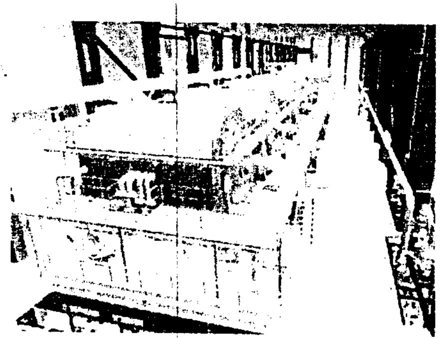
Upgradation of the pulp Washing systems to reduce the organic carry over to bleach plant and to extract maximum chemicals.



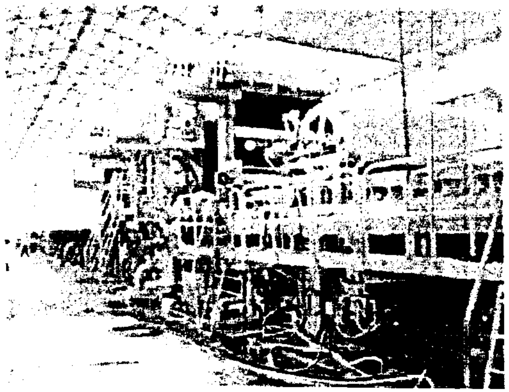


Modified washing systems

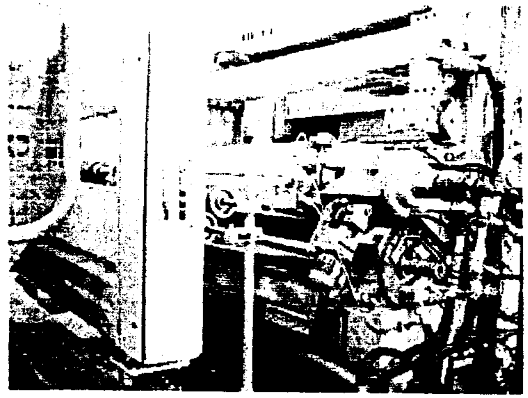




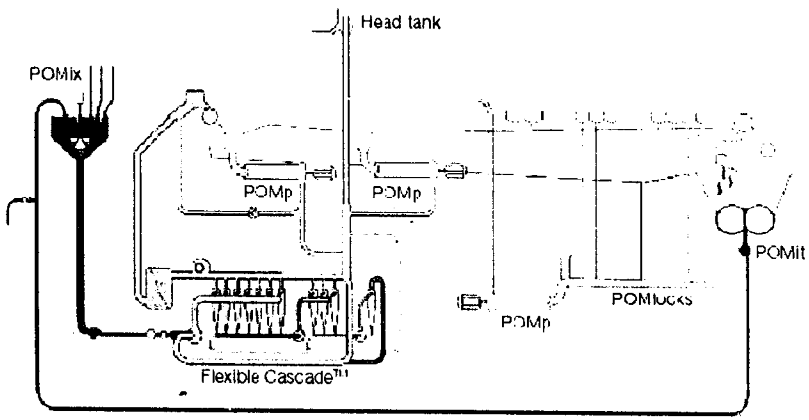
Upgradation and on line control of stock preparation and paper machine



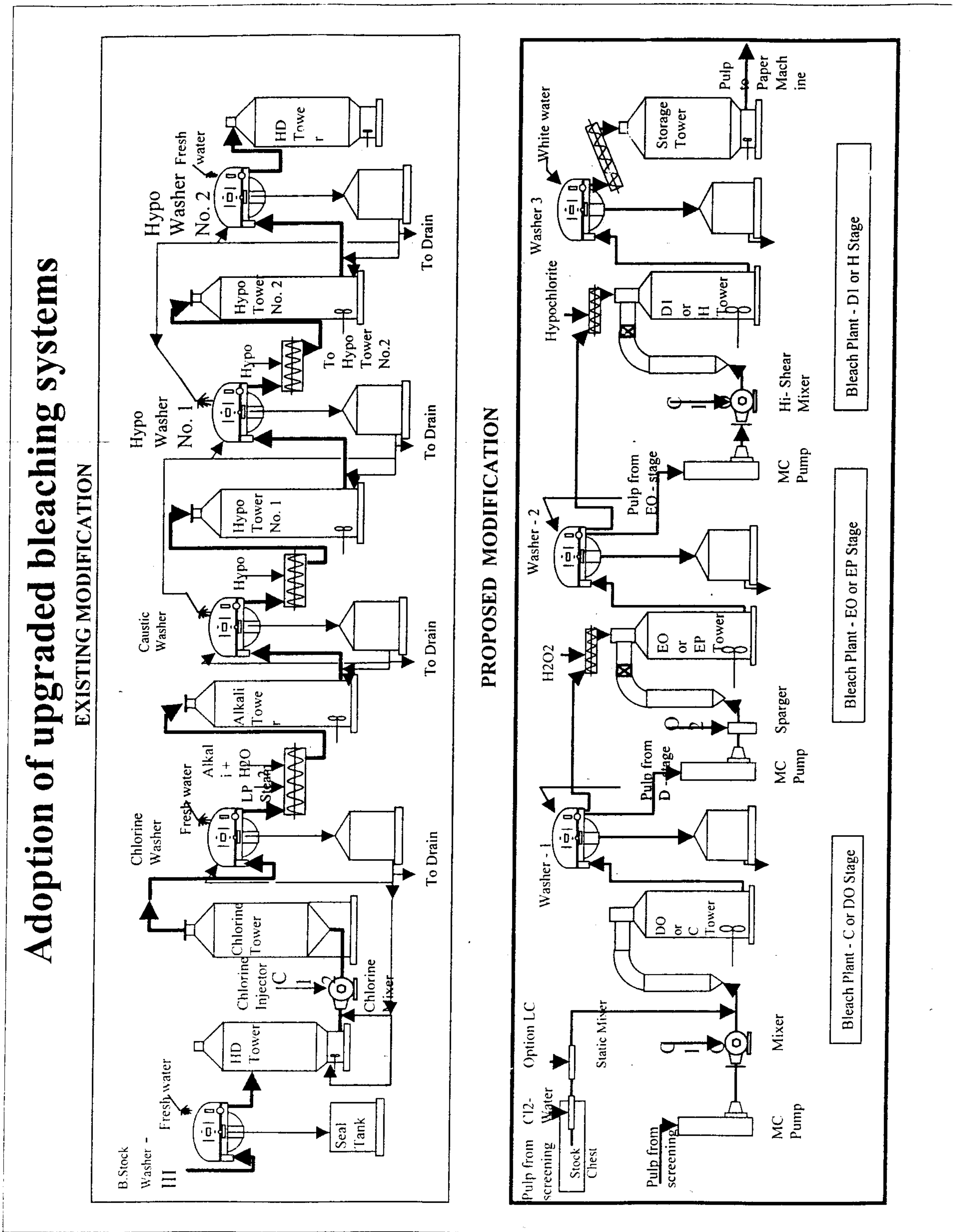
Existing paper machine



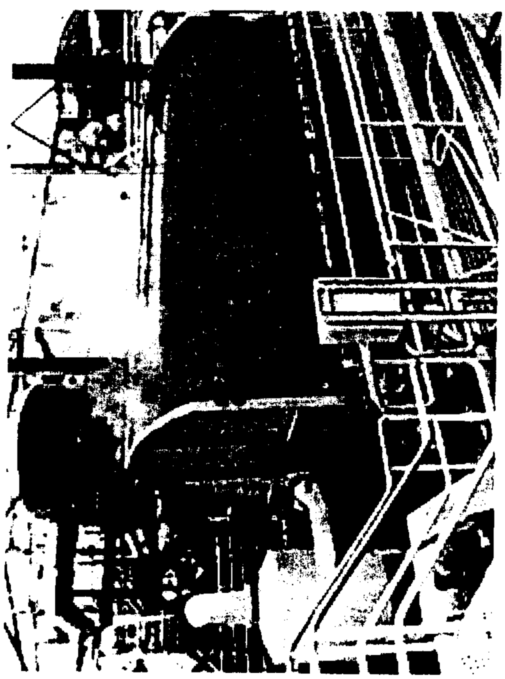
Online measurement systems



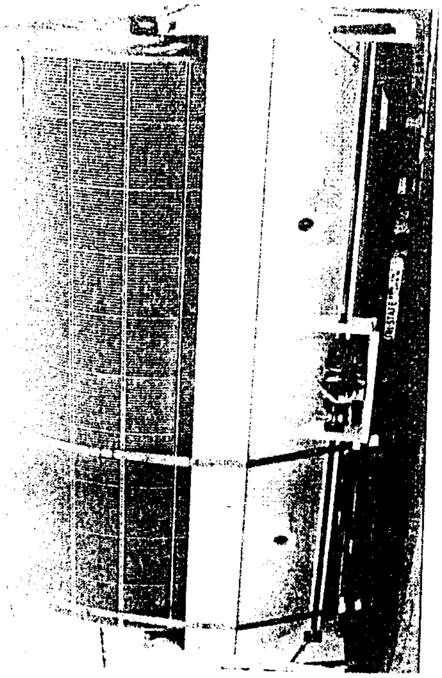
Modified stock preparation


Adoption of upgraded bleaching systems
EXISTING MODIFICATION
B.Stock Washer - III
Fresh water
Seal Tank
HD Tower
Chlorine Injector
Chlorine Mixer
Chlorine Tower
Chlorine Washer
Fresh water
Alkali + LP H2O Steam
Alkali Tower
Caustic Washer
Hypo
Hypo Tower No. 1
Hypo Washer No. 1
Hypo
Hypo Tower No. 2
To Hypo Tower No.2
Hypo Washer No. 2
Fresh water
HD Tower
To Drain
To Drain
To Drain
To Drain
PROPOSED MODIFICATION
Pulp from screening
Stock Chest
Cl2-Water
Option LC
Static Mixer
Pulp from screening
MC Pump
Mixer
DO or C Tower
Washer - 1
Pulp from D - stage
MC Pump
Sparger
H2O2
EO or EP Tower
Washer - 2
Pulp from EO - stage
MC Pump
Hi- Shear Mixer
Hypochlorite
DI or H Tower
Washer 3
White water
Storage Tower
Pulp to Paper Machine
Bleach Plant - C or DO Stage
Bleach Plant - EO or EP Stage
Bleach Plant - DI or H Stage

Upgradation of Lime Mud Filter



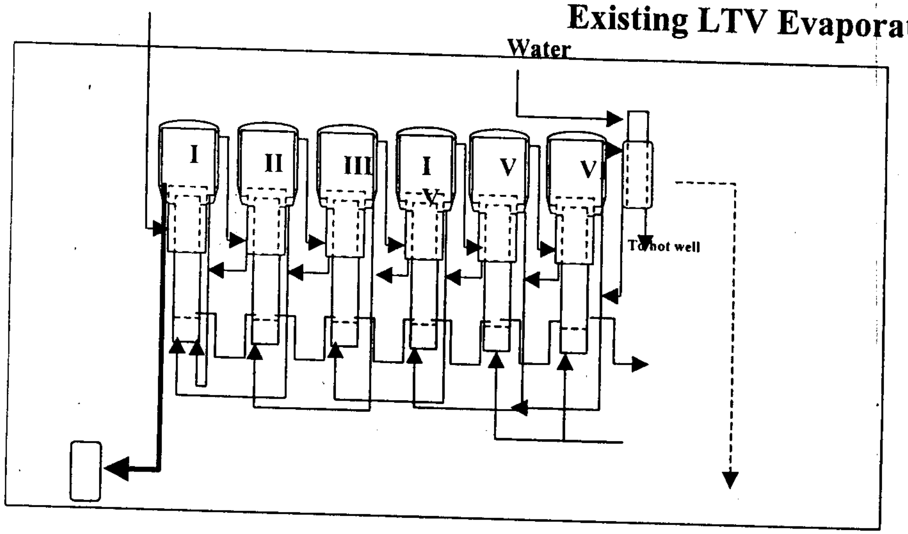
Existing Lime Mud Filter

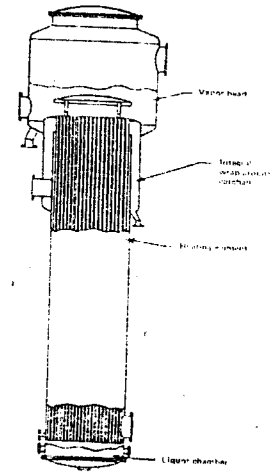


Proposed pre-coat filter with snap blow system

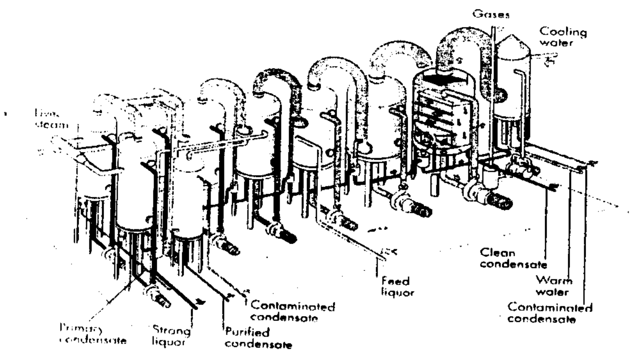
Upgradation of Evaporators

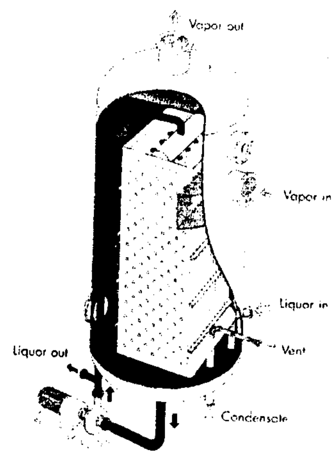
Existing LTV Evaporator Street





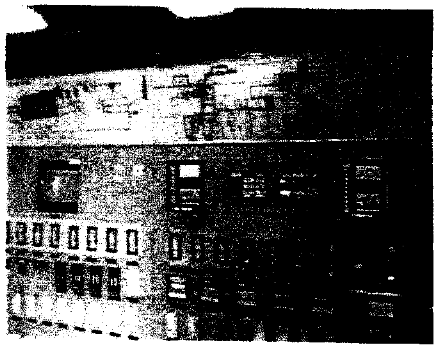
Proposed Falling Film Evaporator Street



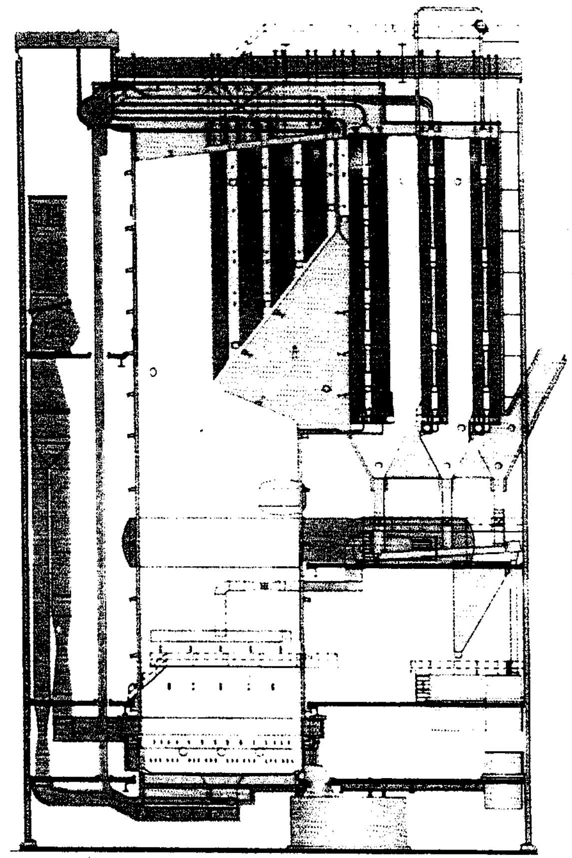


Upgradation of Existing Recovery Boiler with Retrofitting of air Distribution System and Control System.

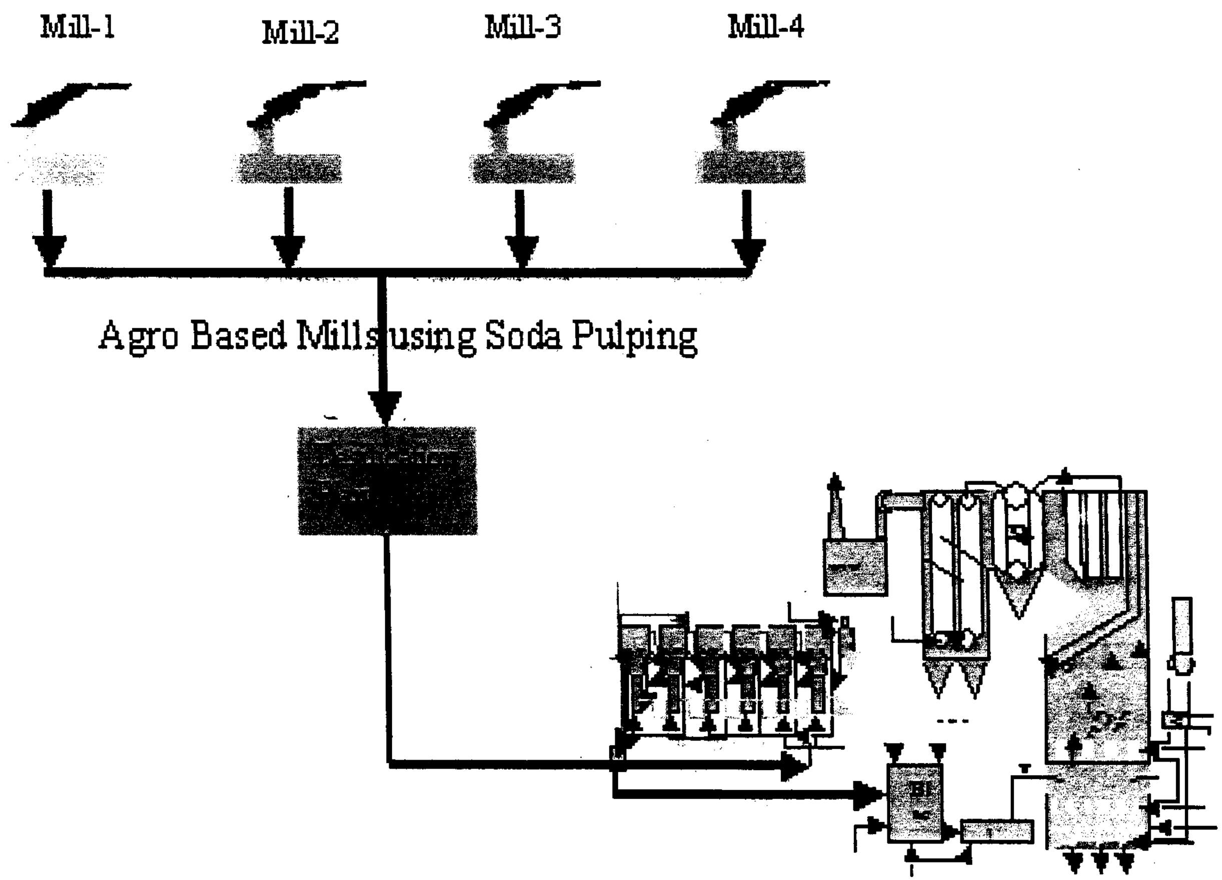
Existing control systems



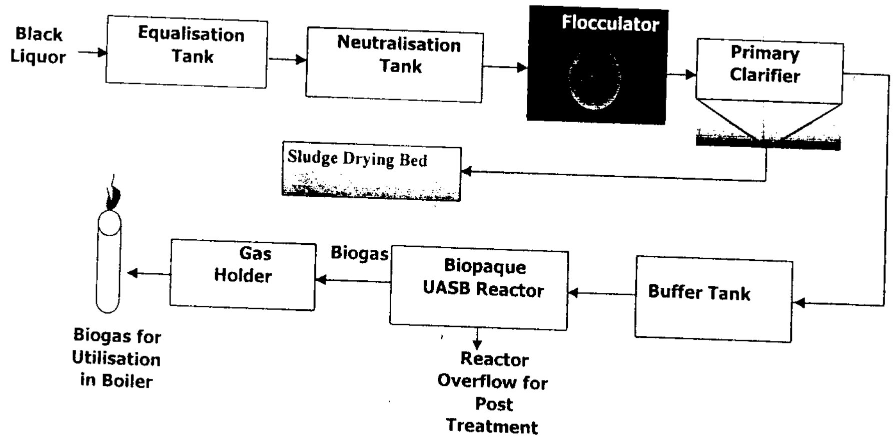
Modification in Air distribution systems



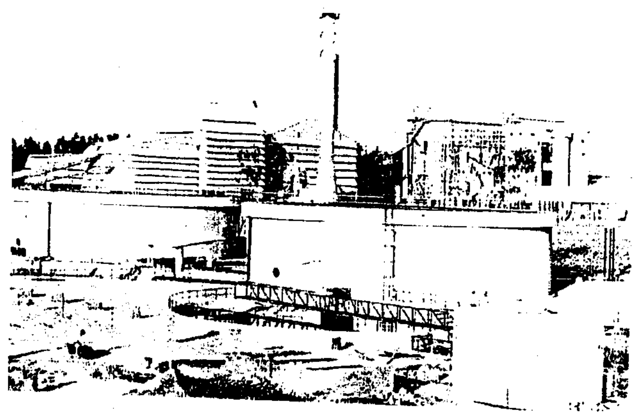
Common Chemical Recovery Plant for Cluster of Mills.



Bioenergy Recovery from Pulp Mill Effluents in Agro Based Mills

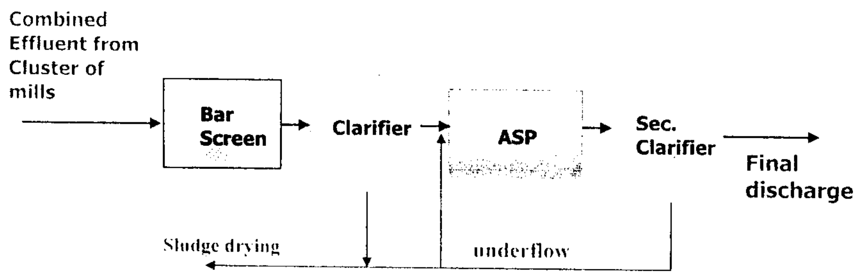


LAY OUT OF BIOMETHANATION PLANT FOR TREATMENT OF PULP MILL EFFLUENT



FULL SCALE BIOMETHANATION PLANT FOR TREATMENT OF BLACK LIQUOR AT M/S SATIA PAPER MILLS, MUKTSAR

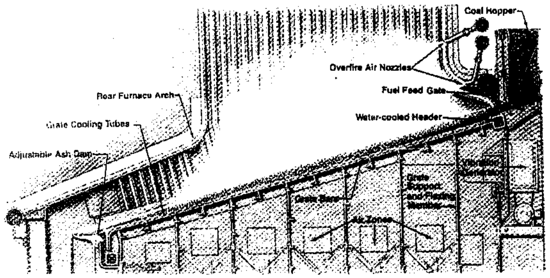
Common Effluent Treatment Plants for Cluster of Mills

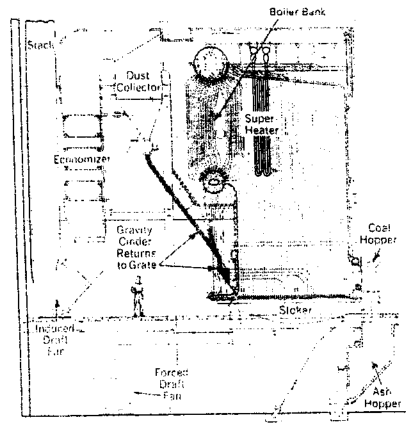


Common ETP for Cluster of Mills

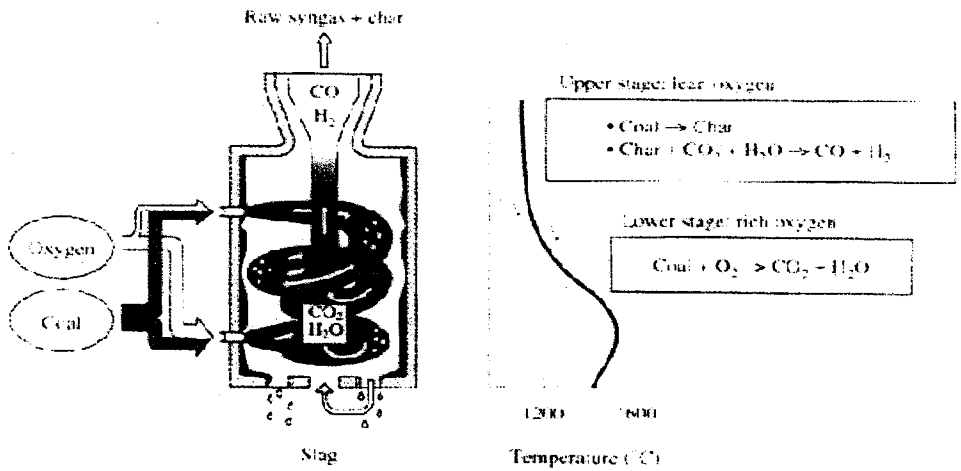
Retrofitting of Conventional Coal Fired Boiler to F.B.C. with Matching Turbines

Existing Stoker coal fired boiler



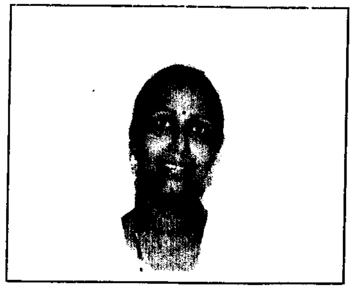


Coal fired Fluidized bed Boiler



PULPING, BLEACHING & WASHING

PULPING AND BLEACHNG CHARACTIERISTICS OF MAJOR AGRO RESIDUES



Dr. (Mrs.) Priti Shivhare Lal,
Scientist B

About The Author

Dr. (Mrs.) Priti Shivhare Lal, Scientist CPPRI, has nearly 13 years of research and development experience in the areas of Pulp and Paper. She holds a Master degree in Chemistry and PhD in the area of Environment analytical chemistry from "Ravishankar University Raipur". Her experience in the areas of Pulping and Bleaching includes, Raw materials preparation, Pulping /Bleaching of wood and non-wood raw materials. She has published more than 30 papers in various national and international journals of Pulp and Paper and Environmental analytical chemistry. She has been selected for SIDA fellowship in 1998 and undergone training programme on environment technology in Pulp and Paper Industry at Markaryd, Sweden.

PULPING AND BLEACHING CHARACTERISTICS OF MAJOR AGRO RESIDUES

Dr. Priti Shivhare Lal, Sandeep Tripathi and Dr. S.V.Subrahmanyam

The Indian paper industry is a mixed bag in terms of capacities and the types of fibrous raw materials. The small paper mills have about 6000 tpa capacity and large paper mills of 120000 tpa capacity, with wide range of fibrous raw material. The fiber resources are forest based, agro based and recycle fiber based with almost equal proportions and the current trend is to use higher RCF proportion. Agro residue segment production is almost equal to the forest-based sector. The production of pulp from major raw materials viz wheat straw, bagasse and rice straw is touching to 0.25 MT, 11% of total global paper making capacity. The production from these raw materials is increasing day by day with depletion of forest based raw materials.

The agro based fibrous raw materials are surplus byproducts of agriculture activity and available in sustained way on seasonal basis. The raw material has lower lignin content. The agro raw materials have high silica and pith that increases the alkali requirement in spite of lower lignin content. The agrr raw materials are bulky causing higher transportation and handling.

Pulping and bleaching characteristics of three major agri raw materials are discussed in the current presentation that include various pulping process, bleaching modifications etc.

1.0 INTRODUCTION

It is expected that total pulp production is ~370 Mt in the world today in comparison to 238 MT in 2000. It indicates that the forest resources required by the year 2010 would be almost doubled based on the present consumption rate. This combined with environment pressure to preserve forests will necessitate the use of alternate fiber sources for pulp and paper.

CPPRI has taken up a number of major projects on non-wood raw materials, specifically on agro residues aided by DOIPP, GOI, UNDP, IAPMA etc. Among these some are 1., Assistance to wood based paper industry, sponsored by UNIDO/UNDP, 2. Preservation of pulp strength during storage, sponsored by IRAPMA, and Modern pulping technology, financed by DOIPP, Min. of Commerce and Industry, GOI.

During the execution of these projects, a significant quantity of data was generated on agro based raw materials used by Indian Paper Industry on their pulping and bleaching characteristics.

The alkaline processes have proven suitable for pulping agro plants, giving good strength properties and high yield. However, it is important to note that many agro based material are pulped so rapidly and there may be no advantage in using sodium sulfide with the caustic soda (kraft pulping) for pulp production. Usually the soda process is sufficient to give good yields and good strength properties and could avoid air pollution problems associated with kraft process.

Continuous pulping is recommended for agro based fiber material due to rapid pulping properties. The reasons could be, lower lignin content and the structure of the agro based raw material. Other advantages of continuous pulping include lower fiber to liquor ratio, higher black liquor concentration to the evaporators and increased out put of pulp. Pandia and Sunds continuous digestion systems have been used for a wide variety of the agro based material.

Pulps of straws and bagasse have shorter fibers length and so are more suitable as substitute of hard wood. Quality writing and printing papers are produced with 90% bagasse or straw in furnish in some countries, and corrugating medium and linerboard with 75% and 50% of these pulps in the furnish respectively.

2.0 BAGASSE

The acid and bisulfite processes have proven to be unsuitable for pulping of bagasse. The process yields a brittle pulp that has low strength compared to pulps produced by alkaline processes. The traditional soda, kraft, and neutral sodium sulfite semi chemical processes have all proven very suitable for production of excellent chemical pulps from bagasse.

3.0 STRAWS

Straw has been used for centuries as a source of papermaking fibre in China and until early 1920s it was a major source of fiber in Europe and North America, which is replaced by wood. One of the main reasons for using straw for pulp is that it is readily available as a residue from food crops. Straw pulping has dominated in developing countries where inexpensive manual labor is available to cut and handle the straw.

All types of straws can be used to produce papermaking pulps. Lower yields are typical from rice straw since it contains greater amount of parenchyma and epithelial cells as well as other fine debris. The high silica content together with the fines present in the stem results in papers with good ink receptivity and high opacity but presents problems in equipment wear and chemical recovery as previously discussed.

The straw fiber has a relatively high length to diameter ratio, which results in good paper properties, however straw fiber is more heterogeneous than wood fiber.

For efficient processing of straw to paper the moisture content of the straw should be kept under 15%.

4.0 EXPERIMENTAL

4.1 Chemical Analysis

Complete proximate analysis of bagasse, wheat straw and rice straw was carried out. Various parameters viz. Ash content, cold, hot and 1%NaqOH solubility, klason lignin, Acid soluble lignin, holocellulose, α, β, and γ cellulose content were determined by standard procedures.

4.2 Pulping Experiments

Experiments were performed in a series digester consisting of six bombs each of 2.5 liter capacity, rotating in an electrically heated polyethylene glycol bath. At the end of the cooking time, the bombs were removed and quenched in the water tank to depressurize and the cooked mass from each bomb was taken for washing. Washing was carried out with hot water till the cooked mass was free from spent liquor. After through washing, the unscreened pulp yield was determined and the pulp was screened in laboratory 'Serla' screen by using mesh of 0.25 mm. slot width.

4.3 Cooking conditions

Raw material in each bomb	:	200g
Bath ratio	:	1:5
Cooking temp. °C	:	160
Cooking time, min.	:	60

Determination of pulp kappa number, brightness and viscosity

Pulp in as such state were analyzed for yield, kappa number (Tappi T:236 OM 99), brightness (ISO 2470) and intrinsic viscosity (Scan C:3)

5.0 POST DIGESTER TREATMENT

5.1 Oxygen treatment

Oxygen pre-treatment of pulp*

Oxygen treatment of pulp samples was carried out in quantum mixture. 250 gm. of pulp was taken for oxygen treatment in reactor vessel, at a time. After mixing the sodium hydroxide to the pulp, the pulp was pre heated in the microwave oven to 95 °C and pH of the pulp was determined. Volume of the reactor vessel is 3.5 liters and it is electrically heated, the temperature of the reactor vessel was maintained 95°C prior starting the experiment. The preheated pulp was placed in reactor vessel. The oxygen gas was injected in to the reactor vessel through the cylinder. Mix time/heat transfer time was given after every 15 minutes for 12 seconds. The oxygen treatment was given using following constant conditions.

Pulp consistency	:	10%
Sodium hydroxide charged	:	2.0 %
Oxygen pressure	:	0.6 Mpa
Treatment temp.	:	95 °C
Treatment time	:	60 minutes

- The procedure of oxygen treatment as described in manual of oxygen reactor supplied by Quantum Inc, Ohio, USA.

After oxygen treatment the pulp pH was determined. Kappa number, brightness, viscosity and yield of the oxygen treated pulps were determined after thorough washing of the pulp.

5.2 Alkaline extraction

Per-oxy-alkaline extraction of unbleached pulp:

Extraction of pulp samples with sodium hydroxide as well as sodium hydroxide together with hydrogen peroxide was carried out at different temperatures viz. 65° C and 85°C for one hour duration. The treated pulps were again washed to remove the extracted residual lignin and subjected for bleaching experiments.

Per-oxy-extraction conditions

Reaction temp.	:	65° C & 85° C
Reaction time	:	60 min.
Consistency	:	8 %

6.0 BLEACHING EXPERIMENTS

6.1 Conventional bleaching

Bleaching of all pulp samples (with or without pretreatment) were bleached by CEH sequence to around + 80% ISO brightness level under the normal bleaching conditions. Different stages of CEH bleaching were optimized and finally the pulps were bleached by using optimum bleaching chemical.

Bleaching conditions:

Parameters	Cl_2 stage	Extraction stage	Hypo stage
Consistency, (%)	3.0	8.0	8.0
Reaction time, (min)	30	60	120
Reaction temp (°C)	Amb	60	40

6.2.1 ECF and TCF sequences

Peroxide Bleaching of Oxygen treated pulp

Chelation Stage

The Oxygen-pretreated pulp is chelated to remove metal ions as the metal ions interfere in peroxide bleaching. The chelation with DTPA was given before I peroxide stage under following conditions. To stop contamination due to metal ions, distilled water was used in each step of bleaching.

Parameters	Chelation	Peroxide stage	Reductive stage
Consistency, %	10	12	14
Temperature, °C	70	75	60
pH	4-5	>12	5
Time, min	25-30	90	120

7.0 RESULT AND DISCUSSION

7.1 Chemical Analysis

Proximate chemical analyses of three major raw materials were conducted and results are depicted in table 1. As according to the nature and structure of raw material, its physical nature etc. the properties of raw materials indicate the same. The cold-water solubility rice straw is maximum (12.3%) in comparison to wheat straw and bagasse. Similar trend appears obviously for hot water solubility. The silica content is major problem for pulping of agro based raw material. Rice straw contains maximum percentage of ash following wheat straw and bagasse. The down side trend is appear in lignin percentage from bagasse to rice straw.

Table – 1
PROXIMATE CHEMICAL ANALYSIS

Parameters	Unit	Bagasse	Wheat straw	Rice straw
Cold water solubility	%	3.8	8.1	12.3
Hot water solubility	%	5.9	12.1	24.8
N/10NaoH solubility	%	35.1	34.4	50.2
Ash	%	2.9	5.1	8-2
Holo Cellulose	%	65.5	68.3	60.9
Pentosan	%	18.8	19.1	16.7
α- Cellulose content	%	-	36.1	36.4
Lignin content (acid insoluble)	%	25.4	20.3	13.4

7.2 Pulping of bagasse, wheat straw, and rice straw

Pulping optimization of bagasse is given in table 2. To get a middle range kappa ~20-21, it required 17% of chemical as NaOH. Yield is around 52% at this kappa number.

Table – 2

PULPING OPTIMIZATION RESULTS BAGASSE

Parameters	**1**	**2**	**3**	**4**
NaOH added (%)	14	15	16	17
Unscreened Pulp yield (%)	54.8	53.9	52.7	52.1
Screen rejects (%)	2.3	1.3	0.6	0.3
Total solid %	8.88	9.14	9.16	9.72
Kappa Number	34.9	26.8	25.9	21.0
Physical strength properties at 240ml CSF				
Freeness ml, csf	-	-	-	250
Burst Index $KPam^2/g$	-	-	-	4.1
Tensile Index Nm/g	-	-	-	69.0
Tear Index mNm^2/g	-	-	-	3.9

Table-3

Pulping optimization results of wheat straw

Parameters	**1**	**2**	**3**	**4**
NaOH added (%)	12	14	16	17
NaOH consumed %	11.52	13.04	14.24	14.7
Unscreened Pulp yield (%)	56.4	51.3	51.8	50.9
Screen rejects (%)	3.25	1.50	1.25	1.0
Total solid %	8.98	9.32	9.48	9.88
Kappa Number	23.3	17.7	16.7	14.5
Physical strength properties at 240ml CSF				
Burst Index, $KPam^2/g$	-	-	-	6.2
Tensile Index, Nm/g	-	-	-	87.0
Tear Index, mNm^2/g	-	-	-	5.2

Table-4

Pulping optimization results of rice straw

Parameters	**1**	**2**	**3**	**4**	**5**	**6**
NaOH added (%)	8	9	10	11	12	13
NaOH consumed %	7.2	8.4	9.3	10.1	11.0	11.8
Unscreened Pulp yield (%)	52.9	52.9	52.1	52.2	50.6	49.9
Screen rejects (%)	0.6	0.7	92.5	0.5	0.8	0.6
Total solid %	7.80	7.90	7.67	8.17	8.70	8.71
Kappa Number	23.4	21.2	20.7	20.5	19.0	17.8
Physical strength properties at 240ml CSF						
Burst Index $KPam^2/g$	2.6	2.6	-	-	-	-
Tensile Index Nm/g	48.0	48.0	-	-	-	-
Tear Index mNm^2/g	4.1	4.1	-	-	-	-

8.0 OTHER PROCESSES

8.1 Additive Pulping

The result of additive pulping of wheat straw is given in table 5. It is clearly indicated that an average 0.05% AQ addition during soda pulping of wheat straw can reduced pulp kappa number by 6-7 point with marginal gain in yield. The drop of kappa depends upon initial pulp kappa number and type of raw material.

Table –5

Sl.	Particulars	1	2	3	4	5	6	7	8
1.	Cooking chemical as Soda, %	16	16	16	16	16	16	16	16
2.	Anthraquinone , %	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07
3.	Unscreened pulp yield , %	50.8	50.9	51.2	51.3	51.3	51.5	51.6	51.6
4.	Screened rejects, %	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
5.	Kappa number	22.8	18.1	15.7	14.9	14.7	14.8	14.9	14.7
6.	**Black liquor analysis**								
	a) pH	9.5	9.2	9.0	8.8	8.8	8.9	9.1	9.0
	b) RAA, gpl	1.67	1.55	1.40	1.24	1.43	0.99	1.24	1.05
	c) Total solids, %	11.4	10.9	10.7	10.5	10.2	9.85	10.6	9.73

9.0 POST DIGESTER TREATMENT

9.1 Oxygen treatment

Results of oxygen treatment of wheat straw and bagasse are depicted in table 6. As reflected from the result, it is clear that almost 50 % drop in unbleached pulp kappa is found in all cases, without much any negative affect on pulp properties. The substantial brightness gain is also observed after oxygen treatment

Table-6

Sl.	Particulars	Wheat straw		Bagasse
1.	Initial kappa number	14	10.9	14.6
2.	Initial pulp brightness %	36.3	37.4	26.1
3.	Initial pulp viscosity cm^3/g	1118	945	840
4.	Oxygen treatment	-	-	-
5.	NaOH added, %	2	2	2
6.	Initial pH	12.5	12.5	12.4
7.	Kappa number	7.7	4.5	5.6
8.	Pulp brightness %	43	54	37.1
9.	Intrinsic Viscosity, cm^3/g	-	-	840
10.	Yield, %	92.0	93	94.3

9.2 Alkaline Extraction / Leaching

The alkaline extraction or peroxy alkaline extraction of agro based raw material is intermediate treatment of unbleached pulp before subjected to bleaching

Table-7

Sl	Parameter's	Bagasse	Wheat straw
1	Unbleached pulp kappa no.	23.9	16.2
2	Unbleached pulp bright. % ISO	32.4	37.1
3	NaOH added %	2.5	2.0
4	Hydrogen peroxide added %	0.0 0.25 0.5 1.0	0.0 0.25 0.5 1.0
5	Leached pulp kappa number	15.0 14.9 14.8 14.4	12.1 12.0 12.0 11.8
6	Kappa number drop %	37.3 37.7 38.1 39.7	25.3 26.0 26.0 27.1
7	Leached pulp brightness % ISO	35.6 36.1 39.5 41.3	39.0 40.7 42.5 46.5

Table - 8

SL.	Particulars	Soda pulp		Soda-Aq pulp	
		E	Ep	E	Ep
1.	Initial kappa no.	22.8	22.8	14.9	14.9
2.	Caustic, %	2	2	2	2
3.	Consistency, %	8	8	8	8
4.	Peroxide, %	-	0.5	-	0.5
5.	Reaction temp. °C	85	85	85	85
6.	Reaction time, min.	60	60	60	60
7.	Final kappa no.	16.7	14.3	10.7	8.1
8.	Kappa reduction, %	26.7	37.3	27.7	45.2
9.	Shrinkage, %	3.0	3.8	2.9	3.7

10.0 BLEACHING EXPERIMENTS

10.1 Conventional bleaching (CEH)

The results of conventional bleaching of three major raw materials are depicted in table 9. It is clear that by applying CEH sequence it is difficult to bleach pulp to high brightness i.e >85% ISO brightness. Bagasse has the better bleaching response than straws. D substitution in Chlorination stage leads to higher brightness in case of bagasse, ~87% ISO. In case of mix pulping for example gunny pulp mixed with rice straw pulp, bleached chemical demand increased due to big difference in unbleached pulp kappa number of different raw material. This causes severe strength loss due to excessive use of chemicals.

Table – 9

Parameters	**W/s Soda**	**W/S Soda AQ**	**Bagasse**	**Bagasse C/DEopD**	**Rice Straw**
Initial Pulp Kappa	22.8	14.9	13.9	13.9	11
Initial Brightness, % ISO	32.4	33.3	44.3	44.3	-
Initial Viscosity cm3/g	745	761	1046	1046	-
BLEACHING SEQUENCE	**CEH**	**CEH**	**CEH**	**C/D Eop D**	**CEH**
Chlorination Stage Cl_2/ClO_2 applied,%	4.9	3.0	3.0	3.07/0.15	2.6
Extraction Stage(E/E_{OP}) NaOH applied,%	2.0	2.0	2.0	1.7	2.5
Peroxide applied, %	-	-	0.5	-0.5	-
Oxygen pressure	-	-	-	2.0	-
H- Stage Hypo applied Avail.Cl_2	2.0	2.0	2.0	-	2.0
D – stage Dioxide applied %	-	-	-	0.5	-
Brightness, % ISO	83	82	83.5	86.1	80.0
Viscosity, cm^3/g	-	-	-	949	-

10.2 TCF sequences:

TCF bleaching of straw and bagasse is better in all manner in comparison to conventional CEH bleaching. TCF bleaching after oxygen treatment of wheat straw pulp resulted in final optimum brightness of 81% iso brightness. While incase of rice straw direct bleaching of 11 kappa pulp could reached to 71% ISO brightness level. Actually it needed kappa before TCF bleaching as low as possible in the range of 3-6. Then it become easy the bleaching of pulp to high ~ 85%ISO brightness.

Table -10

Parameters	Wheat Straw		Rice Straw
Initial kappa number	11.0	14.8	11.0
Initial Brightness	39.4	36.0	-
Chelating agent added (DTPA),%	0.4	0.4	0.5
Pressurized Peroxide (OP) / P1 stage			
Peroxide applied	4	4	5
Brightness obtained, %ISO	78	73.5	68
Yield, %	86.3	88.3	-
Kappa	2.6	3.6	-
Intrinsic Viscosity, cm^3/g	847	828	-
Peroxide Stage	-	-	-
II stage peroxide;	-	-	-
Peroxide added	2	2	3
Brightness obtained, %ISO	81	78	71
Intrinsic Viscosity, cm^3/g	681	760	-

10.3 TCF bleaching of wheat straw

Result of TCF bleaching of wheat straw after oxygen treatment is shown in table 11. It is clear that wheat straw pulp can be bleached to ~77-80% ISO brightness with different sequence. The % reversion of brightness is very low in case of TCF bleaching, in comparison to CEH sequence where the brightness reversion is very high ~14%.

Table - 11

Bleaching Sequence	Brightness	Reverted Brightness	% Reversion
Q-(PO)-P-P-R	79.6	78.4	1.5
O-O-Q-P-P-R	78.6	76.8	2.3
Q- (PO)-P-P	77.0	75.2	2.3
O-Q-P-P-R	77.0	75.9	1.4
CEH	76.3	65.2	14.5

11.0 CONCLUSION

- The sustained availability of agro based raw material, and its impact on forest fiber conservation are the positive aspects for their use in paper industry.

- India being the second largest country in the world utilizing agro based raw material for paper making, and the process technologies are improved year after year for production of pulp from these raw materials.

- CPPRI has conducted various studies on best utilization of these raw materials for pulping and bleaching.

- Post digester extraction of unbleached pulp or oxygen treatment reduces the residual lignin substantially and subsequently reduces bleach chemical demand and effluent load.

- TCF bleaching of pulp with fairly good brightness with minimum brightness reversion is possible after oxygen or peroxy alkaline extraction of pulp.

WASHING PRACTISES IN AGRO BASED MILLS

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About The Author

Dr. A.K. Ray Professor, holds a Bsc. (Honors) in Chemistry, B-Tech in chemical Engineering & Technology, Masters & PhD in Chemical Engineering , Post Doctoral research in University of Quebec on Explosion pulping of Indian Bamboo, Bagasse & rice straw is now working as professor at the Dept. of Paper Technology under IIT, Roorkee. Prior to joining this Institute in year Feb 1982, he was the faculty of National Sugar Institute, Kanpur in the Dept. of Chemical Engineering . Professor Ray was the head of the Institute during 1994-97 & acted as Director from time to time during 1980-91. Prof Ray has been credited with140 research publications out of which 52 published in International journals.

Professor Ray has been credited with number of awards including NOEIDEER gold medal from STAI, Silver medal & Sugar Industry cup from sugar tech. Association of Indian Institute of Chemical Engineers (CHEMCON), distinguished participant certificate from cellulose 91 and American chemical society New ORLEANS, USA. Her has been invited foreign university of America, Canada and China.

Prof. Ray has offered 5 PhD students in the area of modeling & stimulation of pulp and paper making process. His special lies in the area of chemical engineering application to pulp and paper technology, sugar and alcohol technology, mathematical modeling and stimulation and mathematical statistical and their application.

WASHING PRACTICES IN AGRO BASED MILLS IN INDIA

Dr. A.K. RAY

1.0 EXTENDED ABSTRACT

Pulp washing is an essential key unit operation during pulp processing for the manufacture of any kind of paper (writing, printing, NSSC, corrugating medium, board, tissues, sack etc.) and plays a pivotal role in recovery of energy and spent chemicals on one hand, and reducing bleach chemicals vis a vis cost of bleaching and degradation of environment (especially, effluent treatment cost) on the other. Therefore the brown stock requires to be washed very efficiently. The main goals are: with minimum amount of water addition, one can

- Clean the outgoing pulp produced from digester operation as practicable as possible through cleaner water so that it does not carry any black liquor solids (sodium based and lignin based) to bleach plant

- Extract all the solutes (organic and inorganic) present in pulp and put in to the black liquor stream,

To accomplish the above operation many kind of equipments have been developed over the years for washing different kinds of pulps. Regardless of the type of washers used, the separation of black liquor from pulp in the real washing process is accomplished with a combination of displacement and dispersions/diffusion processes, hence departing from a plug flow of wash liquor as expected in an ideal displacement washing. Sorption and diffusion are also important mass transfer phenomena.

The selection criteria of equipments and the mechanism of washing are also dependent on various pulp characteristics obtained from different sources (wood or non-wood, forest based or renewable annual agri-

residues etc.). The pulp characteristics also depends on types of pulping processes viz Soda, Soda-Sulphate, NSSC, Organosolve, Explosion, CMP, CTMP etc.

The washing characteristics of any pulp in turn is highly influenced by its morphological parameters (fiber dimensions etc.) and may other process variables such as specific surface, specific volume, freeness, drainage velocity, drainage resistance, black liquor viscosity, froth formation potential, etc.). The design parameters include the type of equipments, its shape and dimensions, consistency of pulp, vacuum or pressure, degree of submergence, rpm, the degree of cleanliness of the equipment etc.

Plant practicing engineers are often interested to know how to increase the productivity from the washer vis a vis the thickness of the mat with lesser carry over of solids, even from the same type of washer to avoid more pollution load generation and more chemical consumption in subsequent bleach plant discharging pollution load to water bodies.

In this presentation the above aspects are detailed in order to improve the degree of washing for non-wood agri residue based pulps. The effect of characteristics of various pulps such as bagasse, bamboo, grass, rice straw, wheat straw etc. have been emphasized. The effects of all process and equipment parameters on the productivity are discussed in both qualitative and quantitative manner.

Design and Process parameters affecting performance and efficiency are also discussed. Comparison of various equipment used for purpose of washing of agri residue pulp has been made, specially, to check the performance of the equipment in terms of wash liquor usage parameters, solute removal parameters and efficiency parameters. Process control strategy for controlling washing operation for agri-residue pulp has also been discussed highlighting measurement techniques.

Methods of trouble shooting measures for foam control and deaeration aspects etc. and techno-economic factors are explained in brief. Discharge control in washing plants in terms of BOD and soda loss have also been explained but qualitatively.

PAPER MAKING

SLIME CONTROL IN AGRO RESIDUE BASED MILLS

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Dr. R. K. Jain holds M.Sc. and D. Phil. in Chemistry with specialization in Lignin Chemistry. He has the experience of more than 20 years of Research and Development working in Chemical recovery, Energy and Environment and Biotechnology areas in Pulp and Paper Industry. Dr. Jain has more than 50 research papers published in National and International journals and more than 25 research reports and 2 patents at his credit.

He has visited China and Sweden under UNIDO fellowship training programme in the areas of Chemical recovery and Environment management.

He is presently working as Scientist & Office Incharge, CPPRI Base Office, New Delhi and looking after Industrial Coordination and Business Development activities.

SLIME FORMING MICROBES AND EFFECTIVE SLIME CONTROL PROGRAMME IN INDIAN PAPER INDUSTRY

R. K. Jain

1.0 INTRODUCTION

Paper Machine white water system usually supports significant and uncontrolled growth of microorganism in the form of slippery masses known as slime or the bio-film. The formation of slime in paper machine water loop leads to variety of problems related to process, quality and maintenance. This results in increased downtime, lose in productivity, undesirable holes and spots in paper, clogging of felts and wires causing frequent breaks in paper machine, corrosion and odor problems. Further the increased used of recycled waste paper and agro fibre as source of raw material has aggravated this problem therefore presenting new Challenges before Indian paper industry to Maintain Machine run-ability & cleanliness.

Paper mill slime is the accretion or accumulation in paper machine caused by certain microorganisms in presence of Fibres, fillers and other wet end additives. Tighter limitations being placed on fresh water use and wastewater disposal have forced the paper industry to close up their back water system. This factor coupled with use of higher filler levels, increased use of secondary Fibres and wet end additives have created severe problems of formation of uncontrolled growth of microbes (slime) in paper machine which leads to variety of process, quality and maintenance problems in paper machine, corrosion and odour which ultimately causes increased maintenance and production cost.

Conventional slimicides using ecologically compatible slimicides in the past have not been found ecologically compatible and environmentally acceptable. Today due to changing customer's consciousness towards environmentally clean products; industry will be forced to find out alternative slime control additives, which are environmentally acceptable.

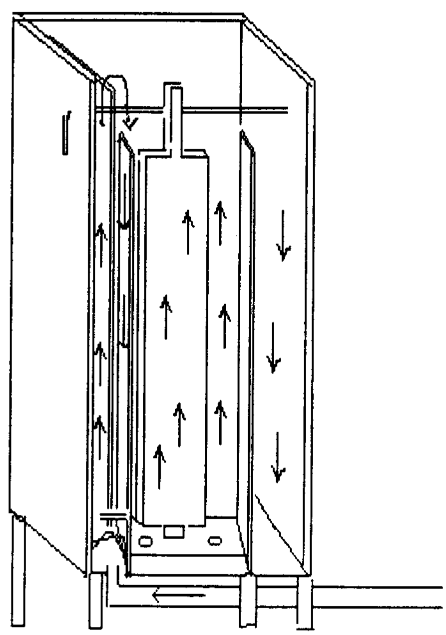
Central Pulp and Paper Research Institute (CPPRI) undertook a study on the control of microbial slime growth in paper machine in agro-based & recycled based paper mill employing alternate ecologically compatible slimicides. Slime control unit was designed and placed in paper machine white water loop which indicated a fast build up of microbial slime on a wood panel fixed up in the unit. Bio-film samples collected from the wood panel at different time intervals were subjected to detailed analysis in respect of physio-chemical, biochemical and microbiological characterizations. The detailed analysis coupled with efficacy test of the slimicides procured from an international company, against the identified microbes indicated a good response towards

use of alternate, ecologically compatible slimicides for the control of slime growth in paper machine.
The present article highlights efforts being carried out at CPPRI on control of slime formation in paper machine in agro / waste paper based mill using identified ecologically compatible slimicides/biocides.

2.0 MATERIAL AND METHODS

2.1 Slime Monitoring and Collection Unit

Slime build up in paper machine and white water loop is a dynamic process and depends upon various factors like raw materials, fillers used, temperature, pH, etc. of the white water. To study the slime build up trends in paper machine an online slime collection and monitoring unit was fabricated and installed in different sections of the paper machine. The unit is shown in FIG.1.



TREND OF SLIME BUILD UP IN PAPER

2.2 Total Bio-film amount analysis

Total amount was estimated from dry weight of bio-film growth, on slime collecting unit fabricated at CPPRI and put up in the paper machine white water circuit in an agro based mill, at fixed time intervals.

2.3 Estimation of total inorganic and organic contents

Total inorganic and organic were measured by standard methods by making ash at *650°C* for one hour.

2.4 Extraction of extra cellular polysaccharide (ECPs) and protein

Bio-film sample were extracted by cold aqueous extraction techniques where in slime was suspended in 8.5% NaCl containing 0.22% formaldehyde. The solution was chilled and mixed in homogeniser and centrifuged at 12,000 rpm for 30 min (1). Supernatant containing ECPs and proteins were estimated as follows:

2.5 Estimation of Extra-cellular polysaccharides (ECPs)

Quantitative estimation of ECP's were carried out using phenol-sulphuric acid method of Dubois etal. by measuring the absorbency at 488 nm(2).

2.5 Estimation of Total Proteins

Cell mass was indirectly quantified by measuring total protein according to Lowry etal by measuring the absorbency at 660 nm(3).

2.6 Microbial assay of various white water and other samples

Total microbial assay of various samples of white water, pulp stocks and slime was carried out by standard pour plate method in nutrient agar medium carried out by serially diluting the samples in normal saline solution to a appropriate concentration in triplicates. Colonies were counted in plates having optimum numbers of colonies i.e. between 30 to 300 with colony counter.

2.7 Relative population density test

Diluted biocide at concentration of 0.5, 1, 5, 7, 10 and 15 ppm ware added to sterile tubes containing suspended cell pellets in 0.2 M phosphate buffer at pH 7.0. The tubes were shaken at 230 rpm at 37°C. Aliquots were removed at regular interval of 2, 4, 6, 8 and 24 hrs and microorganisms were enumerated by standard pour plating method on nutrient agar plates. The percent reduction was determined by comparing with initial bacterial count.

3.0 RESULTS & DISCUSSIONS

3.1 Mechanism of slime formation

In paper and board production, in-plant circulation systems are being adopted to an increasing extent in order to protect natural resources. But at the same time more and more wastepaper is used. This results in a rising concentration of colloidal and soluble substances in the production water of paper mills. Further more, poor wastepaper quality and starch-coated scrap cause additional contamination to the water circulation systems.

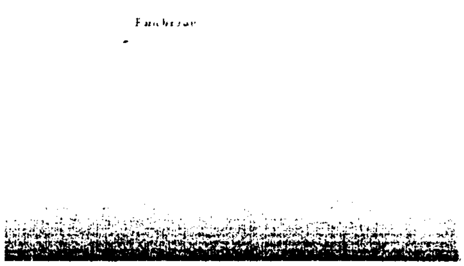
These water systems, which are highly contaminated with organic materials, provide a favorable environment for microorganisms if the temperature is suitable. Then, strong microbial growth is unavoidable.

Neutral operation and a chlorine-free bleaching process further encourage it. This results in slimy deposits and a bio-film on the insides of the water circulation system.

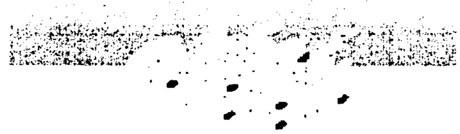
Formation of biological slime arises from the activity of the microorganisms, which are characterized by their high rate of multiplication, making use of various types or organic and inorganic substances.

In this respect, bacterial production of extra-cellular polymer substances (EPC) is crucial in bringing about coherence of the bacteria and stabilizing the films on the surface. Apart from water, which is bound mainly by EPS, many kinds of microorganisms, wood fibres and fillers are also integrated in the bio-film.

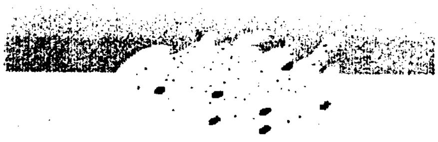
Bio-film formation is a dynamic process that begins with bacterial cells colonizing a submerged surface and continues through a series of events that culminates with detachment, and can be divided into five distinct stages.



Initiation of slime formation



Accumulation of slime forming bacteria



Maturation of slime formation

Photomicrograph of slime forming bacteria

3.2 Five Stage of Slime Formation

The first stage is the formation of a conditioning layer, which forms from reversible and irreversible adsorption of organic and inorganic substances, which are present in the water.

The next stage is bacterial attachment to the surface, or colonization. The initial contact of a bacterial cells to the surface has been shown to be reversible, but the longer a cell stays in place, the harder it is to dislodge as extracellular polymer substances are produced to secure the cell to the surface.

Stage there is growth and early biofilm formation. After cells become firmly associated with the surface, they continue to reproduce and formation of the biofilm begins.

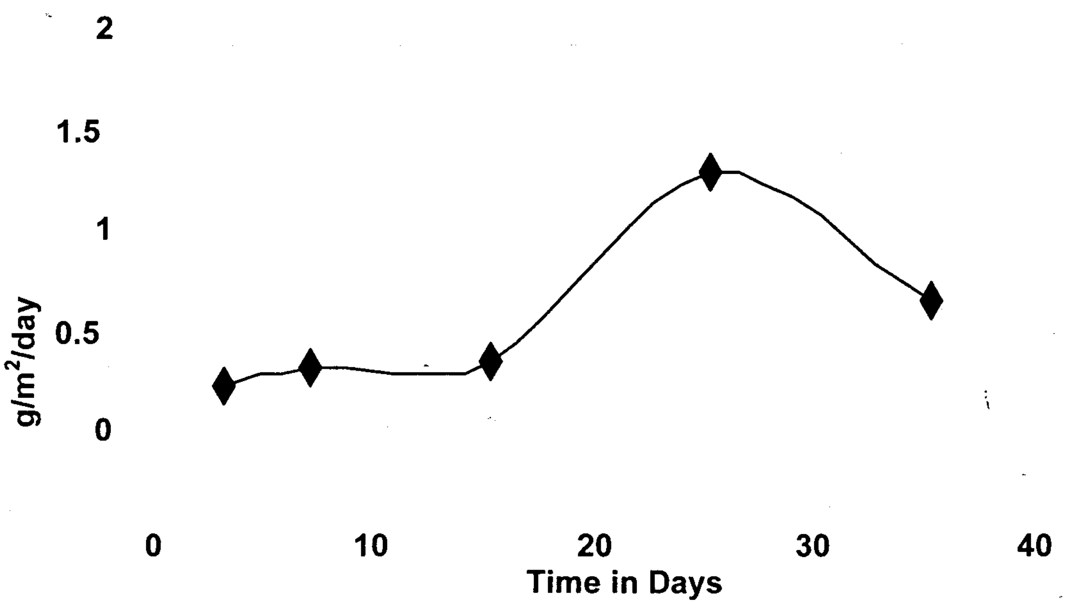
In stage four, the biofilm matures and conditions allow particles in the water, such as fillers, fiber and pitch, to become trapped by the biofilm matrix.

In stage five, once a biofilm reaches a certain thickness, its growth and material discharge tend to be in balance. Studies have demonstrated that single cells or large clumps are routinely, but intermittently, eliminated or sloughed from the biofilm. The thicker the biofilm the greater the probability that large clumps will be sloughed. An obvious function of sloughing is for cells to be dispersed within a system so other sites can be colonized and additional biofilm can be formed.

Formation of slime in paper machine takes place as the white water is enriched with substrate and environmental conditions, as temperature, pH etc. are favorable for microbial growth, which thereby become continuous and uncontrollable phenomena.

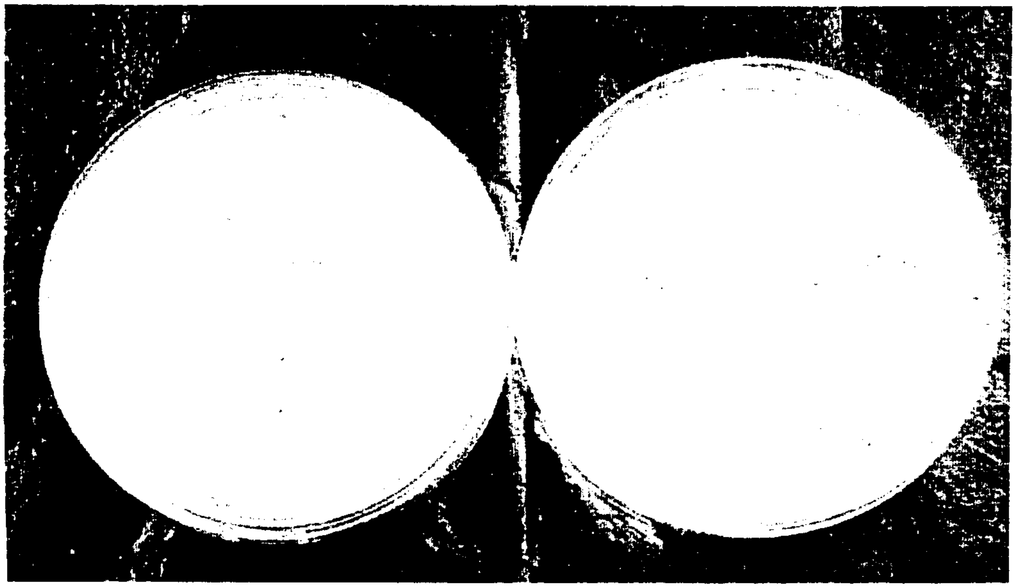
3.3 Slime build up trend in paper machine

Slime build up in paper machine and white water loop is a dynamic process and depends upon various factors like raw materials, fillers used, temperature, pH, etc of the white water. One of the mills was selected by IARPMA and studied for its slime deposit trend in the paper machine by using slime collection unit shown in Fig.-1. The mill is an agro-based mill employing bagasse, wheat straw and Sarkanda as a major fibrous raw materials and producing writing printing grades of paper. The additives added at the wet-end in stock preparation, are rosin (1%), Alum (6-8%), Soap stone (10-12%) and Starch (4-5 kg / tp). The deposits on wooden panel were collected and quantified on a particular area which shows the slime build up trend in paper machine is more or less a sigmoid curve as shown in Fig-2. There is a steady increase of slime formation from 0.4 g/m^2 at 3rd day up to 1.4 g/m^2 on 25th day onwards; slime deposition does not grow further with time. Studies shows that, maximum growth takes place between 21-28 days which then starts sloughing up of the slime to the white water system with the shear force of the white water. Even after a complete and effective caustic boil out programme, slime deposit starts from the 3rd day.



3.4 Microscopic examination of slime

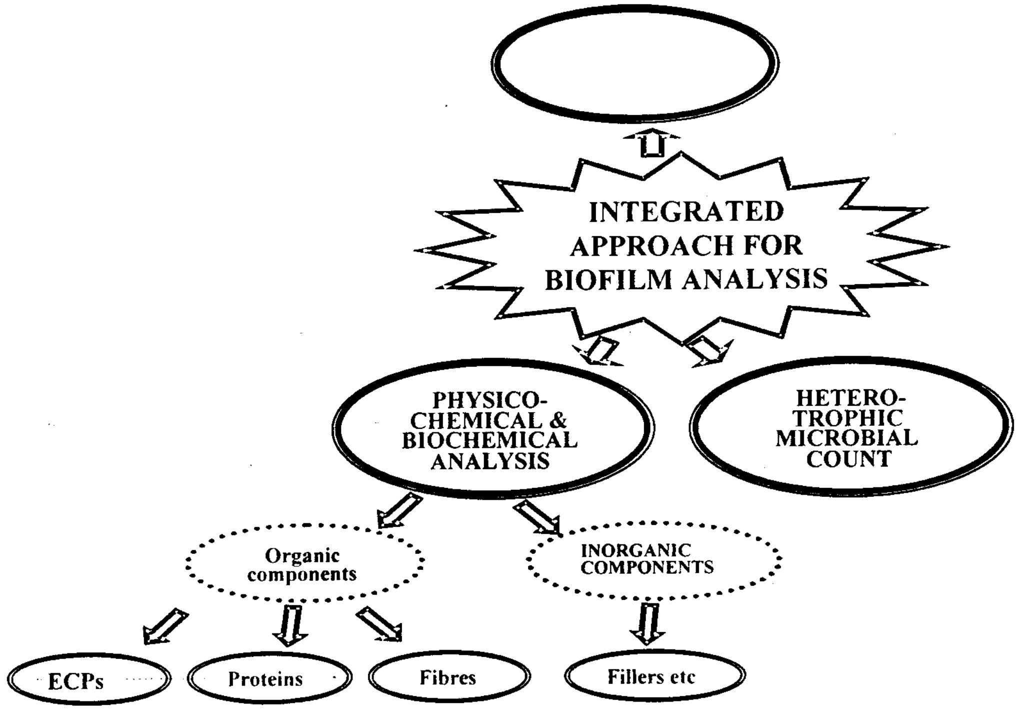
The slime deposited on the wooden panel were collected and studied for is microscopic observation and isolation of bacteria responsible for slime formation. The different microbial colonies isolated from the slime deposited on the wooden panel are shown in Fig.-3 and mainly shows filamentous bacteria responsible for slime deposition.



BACTERIAL COLONIES ISOLATED FROM SLIME SAMPLE COLLECTED FROM THE WOODEN PANEL

3.5 Characterization of slime and white water samples

An integrated approach has been adopted for physico-chemical, biochemical and microbiological analysis of various slime samples collected from time to time as shown in Fig. 4. Table-1 shows the analysis data of slime samples collected from the wooden panel and of the slime samples collected from various points like paper machine wall, wall of krofta, silo etc. It is clear from the result that though the organic and inorganic composition of the slime collected from slime collection unit is similar in composition with that of mixed slime, the ECPs level is almost double in case of mixed slime as compared to slime of slime collection unit. It is established that these mixed slime are matured and old deposits and have more secretion of ECPs, which is the main cause of agglomeration of fibres, fillers and microorganisms. This is the problem-creating agency in paper web on the machine resulting in frequent paper breaks.



INTEGRATED APPROACH FOR BIOFILM (SLIME) CHARACTERISATION

Table – 1

Physicochemical, Biochemical & Microbial Analysis of Slime Samples			
Parameters	**Collection Points**		
	Slime from Slime Collection unit	Mixed slime	Back water
Total organics, % (w/w)	31.00	32	-
Total inorganic, % (w/w)	69.00	68	-
Fibres, % (w/w)	29.2	-	-
ECPs, % (w/w)	0.325	0.62	150 μg/ml
Proteins, % (w/w)	0.226	0.21	255 μg/ml

Microorganisms reach from one part to the other part of the white water loop through backwater, so it is essential to study the degree of contamination through microbial count in the different parts of the paper machine section. Table-2 shows the microbial count of white water collected from different points of the white water loop as well as process water for papermaking. Results shown in Table-2 clearly indicate that the process water contains, as many as 3.3×10^2 numbers of viable microorganisms per millilitre and this number is too high and causative reason of continuous addition of microorganisms to the system. Samples from white water storage tank and premachine chest shows a very high enumeration of 1.1×10^6 and 5.8×10^6 respectively, this may be due to improper cleaning and stagnant stock/ white water. This high microbial stock could work as the seed of slime formation.

Table – 2

MICROBIAL ASSAY OF WHITE WATER / SLIME SAMPLES AT VARIOUS POINTS IN AN AGRO-BASED PAPER MILL		
Sl. No.	**Sample Collection points**	**Heterotrophic viable microbial count (CFU)**
1.	Slime collection unit	1.56×10^7/gm
2.	White water storage tank	1.1×10^6/ml
3.	Krofta	3.2×10^5/ml
4.	Pre machine chest	5.8×10^6/ml
5.	Head box	3.1×10^5/ml
6.	Wire part	9.5×10^5/ml
7.	Process water	3.3×10^2/ml

3.6 Determination of efficacy of various slimicides

Before going for slime control programmes, it is essential to understand the active compounds present in the slimicide. The same was tested and has been tabulated along with their active compounds and shown in Table-3.

Table-3

SOME OF THE IDENTIFIED SLIMICIDES AND THEIR ACTIVE PRINCIPLES	
Slimicide code	**Active ingredient**
Slcd-1	Glutaraldehyde
Slcd-2	2,2, Dibromo, 3-Nitrilo-Propionamide
Slcd-3	5-Chloro-2 Methyl- 4 Isothiozolin-3-One +2, Methyl,4, Isothiazolin-3-One
Slcd-4	2, Bromo-2 Nitropropane-1,3 Diol
Slcd-5	Tetrakis Hydroxymethyl Phosphonium Sulphate (THPS)
Slcd-6	Methylene Bis Thiocyanate (MBT)
Slcd-7	MBT
Slcd-8	THPS + MBT
Slcd-9	Unknown
Slcd-10	Unknown

Table-4 shows the relative population density test and reduction in the microbe using different slimicides at different time periods (Slcd-1 is being excluded as it is not found to be environmental friendly). The significance of relative population density test implies the effectivity of the test slimicides against the tested (predominant microorganisms present in the white water as well as slime samples) microorganism. The test being performed in nutrient broth medium, tested microorganism gets ample of balanced nutrient required for its growth and regeneration, however the effect of slimicides can be interpreted from the rate of kill. The table shows Slcd-7 & Slcd-4 have a very effective antibacterial activity against the test microorganism (both are THPS based slimicides), where as Slcd-3 & Slcd-5 have better killing activity at 2.5 hr to 5.0 hr. In comparison, the biocidal activity of the Slcd-5 is best as it has a very consistent activity and at 24 hr also, its action is more in comparison to other slimicides.

Table-4.

RESULTS OF RELATIVE POPULATION DENSITY TEST OF IDENTIFIED SLIMICIDES AT DIFFERENT TIME PERIODS						
Slimicides	**Time in Hour**					
	0	**0.5**	**2.5**	**3.5**	**5**	**24**
	Bacterial enumereation in CFUs					
Slcd-2	182 $\times10^5$	35 $\times10^5$	26.5 $\times10^5$	35.1 $\times10^5$	47 $\times10^5$	95.2 $\times10^5$
Slcd-3	182 $\times10^5$	40 $\times10^5$	5.7 $\times10^5$	1.15 $\times10^5$	1.9 $\times10^5$	67.2 $\times10^5$
Slcd-4	182 $\times10^5$	55 $\times10^5$	3.6 $\times10^5$	1.5 $\times10^5$	0.6 $\times10^5$	10.8 $\times10^5$
Slcd-5	182 $\times10^5$	15 $\times10^5$	7.5 $\times10^5$	18.2 $\times10^5$	47.5 $\times10^5$	64.8 $\times10^5$
Slcd-6	182 $\times10^5$	84 $\times10^5$	3 $\times10^5$	6.2 $\times10^5$	18 $\times10^5$	72 $\times10^5$
Slcd-7	182 $\times10^5$	85 $\times10^5$	2.55 $\times10^5$	6.5 $\times10^5$	15.5 $\times10^5$	61.6 $\times10^5$
Slcd-8	182 $\times10^5$	30 $\times10^5$	4.7 $\times10^5$	8 $\times10^5$	4.5 $\times10^5$	84.8 $\times10^5$
Slcd-9	182 $\times10^5$	60 $\times10^5$	3.6 $\times10^5$	6.1 $\times10^5$	9.5 $\times10^5$	76.8 $\times10^5$

The efficacy test of selected slimicides was carried out against the consortium of microorganisms present in the white water system. This test was carried out under dynamic conditions of shaking at 130 rpm and 35^{0}C in a rotary shaker cum incubator after addition of 20 ppm of slimicide to the test sample of white water collected from the mill to simulate the mill conditions. Since the mill white water contains a number of microorganisms of different groups, this test is very much effective and necessary to study the action of slimicide as broad spectrum, which is effective against diversified group of microorganisms. Table-5 shows Slcd-5 is highly effective and reduces 99.3 % of the microbial count within 15 minute of time period, whereas Slcd-9, Slcd-2 and Slcd-3 reduce 90-91 % within 15 minute of time period. Fig.5 shows the proposed dosing points for dosing of the identified slimicide / biodispersants in paper machine.

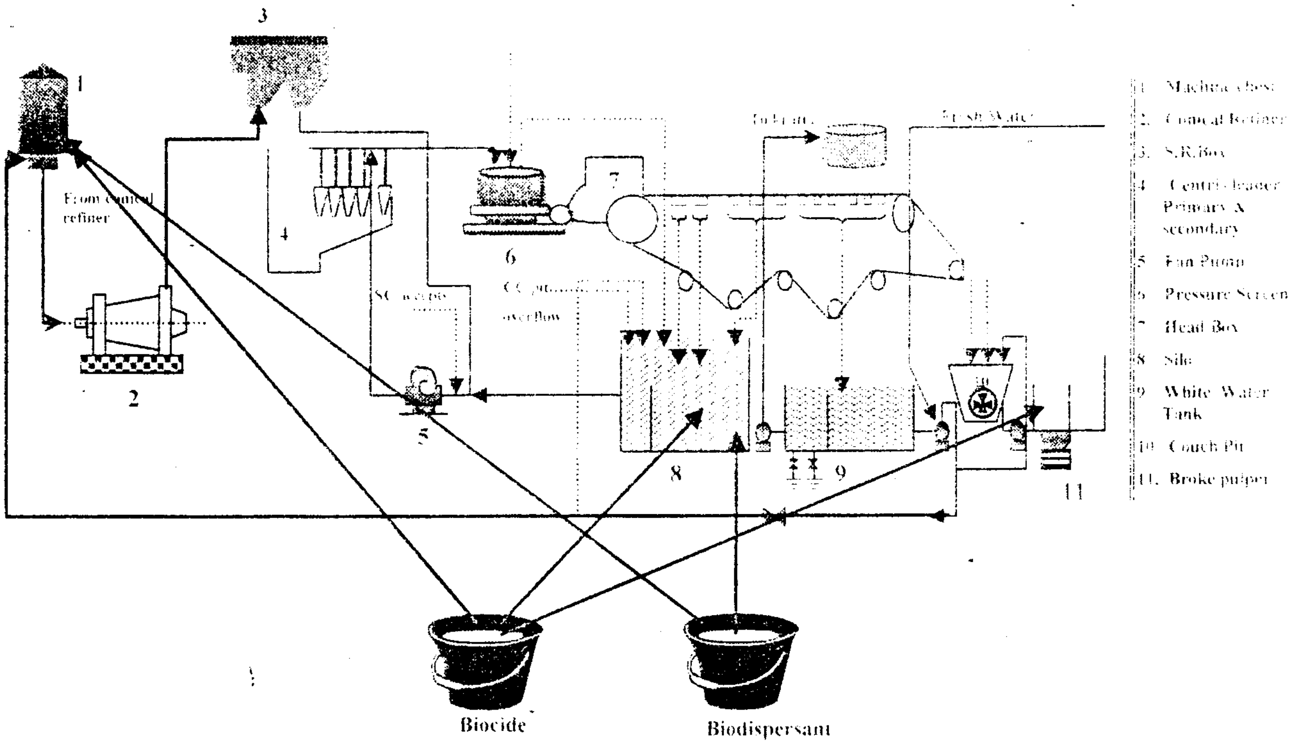
Table-5

PERCENT REDUCTION DURING EFFICACY TEST OF IDENTIFIED SLIMICIDES AT DIFFERENT TIME PERIOD					
Slimicides	**Time**				
	0 HR	**15 Min**	**45 Min**	**2 Hr**	**24 Hr**
Slcd-2	0	90.0	98.2	99.3	96.8
Slcd-3	0	90.9	99.9	99.4	99.8
Slcd-4	0	99.3	98.3	99.5	99.9
Slcd-5	0	64.5	69.0	93.6	97.1
Slcd-6	0	83.6	95.2	98.5	99.7
Slcd-7	0	84.5	95.9	98.4	99.8
Slcd-8	0	84.5	94.5	99.0	99.5
Slcd-9	0	90.9	98.4	95.8	99.9
Slcd-10	0	81.8	99.2	99.8	98.3

The success of any slime control programme for effective control of slime in a paper mill depends broadly on:

- Selection of effective slimicide
- Reliability and accuracy of the slimicide feed system
- Operator sampling & testing for each control parameters
- Manual addition of the proper slimicide at the proper dosage

Process Flow Diagram of Paper Machine No.1 Indicating Proposed Dosing Points for Identified Biocides/biodispersants



4.0 CONCLUSION

4.1 Detailed characterization of the slime with respect to physiochemical, biochemical and microbiological aspects and improved monitoring in terms of slime build up helped in understanding the nature of slime and how to control it in an effective and efficient way.

4.2 Relative population density test and efficacy test using the new slimicide on the slime samples collected from slime collection unit and white water samples from various points of paper machine loops were effective in controlling the microbial growth (slime) in paper machine in an agro-based mills.

4.3 Use of identified ecologically compatible slimicides in combination with biodispersant could be used to achieve optimal slime control programme in terms of efficiency & cost. The programme is being continued at the Institute for promotion of the ecologically compatible slimicides in Indian Paper Industry, which will prove to be more environmental friendly.

4.4 Slimicide – 4 has found to be more effective in controlling the slime, however, the actual cost involved in the slime control programme in any of the mills needs to be worked out after commercial trials.

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QUALITY IMPROVEMENT OPTIONS IN AGRO RESIDUE PULPS

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QUALITY IMPROVEMENT OPTIONS IN AGRO RESIDUE PULPS

Dr.Yasho Vardhan Sood*

ABSTRACT

Agricultural residues pulp is one of the major raw materials for Paper Industry of India. From time to time evaluation of paper samples received in CPPRI, it has been observed that the papers produced by different Indian Mills had wide variation in strength and optical characteristics though the raw material, its processing methods and types of paper machines and their configuration are almost similar. One of the causes identified in the present investigations is the variation in the formation indices of different papers produced by them. The medium sized paper mills, which are mainly based on the agricultural residues, have relatively poorer formation (formation index 31 to 93). As compared to big mills based on bamboo and hardwoods. The formation indices of paper manufactured from waste paper by small capacity mills are quite low (29 to 40). The Stock quality degree, which indicates about the slushing degree of the stock is lower for medium, scale paper mills. The bonding properties (tensile index, burst index) are adversely affected by formation deterioration. The extent of drop observed in the tensile index ranged from 7.8% to 36.1%. Similarly for the bursting strength and tearing strength it ranged from 9.4% to 34.8 % and 6.7% to 42% respectively. Drop in formation also caused drop in sizing degree, retention of the fillers and sp.Scatt. co- efficient values. The regression correlation co-efficient between formation index and tensile strength, tearing strength and sp. scattering co efficient was around 0.60. The fibers used for papermaking naturally flocculate when they are suspended in water. The extent of flocculation depends on the concentration, fibre type, degree of beating, presence of flocculants or dispersants etc. Excessive dosages of alum, wet end chemicals adversely affect the formation. Addition of alum more than 4%, cationic starch more than 2%, retention aid more than 0.2% be avoided to get better formation. Dual type retention aid effect on the formation drop is relatively less. General practice for making the paper from agricultural residues pulps in India is that no refining is done for these pulps. There are generally one or two refiners before fan pump. Instead of refiners a deflaker should be preferred which will give separation effect, hence formation will be improved without much affecting the slowness. For improving the formation the detail like- Stock –wire speed difference. Agitation on the wire, table arrangement, and the shake, the Dandy of the paper machine should also be properly checked and adjusted.

1.0 INTRODUCTION

Agricultural residues pulp is one of the major raw materials for Paper Industry of India and other developing countries .The ratio of non wood pulp to total pulp production in such countries is more than 30% (Table I). The general features of agricultural residue pulps are that these contain short length fibers accompanied by substantial amount of non- fibrous components. Such pulps are slow draining types. From such type of pulp it is generally considered that paper made from these will be of relatively poorer strength than wood pulps. From time to time evaluation of paper samples received in CPPRI, it has been observed that the papers produced by different Indian Mills had wide variation in strength and optical characteristics though the raw material, its processing methods and types of paper machines and their configuration are almost similar. So it is utmost important that the reasons for such wide variation are examined with attempts to understand possible reasons, which in turn will suggest steps for better paper production from such raw materials.

Paper samples manufactured by 25 Indian paper mills were examined in details for the different characteristics viz., formation of sheet matrix, strength, optical etc. The possible ways of making better paper from these raw materials has also been discussed.

2.0 RESULTS AND DISCUSSION

2.1 Formation values of different paper samples

Considering that the processing method and paper machine configuration of different agricultural residues based mills are similar, sheet matrix of different paper samples were studied for the different characteristics in detail. Formation indices measured using Paprican Microscanner of different paper samples manufactured by different mills are recorded in Tables II to IV. Results indicated wide variation in the formation index values. Some mills using agricultural residues as main raw material has quite low value (formation index 31), whereas it is high (formation index 120) for other mills with similar type of raw material (Tables III, IV). In general, the medium sized mills, which are based on agricultural residues, have relatively poorer formation (formation index 31 to 93) as compared to big mills based on bamboo and hardwoods except few exceptions. The formation of paper manufactured from waste paper by Small capacity paper mills is quite low in the range 29 t0 40. The entire paper sample studied had lower value of formation than imported paper (formation index 172). Even the paper manufactured from 100%-recycled paper of foreign origin had much better sheet formation (formation index 82). It is quite contrary to the expectations as straw pulps being shorted fibred should give better formation than wood pulp. Wood fibres are thin walled fibres and are more flexible than straws, when wood fibres form the paper network by lying one fibre on the other there are more chances of contact with each other so little last portion is left free which could not bend. The shorter the fibre (like Straws) the greater the proportion of its length which is undistorted or straight. Conversely, the longer the fibre the greater the proportion which come in contact or can absorb energy much like the compression of the spring. This is reason that long fibres form larger or more difficult to disperse flocs than short fibres. The lower values obtained in the case of short fibred agricultural residues pulps suggest that not much attention be being paid towards paper formation by such mills. To improve the quality of paper from agricultural residue pulps the interest in the topic of sheet formation needs to be renewed in Indian paper makers. Mostly the paper makers in India evaluate formation by traditional visual method. Even today at paper mills the sheet is spread onto a light table for formation check against transmitted light. This visual expression corresponds pretty well to the true basis weight variation for uncalendered paper samples that are made of chemical or mechanical pulp without filler or coating, but fails for paper grades of today which are very complicated in the furnish composition and their process conditions. The evenness of material distribution no more is visually assessable now a day. The formation of a paper is dependent on Number of fibres and crowding number of pulps in a sheet.

2.2 Number of Fibres

The number of fibre (38) required to make a sheet of paper at certain grammage can be calculated as follows

$N = wa^2/Ls$

Where

N: Number of fibres in paper

W : Grammage (g/m^2)

a : The side length of square shaped paper sheet

L : The length weighted average fibre length m

s : Fibre coarseness (g/m)

2.3 Crowding Number

The crowding number, which is an indicator of flocculation tendency of a pulp, can be calculated using the following relationship

$N (crowd) = 5Cl^2/s$

Where

N (crowd) : Crowding number

C : mass stock concentration(%)

L : The length weighted average fibre length m

s : Fibre coarseness (g/m)

Keeping in view the above formulae it becomes clears that as in the case of agricultural residues pulps as the fibre length and coarseness is lower than wood fibres; the number of fibres in a sheet will be higher and the crowding number will be lower. So the better formation is expected if wet end is properly controlled.

The material property of paper having most influence on its perceived quality and profitability is uniformity of its distribution of its material content Formation is defined as the evenness of distribution of the fibre mass in paper (2). According to Sara's definition, the formation is a grammage variation occurring at a wavelength interval of 0 to 70-100mm(3). Norman (4) suggests that that the term "mass formation " should be used to denote small-scale grammage variation, because "formation" is very general and has a wide definition. The most important single property which a paper maker must achieve is to make it as uniform as possible. Formation is one of the most important structural parameters for all grades of paper and board, because it influences nearly all-important properties of the product. Paper is formed continuously by pulsed filtration process from an aqueous suspension of largely natural cellulose fibres having mean fibre length about 1mm, with possible addition of some polymeric retention aids and inorganic fillers. Making idealized uniform sheet is quite difficult as papers are made from naturally grown fibres, so no two are even truly identical, also it is difficult to lay one fibre over the other like brick layer of wall. The reason papers are not truly random is that commercial paper making stock concentration is too high. Even at 0.2% there is so many fibres present per unit volume that they interfere or interlock with each other. In doing so, fibre networks with much larger, high concentration zones- the so-called fibre flocs than the densest portion of random network are formed. Paper is known to have a stratified or layered structure by virtue of hydrodynamics of its forming by pulsed filtration like mechanism, as forecast by Finger and Majewski (5) then proved and expainled by Radvan et al (6). The standard reference structure for paper is therefore a stack of planar random net works of fibres for which many statistical geometric properties are known analytically (7-10).

3.0 EFFECT OF FORMATION ON PAPER CHARACTERISTICS

3.1 Strength Characteristics

To see the effect of formation on the sheet characteristics, paper samples manufactured by a particular mill with it furnish composition but different formation indices were compared for different characteristics. It was observed that the bonding properties (tensile index, burst index) were adversely affected by formation deterioration (Tables II, III, IV). The extent of drop observed in the tensile index was from 7.8% to 36.1%. Similarly for bursting strength and tearing strength it ranged from 9.4% to 34.8% and 6.7% to 42.0% respectively. The regression correlation co-efficient between formation index and tensile strength, tearing strength and sp. scattering co efficient was around 0.60. This indicated that improvement in formation would help to improve these properties to remarkable extent without additional caring for the raw material.

3.2 Sizing and filler retention

Drop in the formation had also caused drop in the sizing degree and retention of the filler in the sheet. The effect is to extent of 2.8% to 22.7% and 2.0% to 31.1% respectively (Tables 111 & IV). Due to poor formation probably considerable portion of useful fines are not retained in the sheet.

3.3 Optical characteristics

Specific. Scattering coefficient is an important property for writing and printing grade papers. The lowering in the formation values also caused drop in this property, which means that opacity of the paper having poor formation will be on the lower side. This is probably due light areas in the sheet, which do not scatter back the light but allows it to pass through. Also the loss of useful fines may be the cause.

4.0 FACTORS AFFECTING THE PAPER FORMATION

Factors that affect the paper formation are of two types: those related to fibre characteristics and those related to process parameters. Morphological features of the fibres such as fibre length and coarseness affect the structure of paper (3,12, 13). This was shown in the statistical geometry approach of Kallmes and Corte (14,15) and in subsequent work of Corte and Dodson(16). They found that the variance of "random" sheets (sheets formed in ideal condition with no fibre interaction) was solely defined by the fibre geometrical morphology and sheet basis weight. This was verified experimentally by Herdman and Corte, who formed handsheet at extremely low dilution from fibres cut to different length (12). It is generally accepted that shorter fibres yield a better formation. Sara has observed this phenomenon by studying the formation of great number of commercial samples made from variety of pulp (3). Most paper grades requiring a high degree of uniformity use shorter hardwood fibres or fibres reduced in length during refining. Smith studied the formation potential of various pulps (17). The formation potential is defined as the experimental relationship between the formation index of a sheet and the consistency of the pulp suspension from which it is made. He found out that for each furnish there is a consistency and degree of refining that together yield an optimal formation The agricultural residues pulps are short fibred pulps and due to slow drainage nature are not given any refining treatment by Indian paper mills but still gave paper of poor formation is quite concerning The different parameters involved in paper making were examined for wood, bamboo, and bagasse pulps to find the causes. The effect of alum, cationic starch, retention aid dosages were examined. The effects of different chemical variables are illustrated in **TABLES 4- 5.**

4.1 Addition of alum

Addition of alum more than 4 % adversely affected the formation index. At 8% alum level the formation values got dropped by about 21 %, 13 % and 24 % for wood pulp, bamboo pulp and bagasse pulp respectively This drop in the formation index caused drop in tensile strength from 77.5 to 65 N.m/g, bursting strength from 5.85 to 4.70 kPa.m^2/g, tearing strength from 14.4 to 13.5 m^2/kg for soft wood pulp. The drop in these properties for bamboo pulp was tensile index 42.0 N.m/g to 35.5 N.m/g, bursting strength 2.70 to 2.30 kPa.m^2/gand tearing strength 5.20 to 4.70mN.m^2/g. Similar drop was observed for the bagasse pulp.

4.2 Addition of cationic starch

Addition of cationic starches more than 2% caused drop in formation by about 20%. Due to this drop negative effect on the strength characteristics was observed. However addition of cationic starch upto 1% had shown improvement in these properties.

4.3 Addition of retention aids

Retention aids are generally added in paper manufacture to improve the retention of fines and fillers. Excessive dosage of retention aid beyond 0.2% had shown adverse effect on the formation. The negative effect on the formation had shown negative effect on the strength characteristics. Dual type retention aid effect on the formation drop is relatively less.

4.4 Refining

Refining is also a highly effective way of changing formation. Unrefined fibres are generally stiff and straight and relatively smooth sided. Refining softens the fibres, fibrillates them and creates fibre debris. Refining also promotes fibre collapse, which is essential for good formation. It is fairly obvious that a better formed sheet can be made from a refined pulp than from unrefined one, since the more flexible fibres, along with fibre debris are going to fill the sheet in better way. For making the paper from the agricultural residues pulps no refining is generally being practiced in Indian mills due to the reason that pulp produced is already slow draining and have freeness in the range 300 to 400 CSF and further it is considered that refining will pose paper machine runnability problem There are generally one or two refiners before fan pump in Indian mills based on agricultural residues, these are put to fiberize possible fibre bundles. Actually these refiners also yield some increase in slowness and in fines which should be avoided. Instead of refiners a deflaker should be preferred which will give fibre separation effect. This needs to be tried on pilot scale.

To assess the degree of slushing, stock quality degree (SQD) number is generally used (37). This value gives an indication about dispersion of pulp prior to refining. The value is based on tensile strength measurement and is calculated by comparing the tensile strength of process sample with the tensile strength of laboratory sample after proper disintegration.

$$SQD(\%) = \frac{\text{Tensile strength of the process sample sheet X100}}{\text{Tensile strength of laboratory sample}}$$

The stock quality degree (SQD) of the pulp sample collected from four medium scale paper mills prior to refining is given in Table IX. The values obtained are quite low which indicate that the pulps are not properly disintegrated prior to refining. Generally a value of more than 75 % is considered appropriate. This indicated that steps are required to properly disintegrate the pulp to make better quality of paper.

4.5 Stock –wire speed difference

Stock leaves the flowbox with a certain velocity and lands on the moving wire. The difference in velocity between the stock and wire has a profound effect on sheet properties through its effect on formation and fibre orientation. It is the difference in velocity of two, which is important despite the fact that it has been common practice for the ratio of stock to wire speed to be quoted. One further comment, which should be made at this stage, is the lack of knowledge that often exists of the true stock speed. This is particularly true for the hydraulic boxes where the velocity is not solely dependent on the pressure head (with some allowance for viscous losses). The velocity in the box is too high for the velocity head and wall friction to be ignored. Some suppliers provide a formula for calculating true jet speed. Paper machines are usually set up to produce the required balance between the machine and cross direction properties of paper irrespective of the nominal stock-wire speed difference that is being used.

At a low stock consistencies the stock –wire speed difference has little effect on formation on a four drinier machine as it is dilute enough for formation to be fully determined by what happens on the wire. If there is sufficient difference between the stock and wire speeds the shear forces created will cause dispersion of the fibres. Thus there is an advantage for formation in running off square (i.e. with a difference between stock and wire speeds). At still higher consistencies the fibres are not so easily dispersed and the beneficial effect of running off square diminishes.

The difference between the stock and wire determines the orientation of fibres in the sheet. As the difference increases there is a greater tendency for fibres to be aligned in the machine direction. When there is no difference in the two speeds, fibre orientation will be close to random as one will get although the component of fibre orientation in machine direction will still exceed that in cross direction due to some alignment by accelerating flows in the flow box.

The influence of stock –wire speed difference over fibre orientation gives the papermaker some control over the ratio between the MD and CD properties of the sheet. As the MD orientation of the fibres increases the MD strength of the sheet increases at the expense of the CD. This effect is shown in Figs 1 (Ref 18,19). MD strength goes through a minimum and CD through a maximum when the jet and wire speeds are identical. Note that the MD strength is still higher when the speeds are identical. Three factors probably contribute to this, the small MD orientation of the fibres even when speeds are identical, as stated above, the stretching of the sheet which occurs when it is pulled from one section of the machine to another and the difference in the MD and CD restraint of the sheet in the dryer section. Figures 1 also show that the effect of speed difference on MD/CD strengths is greater at 0.3% than 0.5& consistency. A change in speed difference of only 5 m/min can have large effect on the MD/CD strength ratio. The optimum stock/wire speed difference will depend on the properties required for the product. This is illustrated in Fig 1. The MD and CD tensile plots have been superimposed so that the aim strengths coincide; there are two stock/wire speed ranges where the specified product quality or tensile strength is met. When other properties are included the specified product quality may only be achieved over very small stock/wire difference range. Any deficiency in the flow box or in its operation, which produces cross direction flow, will move the maximum strength direction away from the MD.

4.6 Agitation on the wire

Earlier discussion had shown that if stock slurry is not agitated after it leaves the slice and lands on the wire, the floc size distribution will get worse. Energy must be put into draining stock to establish and maintain good fibre dispersion. There are two ways of supplying this energy, turbulence and oriented shear as shown in Fig.2. Both of these types are active in causing deflocculation on the wire and maintaining a deflocculated state.

Some years ago it was generally believed that the sheet on the wire should look like a pane of glass, and even some people were able to accomplish this. Much to their dismay the resultant sheet looked terrible. It was terribly flocculated. The problem was that without agitation on the wire, the fibres had adequate opportunity to flocculate. Good agitation on the wire is essential to good formation and is as important as good turbulence in the headbox. Combinations of foil blade angles and table rolls at lower speed can be used to produce turbulence on the wire. An old/new turbulence generator has been gaining renewed interest.

Oriented hydraulic shear is quite beneficial to improving formation. This type of shear is best exemplified by ridge of stock going down the wire, When it hits a drainage element, the ridge splits into two smaller ridges with a valley between. This splitting creates shear, which helps to break flocs and keep the fibres dispersed. Obviously the generation of ridges should be carefully controlled. If they are too large (contain too much energy), they will be disruptive to sheet formation when they divide and can cause spouting on the wire. On the other hand if they are of the correct size, spacing, and energy level, and the splitting is properly done, the resulting improvement in formation can be quite remarkable. The apparent mechanism is for the shear forces to pull the flocs apart and redistribute the fibres.

There are two ways, which improve formation – Sheraton roll and Wunderfoil. The Sheraton roll Fig 3 (known as Sonic roll in Europe) is placed below the wire to introduce fine scale table activity into the stock. Early Sheraton roll was not equipped with a drive, and they had only a slight effect on formation. (21,22). New Sheraton rolls are equipped with a drive. The idea being to make the wire and stock above it vibrates at resonant frequency (210. The Sheraton roll is placed at the beginning of the forming table where there is large amount of undrained stock. By changing the speed of the roll, the right frequency may be found for all speeds and stock thickness on the wire. The Sheraton roll offers an interesting possibility to control table activity at all speeds and grammages especially if amplitude of z-direction motion can be controlled, for instance, by changing the height position of the roll. Some good results have been reported, but exact measurements have not been provided.

The Wunderfoil (known as the Cascade foil in Europe) Fig 4 is a dewatering device that does not generate any table activity (23,24). The surface of foil consists of angled (1°) and plain section. The idea is to trap the removed water between the fabric and the blade surface in a channel of uniform height (25). It is reported that the wunderfoil is an efficient dewatering tool and upto 40% improvement in drainage has been achieved by installing a wunderfoil and modifying the table layout.

Theoretically table activity generated by the Shreaton roll can break the flocs and increase fibre mobility. When drainage is introduced to stock having good fibre mobility (with a Wunderfoil), the drainage distributes fibres uniformly on the small scale.

Kallmes (21) suggests that by installing a Wunderfoil and a driven Sheraton roll in tandem, drainage and table activity can be independently controlled over a wide speed and grammage range. This would be especially beneficial on the early part of the forming table.

4.7 Table arrangement

The table lay out should be designed for good formation, not only for drainage (26). The pre forming section of hybrid formers are quite long, for instance. Because a certain consistency is needed in the gap of the top former, drainage is delayed if the pre forming section is too long, which also means that the generation of table activity is minimal, this results in bad formation of the sheet formed on the pre forming section. There is no universal table layout for all grades (27). This means that the table arrangement on the machine with a wide speed and grammage range is always a compromise (26). The speed range typical for conventional drainage elements is only ± 15-30m/min of the optimum speed (25). The second limitation of the conventional drainage equipment is that increasing table activity also means increasing dewatering.

A typical layout involves the use of widely spaced, low angled foils at beginning of the table (28,29). The distance between the foils decrease and foil angles increase when moving down the table. Typical foil angle at the beginning of table are) 0.5/°-1° (30). On slow machines, large foil angles 3-5°may are used at the beginning of the table (27). The use of widely spaced low angle foils does not always represent the optimum from the formation point of view. The generation of table activity is very gentle (31.32), which is detrimental to formation. On the other hand high foil angles may cause stock jump and a decrease in retention with light grades, and sheet sealing with heavier grades. Therefore the shortest blade pitch possible with low foil angles is probably the optimum configuration at the beginning of the table. The short pitch also means that table activity can easily be maintained during the whole forming process and the reflocculation time between the foils is minimized (30,33). A harmonic table arrangement (using the same blade pitch over the whole forming table) is widely used to help the control and generation of table activity. Pulses at the same frequency force the surface of the stock to vibrate (34,35).

On low speed machines, the generation of table activity is impossible using gravity foils. Therefore table rolls are still used on low speed machines to create table activity and improve formation (27,31,36)

4.8 The Shake

At 2000 fpm and above the shake does little or nothing for formation. There is just too little time for the shake to act on the fibres before they have passed out of the shaken zone. However, high frequency shake at speed below 2000 fpm and especially with heavy weights at speeds of 1000 fpm can produce significant improvement in formation. Investigations have shown that the frequency of shake is more important than amplitude. The higher the frequency the more beneficial is the effect on formation. The effectiveness of the shake in improving formation is roughly directly proportional to the amplitude and square of the frequency and inversely proportional to speed of the machine. This so called shake number, which is defined as

$$S = f^2 a/m$$

Where S = Shake number

f = Frequency, shake/min

a = Amplitude,in
m = Machine speed fpm

Generally shake number above 30 is considered better for formation.

4.9 The Dandy

Historically the dandy roll was used to improve formation of the sheet on slow speed machines where flocculation of the topside of the sheet was inevitable due to poor agitation on the wire and long retention times. The dandy roll was placed in the middle of the suction box section where the sheet was just about to dry. It was supposed to rework the topside of the sheet and break up flocs. It was very efficient and there was a marked improvement in formation. At operating speed of 300 fpm or so the dandy was driven by the sheet and the wire. It ran usually on trunion bearing which were set so that the dandy exerted a certain pressure on the sheet. The original dandies were about 12 inches in diameter or smaller, but as machine speeds increased the shear forces between the small dandy and the wire increased to the point the sheet was disrupted. Simple drives were installed and the situation improved, but they were still troublesome to run and many were removed from service.

5.0 EXPERIMENTAL

Paper samples were conditioned at 27+1°C, 65+2% R.H. before testing. Tests were made according to the following methods: -

Formation index	-	Measured using Paprican Micro-scanner Formation Index is a ratio that is made Up of both the contrast and Size distribution components Of the sheet formation. A Higher formation index Implies a more uniform Sheet.
Tensile index	-	ISO 1924
Burst index	-	ISO 2758
Tear index	-	ISO 1974
Sp. Scattering coefficient	-	SCAN C 2769
Ash content	-	ISO 2144
Cobb	-	ISO 535

6.0 CONCLUSIONS

There is wide variation in formation indexing values of paper manufactured by different Indian paper mills though the raw material, its processing methods and types of paper machine and their configurations are almost similar.

The medium sized paper mills, which are mainly based on the agricultural residues, have relatively poorer formation (formation index 31 to 93). As compared to big mills based on bamboo and hardwoods. The formation indices of paper manufactured from waste paper by small capacity mills are quite lowing (29 to 40).

One of the causes of quality variation in papers of different mills is the difference in the formation index values. The bonding properties (tensile index, burst index) are adversely affected by formation deterioration. The extent of drop observed in the tensile index ranged from 7.8% to 36.1%. Similarly for the bursting strength and tearing strength it ranged from 9.4% to 34.8 % and 6.7% to 42% respectively. Drop in formation also caused drop in sizing degree, retention of fillers and sp.Scatt. co- efficient values.

Excessive dosages of alum, wet end chemicals adversely affect the formation. Addition of alum more than 4%, cationic starch more than 2% retention aid more than 0.2% be avoided to get better formation. Dual type retention aid effect on the formation drop is relatively less.

The stock quality degree which indicate about the slushing degree of the stock is lower in the of medium scale paper mills based on agricultural residues.

General practice for making the paper from agricultural residues pulps in India is that no refining is done for the pulps. There are generally one or two refiners before fan pump. Instead of refiners a deflaker should be preferred which will give separation effect, hence formation will be improved without much affecting the slowness.

For improving the formation the following details of the paper machine should also be properly checked and adjusted-

- Stock –wire speed difference.
- Agitation on the wire.
- Table arrangement,
- The shake.
- The Dandy.

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TABLE-1

PRODUCTION OF NON WOOD PULP BY DIFFERENT COUNTRIES IN1997 (THOUSAND TONNES) BASED ON DATA IN REFERENCE 1.

Country	Non wood pulp	Total pulp	Non wood :Total (%)
China	12238	17380	70.41
India	930	1900	48.94
Colombia	141	317	44.47
Mexico	134	442	30.30
Thailand	108	572	18.88
Argentina	124	749	16.55
Turkey	31	356	8.70
Zimbabwe	2	33	6.10
Iran	10	160	5.88
Indonesia	79	2979	2.65
Yugoslavia	1	44	2.27
Japan	16	11490	0.14
Brazil	52	6347	0.82
France	2	2832	0.07
Hungry	12	12	100
Algeria	5	5	100
Iraq	4	4	100
Tunisia	14	14	100

TABLE –2

FORMATION INDICES OF DIFFERENT PAPER SAMPLES FROM DIFFERENT MILLS AND THEIR EFFECT ON STRENGTH, OPTICAL AND OTHER CHARACTERISTICS OF PAPER
SMALL CAPACITY MILL

Mill No.	Sam No.	Furnish	Formation Index	Tensile Index (N.m/g) Avg.	Burst Index (kPa.m²/g) Avg.	Tear Index (mN. m²/g) Avg.	Cobb g/m² Avg.	Sp.Scat coeff. (m²/kg)	Ash Content (%)	Brightness (%)	Opacity (%)	Fiber Strength Index (km)
1	1 2	Waste paper Waste paper	40 35 (14.3)	38.5 35.5 (9.1)	1.80 1.50 (16.7)	3.25 2.90 (10.8)	23.4 25.2 (7.7)	36.2 34.4 (5.0)	2.4 2.0 (16.7)	58.7 58.4	92.1 91.4	12.1
2	1 2	Waste paper Waste paper	37 30 (19.0)	20.5 15.5 (24.4)	1.05 0.85 (19.0)	3.05 2.75 (9.8)	24.8 27.3 (10.0)	22.1 19.1 (13.6)	6.5 4.5 (30.8)	57.7 57.2	92.6 92.0	12.2
3	1 2	Waste paper Waste paper	30 25 (16.7)	15.5 11.0 (29.0)	.90 .65 (27.8)	2.85 1.65 (42.0)	25.2 28.4 (12.7)	20.4 17.5 (14.2)	8.1 6.6 (18.5)	55.6 55.4	93.8 93.0	11.8
4	1 2	Waste paper Waste paper	35 29 (17.1)	24.5 20.0 (18.3)	1.05 0.85 (19.0)	2.90 1.80 (37.9)	25.4 27.6 (8.7)	35.4 32.0 (9.6)	14.8 13.2 (10.8)	57.1 56.5	93.0 93.6	11.4
5	1 2	Waste paper	36 24 (33.3)	23.5 15.0 (36.2)	1.25 0.70 (44.0)	3.50 2.20 (37.1)	18.0 20.2 (12.2)	54.4 44.2 (18.8)	18.2 15.9 (18.7)	59.7 59.2	91.6 92.1	12.6
6	Imported	Waste paper Waste paper	82	47.5	2.40	6.30	17.5	25.5	12.5	78.5	90.6	14.4

Figures given in parenthesis are percentage change in property.

TABLE –3

FORMATION INDICES OF DIFFERENT PAPER SAMPLES FROM DIFFERENT MILLS AND THEIR EFFECT ON STRENGTH, OPTICAL AND OTHER CHARACTERISTICS OF PAPER

Medium capacity mill

No.	Sam No.	Furnish	Forma-tion Index	Tensile Index ($N.m/g$) Avg.	Burst Index ($kPa. m^2/g$) Avg.	Tear Index ($mN. m^2/g$) Avg.	Cobb (g/m^2) Avg.	Sp.Scatt .coeff. (m^2/kg)	Ash Content (%)	Brightness (%)	Opacity (%)	Fib e Stre ng h Ind ex (km)
1	1 2	Straw & softwood Straw & softwood	64 57 (10.9)	39.0 32.5 (16.7)	1.55 1.25 (19.4)	4.05 3.00 (24.7)	18.5 22.7 (22.7)	33.6 29.2 (13.1)	16.4 13.5 (17.7)	69.1 69.4	90.3 89.9	1[illegible]
2	1 2	Straw & softwood Straw & softwood	47 39 (17.0)	28.5 24.0 (15.8)	1.10 0.95 (13.6)	3.20 2.80 (12.5)	20.7 23.4 (11.5)	28.5 25.5 (10.5)	15.6 14.8 (5.1)	68.7 68.1	91.4 90.0	1[illegible]
3	1 2	Bagasse& Softwood Bagasse& softwood	46 40 (13.0)	20.5 17.5 (14.6)	1.20 1.00 (16.7)	4.95 3.50 (29.3)	20.0 22.4 (10.7)	27.5 24.5 (11.6)	6.6 4.5 (31.1)	71.4 71.0	87.6 87.2	10.[illegible]
4	1 2	Straw & softwood Straw & softwood	59 49 (16.5)	39.5 27.5 (30.4)	1.50 1.10 (26.7)	3.40 2.40 (29.4)	19.5 21.2 (8.0)	38.5 35.5 (7.8)	17.5 15.2 (13.1)	68.0 67.9	91.2 90.0	10.8
5	1 2	Straw & Rag straw & Rag	89 80 (11.3)	32.0 26.0 (18.8)	2.40 2.05 (14.6)	2.50 2.05 (18.0)	20.5 21.9 (6.8)	42.8 39.5 (7.7)	18.9 16.7 (11.6)	73.3 73.0	90.5 89.9	11.0
6	1 2	Straw & Rag Straw & Rag	93 85 (8.7)	28.4 26.0 (8.5)	1.35 1.10 (18.5)	3.30 2.90 (12.1)	17.1 18.5 (8.2)	44.6 41.4 (7.2)	26.4 24.2 (8.2)	74.1 73.3	91.1 90.0	11.1

7	1 2	Straw straw	36 31 (13.9)	29.5 24.5 (16.9)	1.10 0.90 (18.2)	3.00 2.80 (6.7)	19.5 21.5 (10.3)	35.5 33.2 (6.5)	15.2 14.8 (2.6)	68.5 68.1	92.4 92.2	9.4
8	1 2	Bagasse& softwood Bagasse& softwood	57 50 (12.3)	31.5 27.5 (12.7)	1.40 1.10 (21.5)	4.70 4.10 (12.8)	20.5 21.8 (6.3)	35.1 33.8 (3.7)	15.2 9.0 (15.9)	72.5 71.5	89.4 88.8	10.4
9	1 2	Bagasse& softwood Bagasse&sof twood	56 66 (17.9)	32.5 41.5 (28.8)	1.60 1.75 (9.4)	2.35 2.65 (12.8)	22.0 19.2 (14.6)	34.1 36.5 (7.0)	13.6 14.5 (6.6)	71.5 70.5	88.8 87.0	10.6
10	1 2	Straw & softwood Straw & softwood	98 56 (42.9)	34.0 20.0 (41.1)	1.70 1.40 (17.6)	4.60 3.70 (19.6)	18.6 22.8 (18.4)	43.0 38.5 (11.6)	11.5 9.2 (20.0)	69.9 69.0	91.4 90.2	10.8
11	1 2	Straw & softwood Straw & softwood	52 45 (13.5)	41.5 29.5 (28.2)	1.50 1.30 (13.3)	3.50 2.95 (15.7)	19.6 21.8 (11.2)	34.3 31.0 (9.6)	12.4 10.6 (14.5)	68.5 67.6	91.2 90.0	10.3

Figures given in parenthesis are percentage change in property.

TABLE-4

ORMATION INDICES OF DIFFERENT PAPER SAMPLES FROM DIFFERENT MILLS AND THEIR EFFECT ON STRENGTH, OPTICAL AND OTHER CHARACTERISTICS OF PAPER

LARGE CAPACITY MILL

No.	Sam No.	Furnish	Formation Index	Tensile Index (N.m/g Avg.	Burst Index ($kPa.m^2/g$) Avg.	Tear Index ($mN.m^2/g$) Avg.	Cobb (g/m^2) Avg.	Sp.Scatt coeff. (m^2/kg)	Ash Content (%)	Brightness (%)	Opacity (%)	Fiber Strength Index (km)
1	1 2	Bagasse &bamboo Bagasse & bamboo	110 100 (9.1)	49.5 45.5 (8.1)	2.05 1.85 (9.8)	4.50 4.20 (6.7)	20.7 21.9 (5.8)	44.2 39.8 (10.0)	15.2 14.0 (7.9)	77.5 77.0	89.8 89.2	11.0
2	1 2	Hardwood &bamboo Hardwood &bamboo	120 91 (24.2)	47.0 30.0 (36.1)	2.30 1.50 (34.8)	6.10 5.10 (16.4)	17.8 18.3 (2.8)	48.2 44.3 (8.1)	14.5 12.6 (13.0)	77.5 76.5	90.2 89.9	13.2
3	1 2	Hardwood& bamboo Hardwood& bamboo	138 120 (13.0)	49.5 40.5 (18.2)	3.10 2.65 (11.7)	5.90 5.10 (13.6)	18.8 20.4 (7.9)	42.7 38.9 (8.9)	15.1 13.8 (8.6)	78.9 78.0	91.2 90.5	13.4
4	1 2	Bamboo & hardwood Bamboo & hardwood	68 58 (14.7)	28.0 24.5 (12.5)	1.40 1.20 (14.3)	6.20 5.50 (11.3)	18.4 19.1 (3.8)	39.8 37.5 (5.8)	14.5 13.1 (9.7)	77.0 76.5	87.5 87.2	15.5
5	1 2	Bagasse & softwood Bagasse & softwood	120 100 (16.7)	38.5 35.5 (7.8)	2.05 1.75 (14.6)	5.00 4.50 (10.0)	18.6 19.8 (6.5)	37.9 35.4 (6.6)	15.2 13.8 (9.2)	78.5 78.1	90.1 89.8	11.8
6	1 2	Hardwood & bamboo Hardwood & bamboo	106 94 (11.3)	42.5 37.0 (12.9)	1.90 1.65 (13.2)	5.80 5.04 (13.1)	17.4 18.6 (6.9)	39.2 36.5 (6.9)	13.5 12.8 (5.2)	78.9 78.0	91.2 90.6	13.1
7	1 2	Hardwood & bamboo Hardwood & bamboo	110 100 (9.1)	47.5 42.5 (10.5)	2.85 2.45 (14.0)	5.80 5.50 (5.2)	17.4 18.5 (6.3)	47.5 45.5 (4.20)	15.5 13.9 (10.3)	78.9 78.5	90.5 90.2	12.6
8	1 2	Hardwood & bamboo Hardwood & bamboo	95 80 (15.7)	38.5 35.5 (7.8)	2.45 2.10 (14.3)	4.90 4.70 (4.1)	17.6 18.8 (6.8)	46.5 43.5 (6.5)	14.5 13.2 (9.0)	79.9 78.5	90.4 89.8	12.7
9	1 2	Hardwood & bagasse Hardwood & bagasse	115 100 (13.0)	46.5 31.0 (33.3)	2.30 2.00 (13.0)	6.10 5.80 (4.90)	17.2 18.9 (9.9)	48.3 46.3 (4.1)	12.6 11.2 (4.1)	78.8 78.5	90.2 89.7	11.8
10	1	Hardwood& softwood (Imported white printing paper)	172	41.0	3.05	6.75	17.1	37.5	24.9	90.2	89.8	12.1

Figures given in parenthesis are percentage change in property.

TABLE-5

EFFECT OF DIFFERENT CHEMICAL VARIATIONS ON THE FORMATION OF HANDSHEETS MADE FROM DIFFERENT PULPS

Softwood pulp beaten to 400±20 ml CSF

Parameter	Formation Index	Tensile Index (N.m/g)	Burst Index (k.Pa.m^2/g)	Tear Index (mNm^2/g)	Sp.Scatt. Co-eff. (m^2/kg)
Pulp as such	114	77.5	5.85	14.4	21.7
Rosin Soap Size (2%)	113	76.5	5.80	14.2	21.1
Alum dose					
2 %	114	74.4	5.70	14.1	21.3
4 %	110	72.5	5.20	14.0	22.4
8 %	90	65.0	4.70	13.5	23.5
10 %	77	59.0	4.10	12.0	23.8
Cationic Starch					
1 %	100	82.5	5.90	13.5	16.1
2 %	95	83.4	5.95	13.0	17.2
3 %	80	72.7	5.70	12.0	17.7
Retention aid Polyacrylamide type					
%	100	81.0	5.40	14.0	19.9
%	95	80.5	5.30	13.8	21.9
0.4 %	90	77.3	5.00	13.0	22.0
0.8 %	76	72.5	4.80	12.1	22.6
Dual type retention aid	112	84.5	6.10	13.9	23.4

TABLE -6

EFFECT OF DIFFERENT CHEMICAL VARIATIONS ON THEFORMATION OF HANDSHEETS MADE FROM DIFFERENT PULPS

BAMBOO PULP BEATEN TO 400±50 ML CSF

Parameter	Formation Index	Tensile Index (N.m/g)	Burst Index (k.Pa.m^2/g)	Tear Index (mNm^2/g)	Sp.Scatt. Co-eff. (m^2/kg)
Pulp as such	137	44.5	2.90	5.40	35.4
Rosin Soap Size (2%)	135	43.5	2.85	5.35	34.9
Alum dose					
2 %	136	42.0	2.70	5.20	35.5
4 %	125	38.5	2.50	4.90	35.6
8 %	118	35.5	2.30	4.70	36.2
10 %	104	32.5	2.00	4.50	37.8
Cationic Starch					
1 %	130	49.5	3.15	5.00	33.4
2 %	131	50.5	3.20	4.95	33.2
3 %	100	45.5	2.60	4.75	33.4
Retention aid Polyacrylamide type					
0.1%	130	40.5	2.60	5.30	34.2
0.2%	110	40.0	2.50	5.30	34.1
0.4%	90	37.5	2.30	5.10	34.0
0.8%	85	34.5	2.00	5.00	34.6
Dual type retention aid	132	50.5	3.20	5.30	33.5

TABLE-7

EFFECT OF DIFFERENT CHEMICAL VARIATIONS ON THE FORMATION OF HANDSHEETS MADE FROM DIFFERENT PULPS

Bagasse pulp beaten to 350±50 ml CSF

Parameter	Formation Index	Tensile Index (N.m/g)	Burst Index (k.Pa.m^2/g)	Tear Index (mNm^2/g)	Sp.Scatt. Co-eff. (m^2/kg)
Pulp as such	149	50.5	2.50	3.10	17.9
Rosin Soap Size (2%)	149	50.0	2.45	3.10	17.8
Alum dose					
2 %	148	50.0	2.45	3.05	18.3
4 %	130	45.5	2.25	2.90	18.5
8 %	112	40.5	1.90	2.70	18.8
10 %	104	35.5	1.60	2.50	19.3
Cationic Starch					
1 %	147	52.5	2.95	2.90	18.1
2 %	146	52.0	2.95	2.85	18.0
3 %	124	45.5	2.50	2.65	18.9
Retention aid Polyacrylamide type					
0.1%	145	50.5	2.50	2.90	17.4
0.2%	140	50.0	2.50	2.85	17,5
0.4%	100	47.5	2.20	2.50	17.7
0.8%	80	40.5	1.90	2.00	17.9
Dual type retention aid	146	50.5	2.40	3.05	17.8

TABLE-8

EFFECT OF DIFFERENT CHEMICAL VARIATIONS ON THE FORMATION OF HANDSHEETS MADE FROM DIFFERENT PULPS

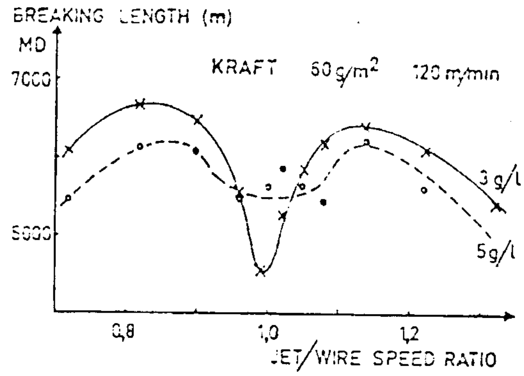
Wheat straw pulp beaten to 350±50 ml CSF

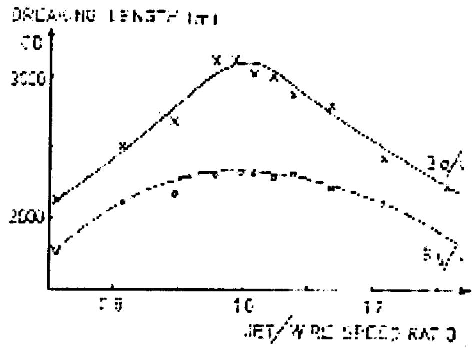
Parameter	Formation Index	Tensile Index (N.m/g)	Burst Index (k.Pa.m^2/g)	Tear Index (mNm^2/g)	Sp.Scatt. Co-eff. (m^2/kg)
Pulp as such	151	46.0	2.05	5.10	42.4
Rosin Soap Size (2%)	150	45.5	2.00	5.00	42.3
Alum dose					
2 %	149	43.0	1.95	4.90	41.4
4 %	145	40.5	1.90	4.70	40.5
8 %	120	35.5	170	3.80	39.5
10 %	100	30.5	1.40	3.00	37.5
Cationic Starch					
1 %	146	48.5	2.05	4.70	41.1
2 %	142	47.0	2.00	4.50	39.0
3 %	120	44.5	1.80	4.00	38.1
Retention aid Polyacrylamide type					
0.1%	146	47.5	2.10	4.80	41.4
0.2%	143	47.0	2.00	4.75	41.0
0.4%	109	43.5	1.80	4.00	39.7
0.8%	89	39.5	1.60	3.00	35.9
Dual type retention aid	148	45.5	2.00	4.90	42.0

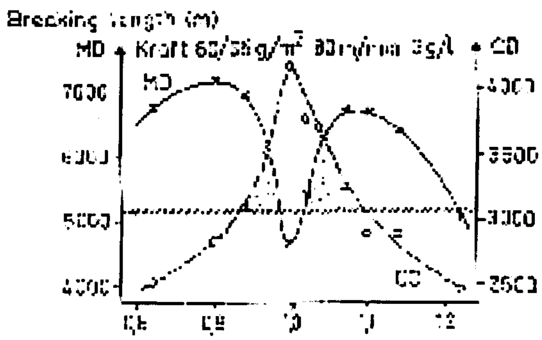
TABLE-9

STOCK QUALITY DEGREE (SQD) OF FOUR MEDIUM SCALE PAPER MILLS

Mill	SQD (%)
1	42
2	44
3	46
4	48


BREAKING LENGTH (m)
MD
7000
KRAFT 60 g/m² 120 m/min
5000
3 g/l
5 g/l
0,8
1,0
1,2
JET/WIRE SPEED RATIO


CD
3000
2000
3 g/l


Breaking length (m)
MD
CD
7000
5000
4000
3500
3000
2500

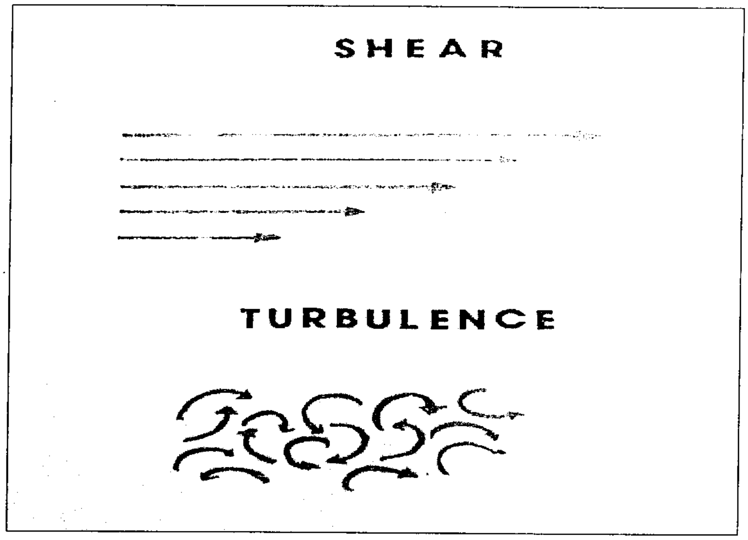


FIG. 1 OPTIMIZING STOCK/WIRE SPEED RATIO

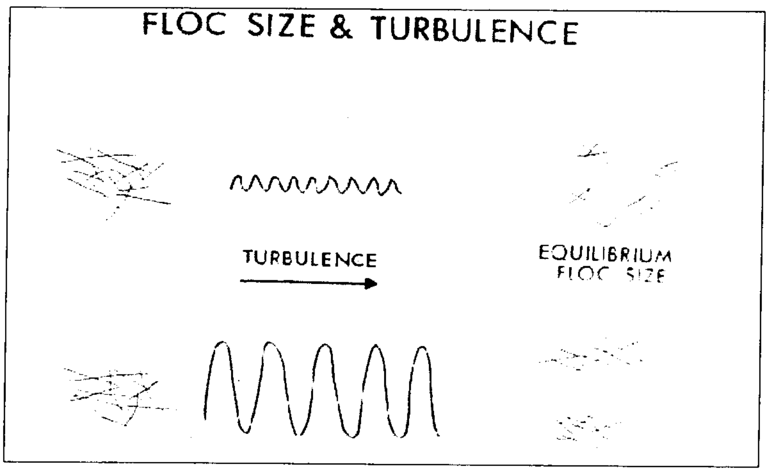
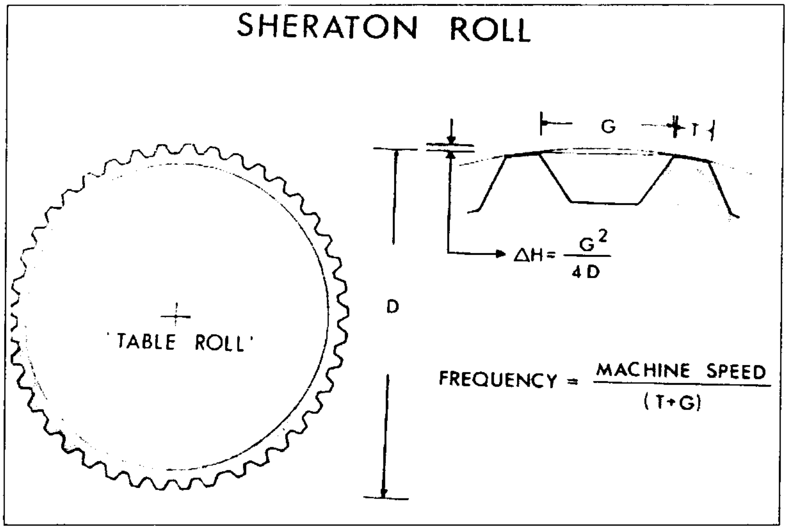


FIG. 2 TURBULENCE AND ORIENTATION SHEAR IN STOCK



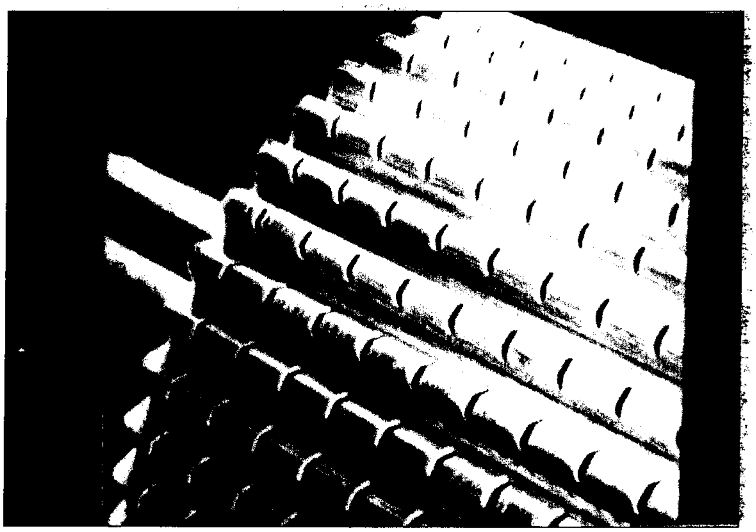


FIG. 3 SHERATON ROLL AND AMPLITUDE OF PULSE GENERATION IN IT (REF. 20)

NEUTRAL & ALKALINE PAPER MAKING AND ITS RELEVANCE TO AGRO RESIDUE PULPS

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About The Author

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NEUTRAL AND ALKALINE PAPER MAKING AND ITS RELEVANCE TO AGRO RESIDUES PULPS

Dr. Y.V. Sood

1.0 INTRODUCTION

In India most of the paper mills are still sizing the paper under acidic conditions using mainly Rosin size and alum. Whereas, now-a-days most of the other countries have adopted neutral/alkaline papermaking process. Historically neutral papermaking was originated with the development of alkyl ketene dimmer (AKD) sizes in the mid 1950;s in North America. More than 80% of North American paper production is now alkaline. By the turn of century, virtually all wood free sheet produced in North America will be alkaline (1). European paper makers had also adopted alkaline papermaking since 1960's. This alkaline sizing had given them the option of switching from the use of imported clay to calcium carbonate, a locally available pigment that was completely unsuitable for use in the acidic systems. This adoption of alkaline sizing has been brought about basically by convergence of process economics and sheet quality. Alkaline sheets are usually stronger and more permanent than sheets produced in an acid alum system. Today after more than two centuries of acid papermaking, one can look back and trace the problems of embritted and yellow paper with the introduction of alum/rosin as internal sizing agents. Paper produced before the wide spread use of alum show remarkable stability compared with sheets sized by alum & rosin in an acidic environment. Process economic played a major role in the accession of rosin/alum as an inexpensive and effective internal sizing agent in 1807, when the demand for cheap printing paper began to racket upward. By the early of this century, the detrimental effects of acid sizing were well recognized. However the absence of suitable sizing alternative remained a significant obstacle to change till a viable method of alkaline sizing was invented. Presently the alkaline revolution is under way all over the world.

2.0 AGENTS OF NEUTRAL SIZING

Presently following three most common neutral sizing agents are available.

Alkyl Ketene Dimer (AKD)

Alkenyl Succinic Anhydride (ASA)

Neutral Rosin System.

The primary difference between rosin and reactive sizes (AKD, ASA) are that in rosin sizing it is rosin and aluminum precipitate which renders the fibre hydrophobic. In the case of reactive sizes, a covalent bond is formed between the hydrophobic molecule and cellulose of the pulp fibre. A further difference is with the chemical structure of hydrophobic functions. In the case of rosin it is in the form of fused ring arrangement of aromatic ring whereas with reactive sizes it is typically a long hydrocarbon chain of the aliphatic origin (Fig.1). The historical development of neutral papermaking and the development of the three main neutral sizing system (AKD, ASA and neutral) have been well reviewed (2,3).

2.1 Sizing with different chemicals

2.1.1 Alkyl ketene dimer (AKD)

The ketene dimmer itself is a waxy solid having a melting point around 55^0 C and is produced mostly from stearic acid, which is extracted form oils and fats. As such it is not readily applicable to a papermaking systems. The commercially available (AKD) sizes are normally supplied in emulsion form; the ketene dimmer dispersed in water and is readily transported, stored and matered into the stock approach flow system. AKD itself is non-ionic and is not substantive to the cellulose fibre, which are anionic (having a negative charge). The AKD particles in the dispersion are made cationic (having a positive charge) by using cationic starch in the manufacture of the AKD emulsions. The particles are coated with the starch and take on overall cationic charge. By this method the AKD particles are attracted to the fibres in the stock and retention is greatly enhanced. AKD reacts with the cellulose in fibre to form covalent bonds. The general mechanism of reaction is shown in Fig.2 because it is a reactive size so it can also react with water in the system. When it does, the reaction product contributes nothing to sizing. This is prevented from doing so in the emulsion because it is made acidic. At the low level of pH this hydrolysis tendency is greatly reduced. At the pH level of neutral papermaking the hydrolysis reaction rate will proceed more quickly and for this reason it is normal to add AKD quite late in the papermaking system. The rate of sizing development increase as pH increases from 6.5 to 8.5, however, the ultimate degree of sizing begins to level off at pH 7.5 (4).

2.1.2 Alkenyl Succinic Anhydrides (ASA)

The development of alkenyl succinic anhydride as sizing agent came later than the AKD and took place in 1974(5). Like AKD'S they are liable to undergo reaction with cellulose and water and reaction path is shown in Fig.2. The ASA'S are considerably more reactive than the AKD'S and can promote sizing without heat treatment (6) unlike AKD, which are derived from fatty acids, the ASA'S are petrochemical based.

ASA is an unsaturated fatty acid anhydride and is most reactive amongst sizing agents. It must be emulsified on site and must be used shortly after make up. In addition, first pass retention must be maximized usually with a cationic polymer or cationic starch addition, to prevent recirlculation of the size in the wet end. All these steps will minimize hydrolysis, which can result in poor sizing (7-9). The hydrolyzate can also cause press picking problems because of its tackiness, but its effect can be minimized by employing sufficient aluminum ion at a pH greater than 7 (10). An advantage of ASA sizing in that, due to its reactive, 80-100% of the ultimate effect is achieved while on the machine. This effect allows for good holdout of size press solution.

2.1.3 Neutral Rosin System

Neutral rosin systems employ dispersed rosin acid size emulsion, which may be either cationic or anionic. Cationic material such as polyaluminum chloride or synthetic polymer is used to retain the size (11-14). System operates around pH 7 or lower but can go as high as about 7.5 depending upon carbonate content and the degree of sizing required (15). With system employing polymer to retain the rosin emulsion, alum must still be used to provide aluminum on the fibre surface to orient and bond the rosin in the dryer section. Morton states that this system should give good sizing on machine with fewer control problems than the reactive sizes and should be more cost effective (16). In general, these systems cannot provide high level of sizing, especially as carbonate level and pH increase.

3.0 TECHNICAL ASSPECTS OF CHANGING TO NEUTRAL PAPERMAKING

With the change from acidic to neutral sizing the changes, which are expected to occur in the paper making system, are included in **Table 1.**

TABLE -1

TECHNICAL CHANGES WITH NEUTRAL PAPERMAKING (17)

Primary Change	Dependent Change	Ultimate benefit
Absence of alum	Reduced deposition	Less down time
		Lower chemical cost
	Lower ionic concentration	More closure of water system possible
	More stable wet end	
	More effectiveness use of retention aids	
	Higher single pass retention	Lower Losses Lower effluent cost Less sheet 2- sidedness
	Stronger sheet	
	Higher filler contents	Cheaper furnish costs

Neutral wet end	Less strength loss	Improved permanence
And sheet pH	Less corrosion	Lower maintenance costs
	Compatibility with calcium carbonate	Cheaper furnish costs
Replace clay by chalk	Better drainage	Higher output if dryer limited
		Lower energy use if not drying limited
	Lower flow box consistency	Improved sheet formation
	Brighter Product	Less optical whitener needed
		Use lesser bleached pulps

The more detailed comparisons of acid and alkaline sizing system had been given in (18-20). The key points from these publication are summarized in **Table 2 & 3.**

TABLE –2

COMPARISON OF ACID & ALKALINE SIZING SYSTEM

Parameter	Acid rosin sizing	Alkaline sizing (AKD, ASA)
PH range	3.5 – 6.0	7.0 – 10.0
Size storage life	Months, years	Hours, days, weeks
Time to full sizing development	Second, Minutes	Hours, days
Typical size doses (% wt. based in fiber)	0.25 – 1.5	0.1 – 0.4
Robustness of entire sizing	Robust	More sensitive

TABLE –3

BENEFITS AND PROBLEMS WITH NEUTRAL PAPERMAKING

Benefits	
Process	**Product**
Improved productivity	Cheaper furnish
Improved run ability	Improved strength
Improved retention	Improved longevity
Easier water removal	Higher filler possible
More stable wet end chemistry	Improved printability
Reduced energy needs	Greater uniform
Reduced foaming	Less 2 - sidedness
Reduced corrosion	-
Less chemical deposits	-

Higher coating mix solids	-

Problems	
Process	**Product**
Inadequate machine cure	Incorrect sizing
Press picking	Inadequate sizing
Greater slim growth	Surface slipperiness
Retention sensitivity	Dyeing difficulties
Greater wire wear	-
Chemical incompatibility	-
Impaired effluent clarification	-

An alkaline papermaking system can offer important benefits to the papermaking beyond its effect on permanence. There are six areas where substantial improvement to the entire papermaking process had been reported. These are summarized as follows-

3.1 Sheet Economics

Forming the sheet at high pH and avoiding rosin size and alum indicates the potential of more sheet strength. The alkaline sheet in turn has increased the possibility of increasing the filler loading. The cost of filler such as clay and calcium carbonate is considerably lower than price of fibers. The higher strength of an alkaline sheet permit to use weaker fibres thus lowering the cost of production.

3.2 Possibilities of addition of the calcium carbonate

Calcium carbonate, in addition to providing a natural buffer to inhibit the aging process, has four important properties which contribute to its value an internal filler for paper (i) in solution, it provides ideal pH and alkalinity control for the paper making process (ii) its surface area is similar to fines, making it a suitable substitute for fibre and relatively easy to size (iii) as a filler, it has high brightness properties Fig. 3. And (iv) the calcium ion adds positives charge to help balance the electrophoretic mobility of the paper making process water system.

3.3 Water pollution

The uses of alum, particularly in hard water areas where alum addition level are high, causes severe problems as water reuse is increased. Papermaker's alum dissociates in water to form alumina and sulphate ion. Sulphate ion and some acids forms of alumina are very highly corrosive, form scale and deposit and create inefficient sizing conditions for the use of rosin size. These particles have no particular affinity for cellulose and don't retain well in the paper during sheet formation, consequently, a build up occurs in the paper machine process water. The more the system is closed, the greater the build up. Alum and acid papermaking impose a definite restriction on the extent to which paper mill can reuse its process water and reduce its effluent discharge. Operating alum free at neutral to alkaline pH with an alkaline sizing agents raise the ceiling on white water closure. A few mills have reported reducing their effluent Discharge as much as 75% after converting to alkaline system. In general, one pound of an alkaline size replaces several pounds of rosin size, thereby reducing the organic materials added to the process water. This, plus the option to reduce effluent volumes at high levels of closure, gives an alkaline system greater potential to reduce BOD and COD levels.

3.4 Energy

Papermaking has a high-energy requirement. Major areas of energy consumption are drying, refining, and, sometimes, process water temperature control. The alkaline system offers opportunities to conserve energy in each of these areas.

3.5 Productivity

An acid papermaking environment is corrosive. In the same manner the acidity affects the life expectancy of paper by breaking down the amorphous structure of cellulose. Acidity also affects the working parts of a paper machine by corroding the exposed metal surface. An alkaline papermaking environment is non-corrosive, extends life, and reduces the maintenance costs. An alkaline papermaking is cleaner than an acid system. All this increased the productivity.

3.6 Paper Quality

An alkaline sized paper is stronger and is permanent in respect to again characteristics of its important structural properties. Typical result on the permanence and durability (21) of alkaline and acid sizing of appear are depicted in Fig. 4. It clearly shows the deteriorating effect of an acid system on the critical paper strength properties of tear and fold with aging time.

In addition a substantial difference in performance between the two systems is their capabilities to resist to penetrations. The strongly held covalent bonds of the alkaline system provide a full range of sizing protection, especially against alkaline penetrates. This protection is important for certain aqueous coating preparations and liquid packaging. On the other hand aluminum Oleate Bridge between rosin and cellulose surface functional groups is prone to alkaline hydrolysis under these conditions, which leads to unacceptable sizing performance.

The reason put forward for using ASA and AKD neutral sizes are many and diverse and have been covered in the literature many times. However, many benefits tend to be of a technological nature. Indeed it can be argued that these improvements will have a positive impact on the overall economic picture

4.0 MAKING NEUTRAL SIZED PAPER FROM AGRICULTURAL RESIDUES PULPS

Agricultural residues pulps are typical pulps. These are short fibred pulps with lots of fines fibre like parenchyma cells as compared to wood or bamboo pulp. The fines content ranges from 30 to 40% also the charge density of agricultural pulps (Table IV.) is higher than other paper making fibres, so the chemicals to produce neutral sized paper from agricultural residues needs to be of special composition. Different new formulations of sizing chemicals are available in the market from the conventional acid system with rosin paste and fortified rosin soap to neutral rosin dispersions, synthetic sizing neutral like ASA and AKD. Generally these are following problems associated with ASA, AKD neutral/alkaline sizing chemicals.

- Low frictional co-efficient of AKD sized paper.
- Unstable sizing or difficulties in controlling sizing level.
- Instability of size emulsion and handling problems.
- Formations of deposits in papermaking system.

TABLE-4

SURFACE CHARGE DENSITY OF DIFFERENT TYPES OF IMPORTED & INDIGENOUS PULPS

PULP	SURFACE CHARGES (SURFACE CAHRGE (-μ. eg/g))
Bleached softwood (imported)	9
Bleached eucalypt pulp (imported)	13
Unbleached eucalypt pulp	23
CEHH bleached eucalypt pulp	29
Unbleached bagasse pulp	26
CEH bleached bagasse pulp	33
Unbleached bamboo pulp	20

CEHH bleached bamboo pulp	24
CEH bleached wheat straw pulp	28
CEH bleached rice straw pulp	30
Unbleached jute pulp	17
CEH bleached jute pulp	19
HH bleached cotton linter pulp	23

In such scenario, sizing at nearly neutral pH with dispersed rosin emulsion offers good alternative with improved paper strength properties and machine runnability.

Sizing experiments with agricultural residues pulps had shown that dispersed rosin is relatively more effective than rosin soap (Fig.5) Fig.6 illustrates the effect of stock pH on the degrees of sizing on agricultural residues pulp with rosin soap/alum and dispersed rosin/alum system. At pH range 4 to 6.2 rosin soap/alum system fails to give effective sizing above pH value of 5.2. The effective sizing at 4.0 to 5.2 pH is probably due to highest charge density of alum at the pH. However dispersed rosin gave effective sizing from pH 4 to 6.7

These observations can be explained on the basis of sizing mechanism of dispersed rosin and rosin soap. Soap reacts with alum as soon as it is added to the paper stock. Both electro static bonding and co-ordinate bonding participate in this reaction, which obviously results in as strong bond complex as illustration in Fig.7. Since alum is able to form ionic and coordinate bonds with rosin only at acidic pH, sizing with soap size has to be developed in low pH region.

On the other hand, dispersed rosin consist of rosin acid droplets where have considerable surface area. Therefore its retention is a consequence of colloid and surface chemistry. Dispersed rosin does not react directly with alum to form aluminum resinate. The alum acts as a bridge between the negatively charges fiber and negative charge rosin micelle Fig.7.

In rosin alum system, rosin in either its free acid or soap form will react with alum to give aluminum ester products, which create hydrophobicity. In case of soap rosin size under acidic condition most of the rosin size reacts rapidly with alum in solution to give the aluminum ester products, which create hydrophobicity. In case of dispersed rosin size the reaction of rosin acid and alum does not proceed in solution, but occur on the fibre surface in the drying section. The dispersed rosin size particles are relatively free to migrate during the drying process, throughout the paper web However, as the paper temperature increases on its movement over the drying cylinder, the heat creates a sintering process where the rosin particles melt and distribute uniformly over the surface area of fibre to form the aluminum resinate.

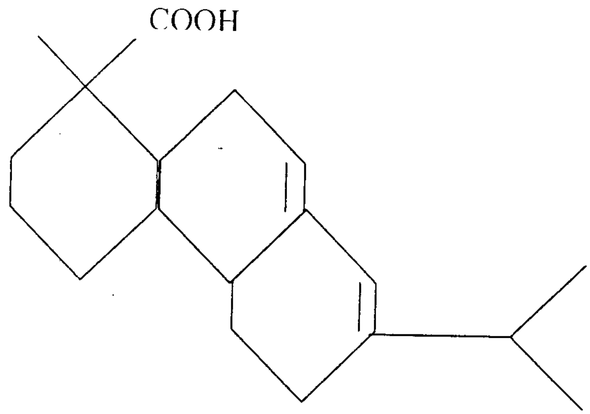
Addition of PAC in place of alum did not show much difference in sizing improvement up to pH value of 6.0, at pH higher than 6.0 PAC showed better effect indicating that addition of PAC will be required at higher pH. Different modes of addition of alum and PAC play an important role on the sizing efficiency especially at neutral pH. Two modes of mixing were tried. One seperate i.e. rosin size followed by alum/PAC, another premixing in which alum/PAC was mixed with rosin size and then mixture of these two was added to the thick stock. An improvement in the Cobb value was observed, when rosin size and alum/PAC were premixed (Fig 8.). Premixing allows interaction in an environment where the cationic charges of alum/PAC are higher than it would be in the elevated pH stock. Hence, a higher degree of reactively is achieved with available rosin leading to increased retention and sizing. Also premixing allows the formation of discrete aluminum/size particles immediately in presence of fiber and minimized any opportunity for polycation or cat ion to interface.

5.0 CONCLUSIONS

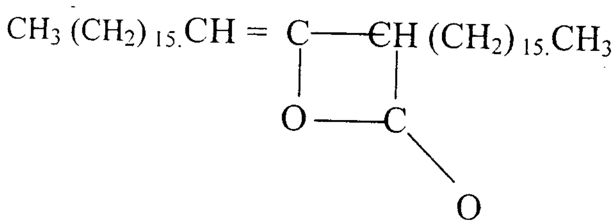
1. Agricultural residues pulp can be sized at neutral/alkaline pH by using ASA, AKD sizes. However AKD, ASA, formulations should be specific keeping in view relatively higher negative fibre charge as compared to other paper making fibers.

2. Dispersed rosin with alum and PAC may be the better option for neutral papermaking from agricultural residues pulp followed by reactive sized.

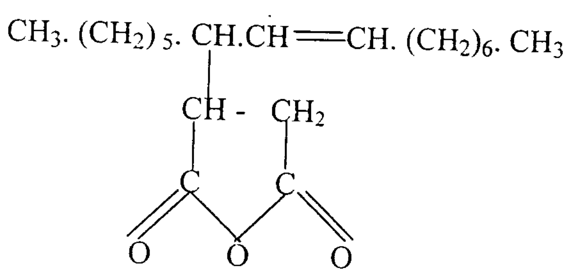
3. Premixing of dispersed rosin with alum/PAC prior to addition to the stock gave better sizing than seperate addition.



Rosin (Abietic acid)



Alkyl Ketene Dimer (AKD)



Alkenyl Succinic Anhydride (ASA)

Fig.1 Chemical Structure of Different Sizing Agents

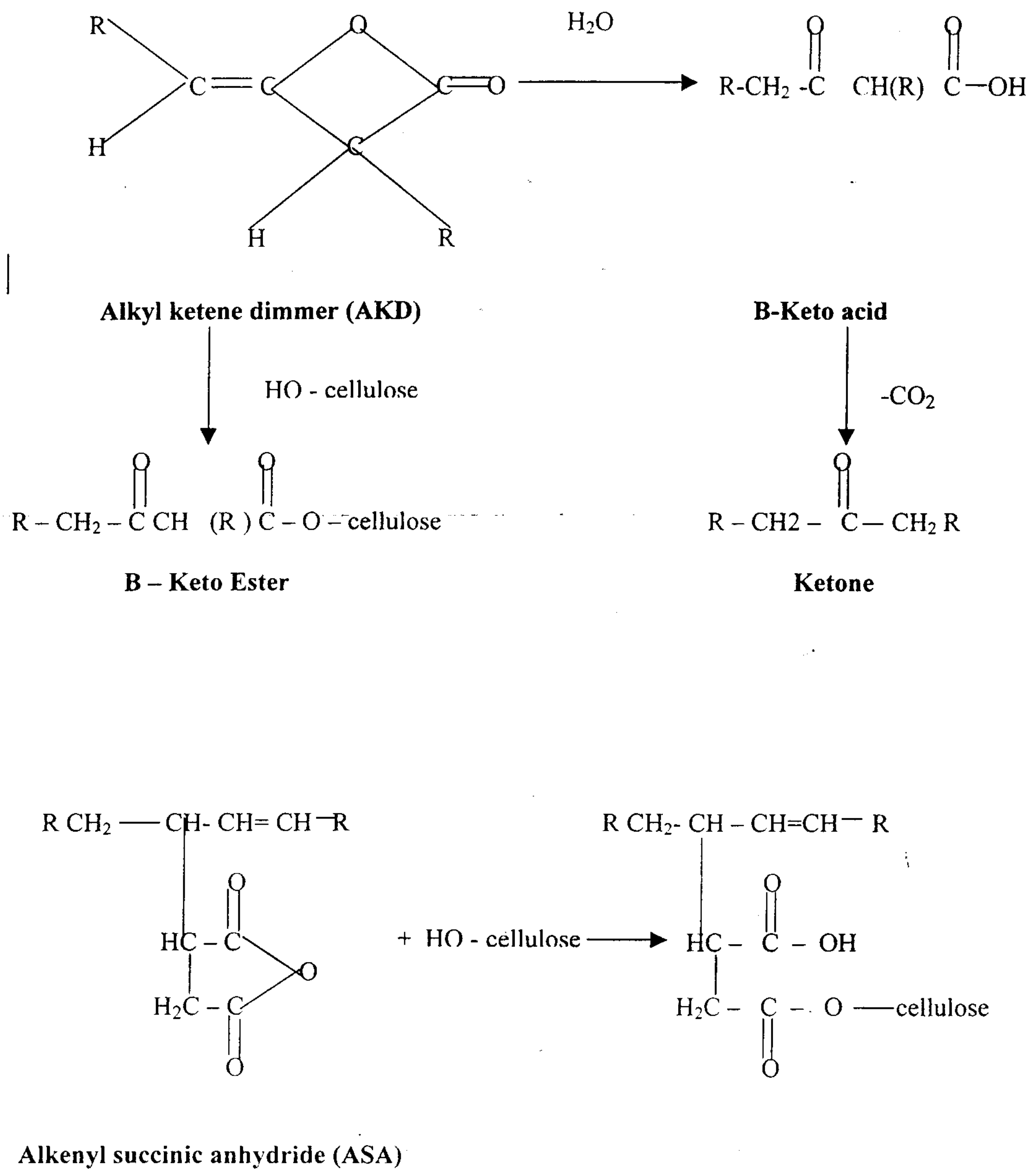


Fig.2 Mechanism of reaction of AKD and ASA with cellulose

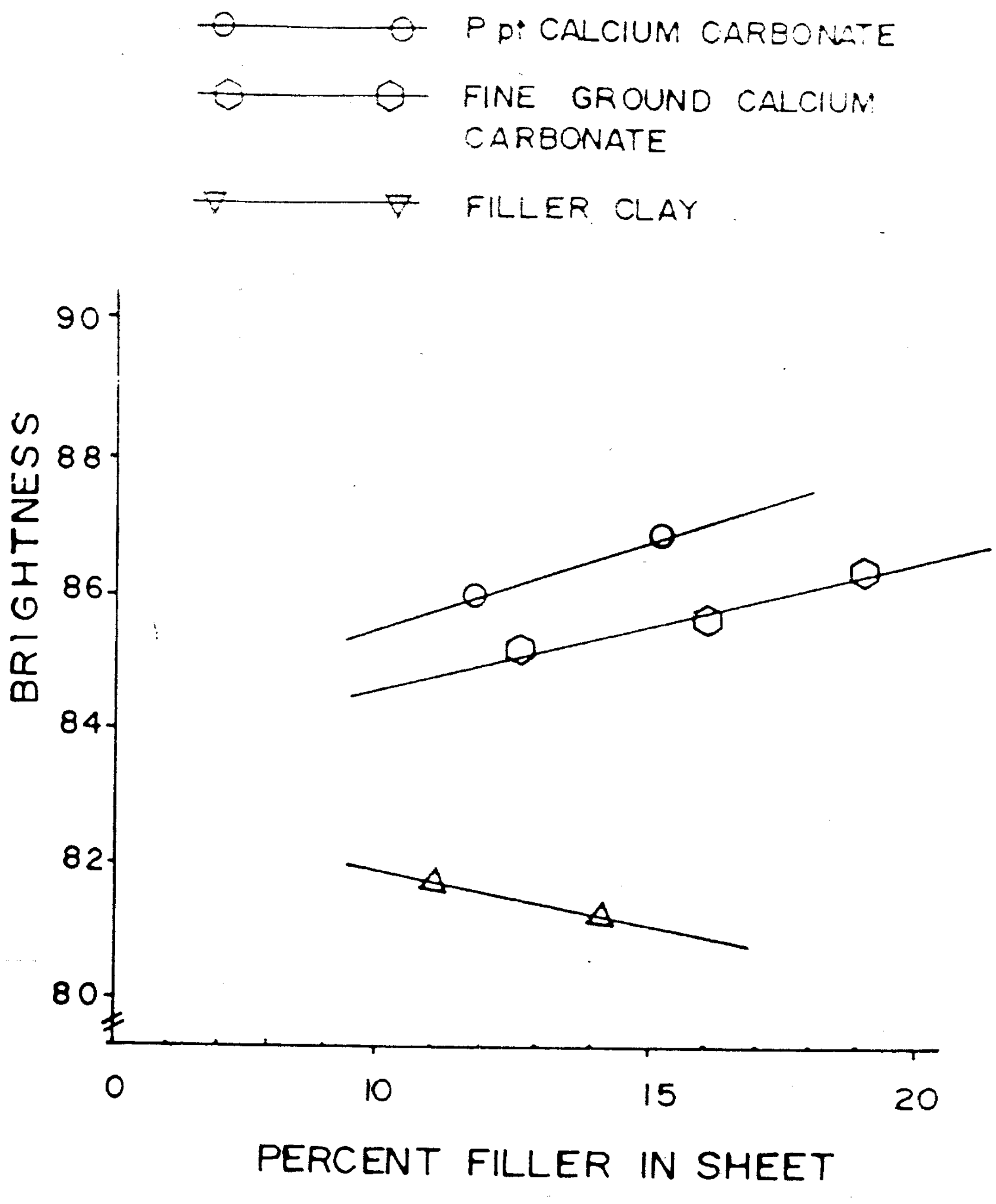


FIG.3, BRIGHTNESS Vs LOADING WITH CLAY & CALCIUM CARBONATE

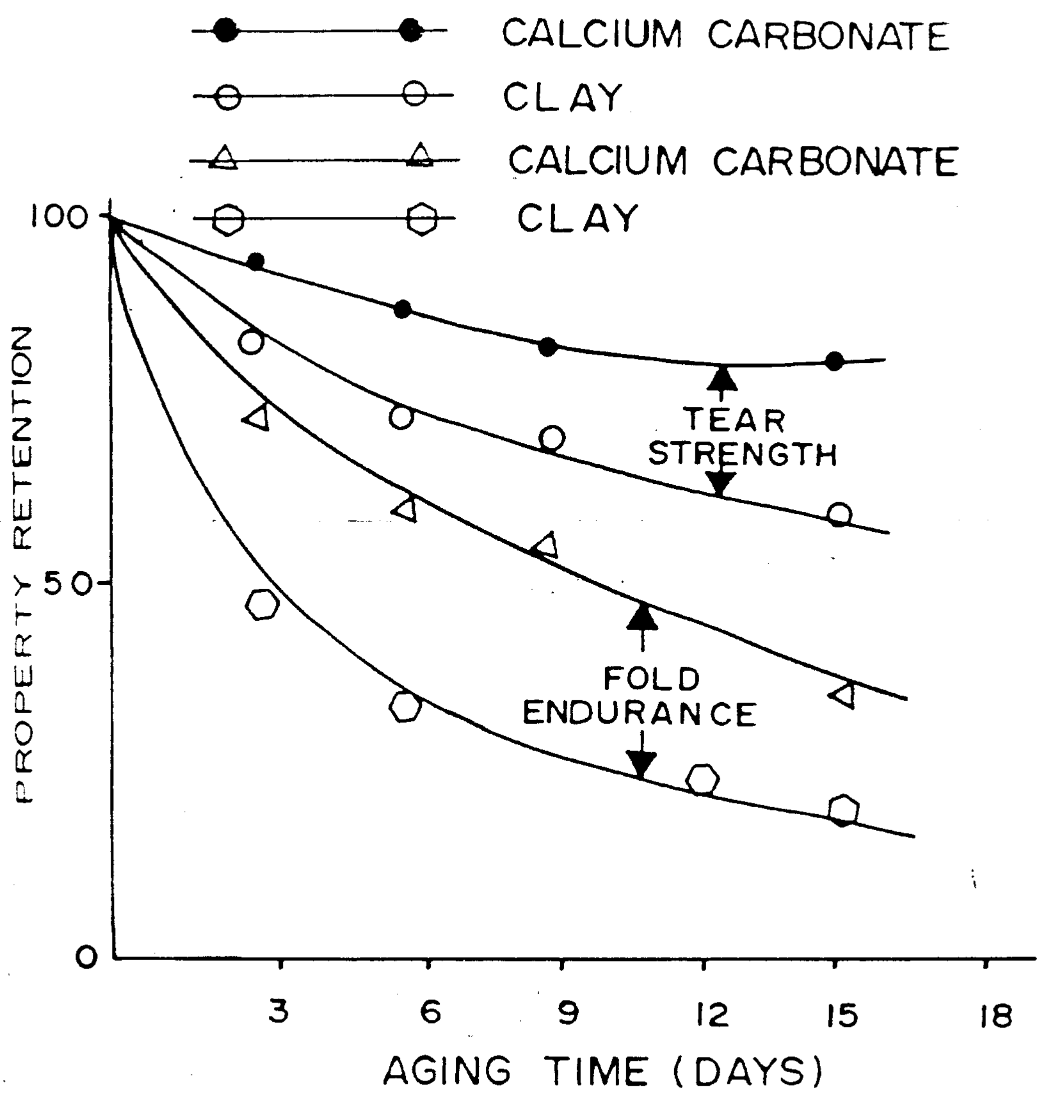


FIG.4, ACCELERATED AGING OF PRINTING PAPERS MADE UNDEF ACIDIC & ALKALINE CONDITIONS.

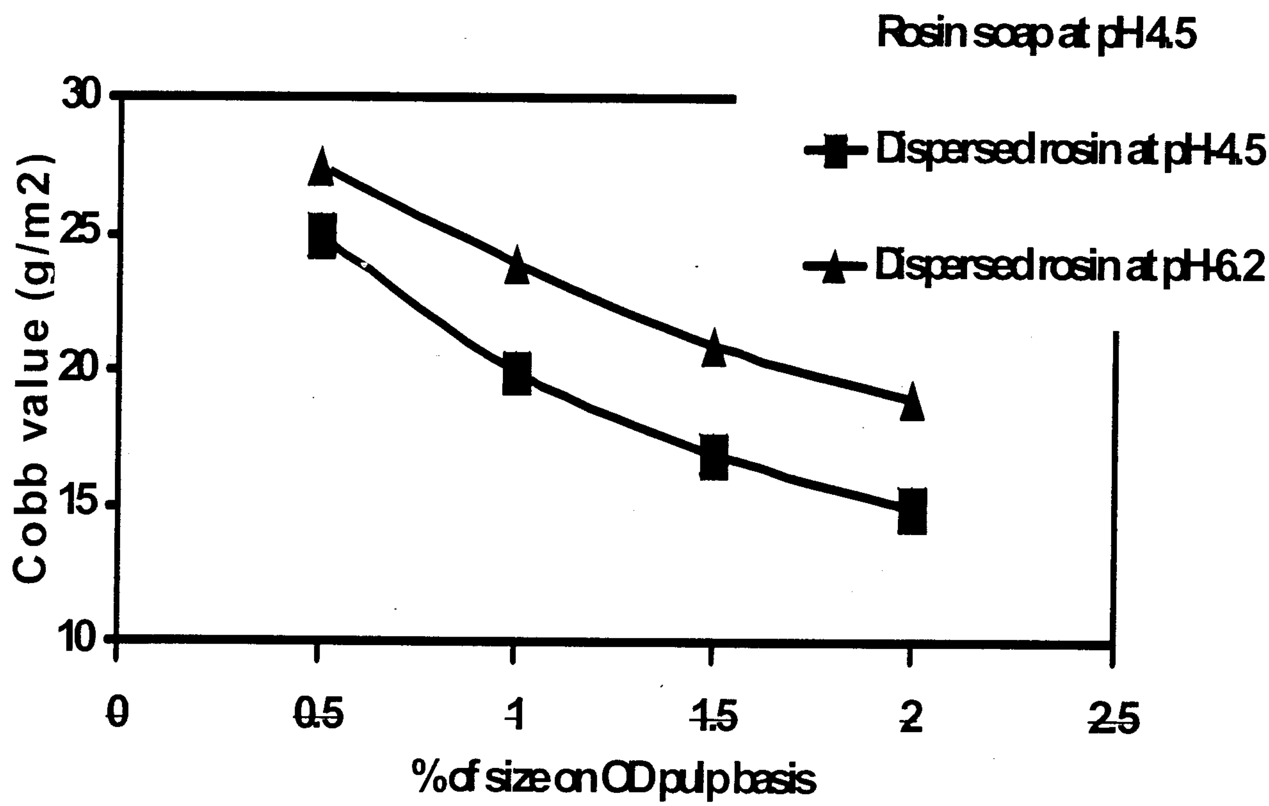


FIG. 5 EFFECT OF SIZE DOSAGE ON SIZING ON COBB60 VALUE AT DIFFERENT pH

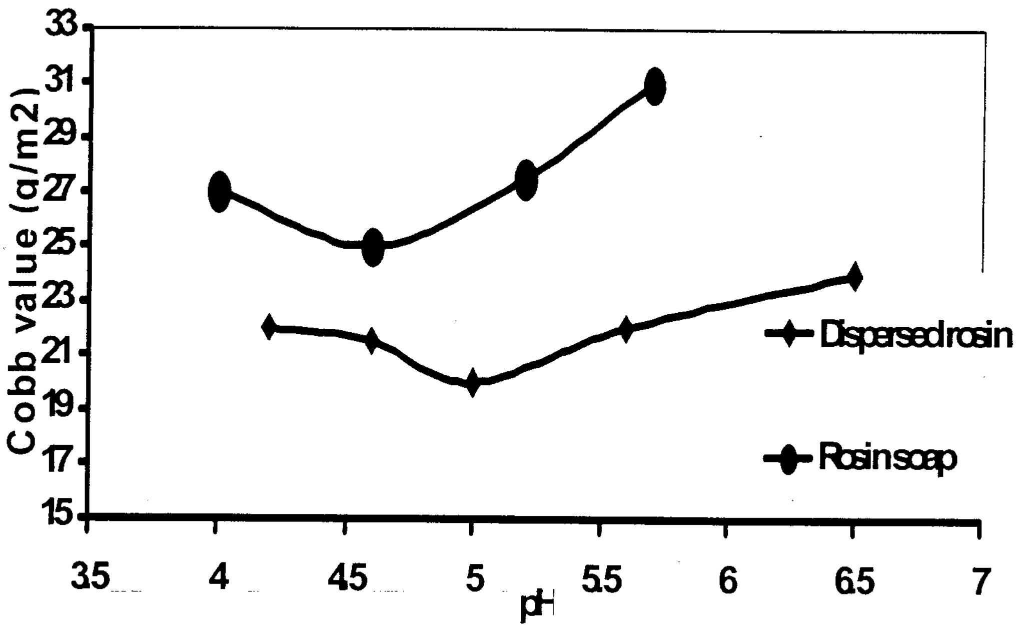


FIG.-6 EFFECT OF pH ON SIZING WITH ROSIN SOAP AND DISPERSED ROSIN

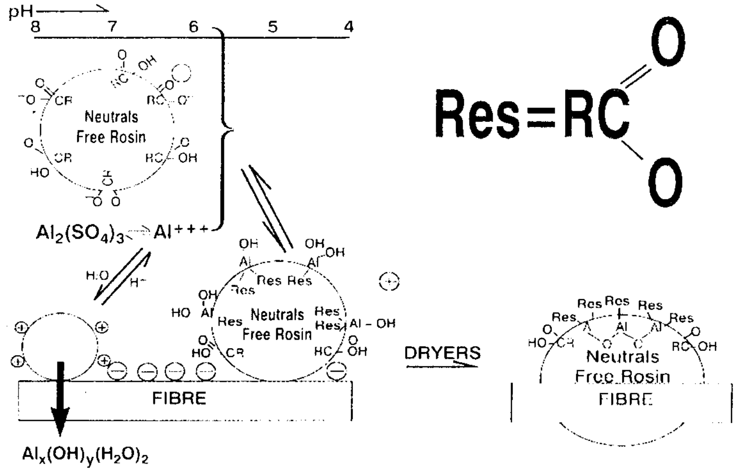


FIG 7: MECHANISM OF SIZING WITH DISPERSED ROSIN/PAC OR ALUM

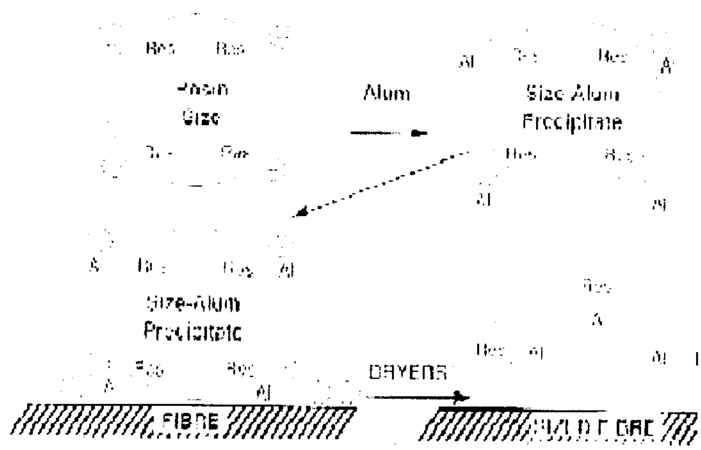


FIG.-8 : MECHANISM OF SIZING WITH ROSIN AND ALUM

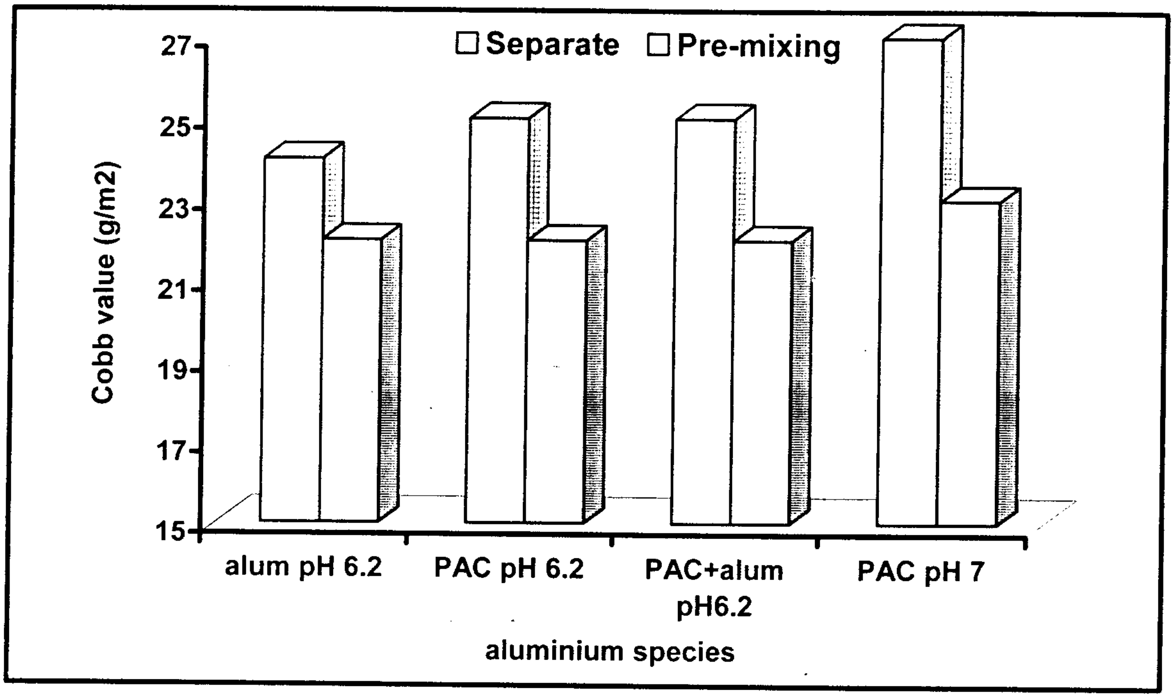
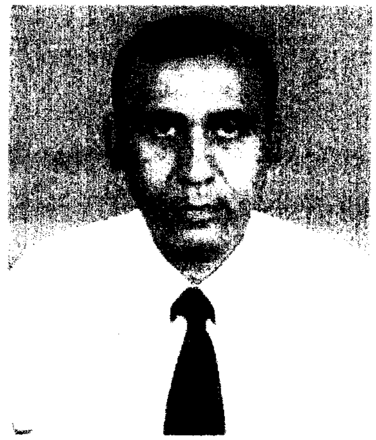


FIG.-9 : EFFECT OF MODE OF ADDITION ON COBB VALUE

BLACK LIQUOR CHARACTERISTICS & CHEMICAL RECOVERY

NON-WOOD BLACK LIQUOR CHARACTERISTICS OF MAJOR AGRO RESIDUES



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About The Author

Dr. R.M. Mathur, is presently working as Scientist E-II and Head, Chemical Recovery, Energy Management, Environmental Management and Biotechnology Division.

After completing his D. Phil in Pulp Chemistry, joined CPPRI, in 1978. He has more than 100 publications to his credit. Area of specialization includes Black liquor properties, Lignin byproducts, Energy Conservation in Paper Industry and Biotechnological applications.

He has widely traveled abroad as UNIDO fellow to Canada, France, Germany, Australia & Japan and been to Turkey & Thailand for Demonstration of Desilication Technology developed by CPPRI. He has four patents to his credit.

NATURE OF BLACK LIQUORS FROM WOOD AND NON-WOOD RAW MATERIALS & RELATED PROBLEMS

Dr. R.M.Mathur & Dr. A.K.Dixit

1.0 GENERAL CHARACTERISTICS OF BLACK LIQUOR

The properties of black liquors are important parameters in the design and performance of chemical recovery unit operations. Black liquor properties depend on the raw material, the pulping conditions, the equipment used for pulping and the treatment of the black liquor after pulping. The major variables in the conditions are the concentrations of the different chemicals in the cooking liquor, the chemical charge on the raw material, the cooking temperature and the length of the cook. Black liquor properties are not constant. They change as the liquor flows from digesters, pulp washing, evaporation and storage.

Rheological and combustion properties of black liquor are two important parameters governing the behavior of the liquor during chemical recovery unit operations. These parameters are significantly influenced by the chemical composition of the black liquors. The following factors are responsible in general for poor liquor performance in the chemical recovery section:

- Lower weak black liquor solids concentration.
- Higher quantities of inert materials like silica and other non-process elements like potassium and chlorides.
- Poor flow behavior resulting in higher black liquor viscosity.
- Poor combustion behavior due to poorly dispersed macro-molecular structure of the organic molecules.

Due to these, significant changes are observed in nature of black liquor from wood, bamboo &agro based raw materials. Utilizing the well equipped laboratory facilities of CPPRI, We could successfully explore the reasons for indifferent liquor behavior in black liquors.

High inert like silica and its compounds, higher suspended matter and also higher proportions of hemicelluloses-lignin complexes are found to be the major reasons of poor black liquor behavior of agro based liquors during chemical recovery operations, which makes handling of these liquors more difficult process in comparison to wood black liquors.

In order to overcome some of the above mentioned problems of agro based black liquors, CPPRI successfully came out with Desilication technology to control the problems of evaporator scaling, poor black liquor combustion and lime sludge settling rates commonly encountered in silica rich black liquors.

Further to improve the black liquor flow behavior in terms of viscosity reduction, black liquor thermal treatment technology especially for bagasse liquors having high viscosities has been successfully tried on pilot plant scale commissioned at CPPRI.

2.0 BLACK LIQUOR COMPOSITION

Efficient and continuous operation of heat exchangers, evaporators and recovery furnace is largely influenced by the Physico–chemical properties of spent liquors. Analysis of black liquor is very important and a great deal of efforts has been devoted to improvements of methods suitable for wood and non-wood black liquors and soda kraft liquors. **Table-1** shows the typical proximate analysis of wood and non-wood black liquors.

TABLE –1

PROXIMATE CHEMICAL COMPOSITION OF BLACK LIQUORS

Particulars	Wood Black Liquor (Kraft)	Agro Residue Black Liquor (Soda)
Raw material:		
Ash, %w/w	0.2-0.5	5-18
Lignin, %w/w	25-32	15-25
Black Liquor:		
Organics, %w/w	64-70	68-72
Inorganic, %w/w	30-36	28-32
Organic constituents:		
Lignin		
-HMW, %W/W	25	20
-LMW, 5W/W	15	15
Organics acids, %w/w	15-20	10-15
Hemicelluloses, %w/w	1-2	7-17
Process & Non-Process Elements:		
Sodium, %w/w as Na	19-21	13-19
Silica, %w/w	0.2-0.8	3-15
Chlorides, %w/w as Cl	0.1-1.0	1-2.0
Potassium, %w/w as K	1.0-3.5	2.0-4.0

Physico-chemical properties of the black liquors have pronounced influence on the efficiency of the chemical recovery systems. Black liquor properties like viscosity, boiling point elevation, heating value and swelling volume index are significantly influenced by the physico-chemical composition of the black liquor properties and presents typical data for each.

3.0 BLACK LIQUOR VISCOSITY-RHEOLOGICAL PROPERTY

Viscosity is the physical property of a fluid that resist flow. In liquid ,it is the measure of internal friction of the liquid in motion.

$$\text{Viscosity, } \eta = \frac{\text{Shear stress}}{\text{Shear rate}} = \frac{1}{D}$$

Substances differ not only in viscosity, but also in their general flow behavior due to their varying chemical structure. Based on the viscometric flow behavior, the liquids can broadly be classified as –Newtonian liquids and non-Newtonian liquid. Most common fluids such as shear water have viscosities, which are not effected by the flow conditions such as shear rate. These fluids are referred to as Newtonian fluids. Black liquors like many other polymers melts and solution is non-Newtonian under certain conditions and specially at higher solids concentrations. Agro based black liquors start showing a non-Newtonian behavior at low solid concentration in concentration in contrast to bamboo and wood black liquors, which show a non-Newtonian tendency at considerable higher solids concentration.

Viscosity of black liquor changes the most with composition, temperature and pulp mill operating practices. The viscosity of black liquor is the most important variable because of its impact on evaporation rate heat transfer rate decreases as the viscosity increases. Following equation shows the approximate relationship.

$$q = \frac{1}{\mu^{0.4}}$$

Where q is the rate of heat transfer and μ is the viscosity.

Wood black liquors have shown that a decrease in viscosity by a factor of 10 can increase the evaporator capacity by 1.5-2.0 times. Similarly, an increase in viscosity by a factor of 10 halves the capacity .The effect of viscosity on evaporator capacity is greater at higher viscosities.

3.1 Factors determining black liquor viscosity

Viscosity is very strongly affected by both, the liquor dry solids content and temperature. The nature of the organics, its molecular weight and colloidal state are important factors in determining the viscosity of particular liquor. Fig-2 shows the viscosity values of wood, bamboo and agricultural raw materials, which show significant variations in the flow behavior. These are affected by:

- Kind of raw material used
- Type of pulping conditions
- Processing conditions of washing

Similarly, processing conditions also significantly affect the liquor flow behavior, so that the liquor samples from two mills at two different times can have viscosities different at the same conditions of dry solids content and temperature. The solids content and temperature of the black liquor affect viscosity. The phenomenon is similar in both wood and non-wood black liquors.

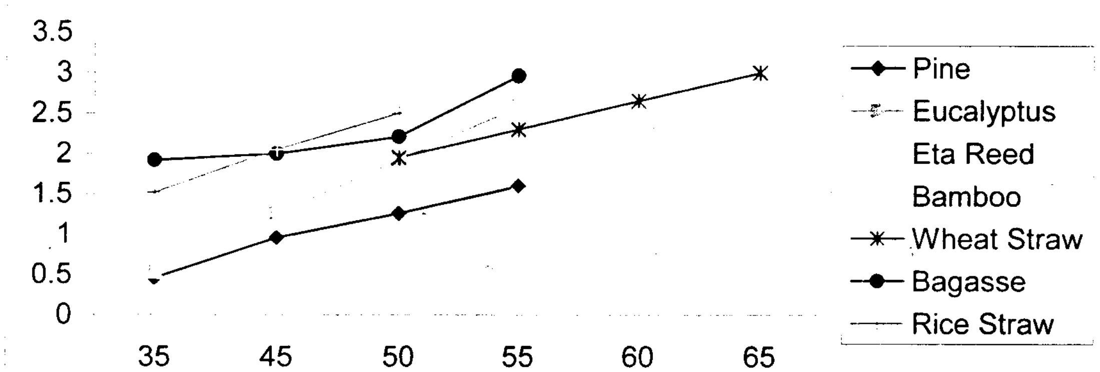

FIG-2 RHEOLOGICAL BEHAVIOR OF WOOD & NON WOOD BLACK LIQUORS

The strong impact of alkali concentration on the black liquor viscosity is the quite evident from our earlier studies. To avoid high viscosity of black liquors in the evaporators during concentration and lignin precipitation, the Residual Active Alkali (RAA) concentration should be at least 4-5% as Na_2O based on black liquor solids.

RAA concentration below 4% as Na_2O may affect viscosity. However, the RAA level beyond a certain optimized value in a particular black liquor will also adversely affect the rheological properties of black liquor.

These are general guidelines based on experience. The concentrations may be higher for hardwoods and bamboo in comparison to agro based liquors. For safe operation, they should be checked for the specific liquor.

4.0 BOILING POINT RISE (BPR)

The temperature, where black liquor evaporation occurs is higher than the evaporation temperature of water at the same pressure. As black liquor dry solids increases, this difference between black liquors and water boiling temperature increases.

Boiling point elevation impacts evaporation capacity by decreasing the effective thermal driving force as shown in the following equation. Evaporation capacity decreases as the sum of the boiling point elevation for all effects increases.

$\Delta T = T_{Stm} - T_{VH} - \Sigma$ (BPR), where ΔT is the difference in temperature, T STM & T VH refer to steam and vapor temperatures and Σ (BPR) is the sum of the boiling point elevation in different effects.

4.1 Process parameters controlling boiling point rise

The inorganic content of black liquor determines its boiling point elevation, factors which control the ratio of inorganic to organics also control the BPR. At higher solids concentrations, the organic components also start influencing the BPR. **Table –2** shows the boiling point rise for wood and bagasse black liquors.

TABLE-2

TRENDS IN TOTAL SOLIDS IN WOOD AND NON-WOOD BLACK LIQUORS

Total Solids, % w/w	Boiling Point Rise	
	Wood Black Liquor	Bagasse Black Liquor
15	1.98	0.7
20	5.0	2.0
30	8.5	4.6
40	10.2	6.4
50	11.5	8.0
60	13.5	9.4

Wood black liquors show higher BPR values in comparison to bagasse black liquors as they are cooked with higher chemical charge.

5.0 BLACK LIQUOR HEATING VALUE

The heating value of the black liquor is a measure of its performance as a fuel. It has a large impact on steam generation rate and the pulp production that a recovery boiler can support. The following formula can roughly estimate the heating value with a known carbon content.

$$HHV=29.35(C)+3.959\pm0.42$$

Where "C" is the carbon content of the black liquor dry solids, kg C/kg dry solids. The values vary within the ± 0.42 MJ/kg dry solids.

6.0 SWELLING VOLUME RATIO

It is an empirical method to assess the burning characteristics of the black liquor. The swelling process is similar to cooking of the coal. Swelling of the black liquor is the second stage of black liquor combustion stage in the recovery boiler after drying. The swelling is invariably related to:

- Thermo-plasticity of organic matter in black liquors.
- Liquor composition variables
- Amount of dead load inorganic like silica & chlorides or
- Furnace variables such as furnace temperature, heat flux and gas composition.

The swelling index clearly defines the burning behavior of black liquor and is a supporting base for gross heating value in predicting the burning behavior of the black liquor as heating value only provides the thermal energy balance, but does not give any idea on the burning behavior of the black liquor. Table-3 provides the relative GCV values and the swelling volume ratio for wood and non-wood black liquors. These results clearly indicates, that liquor having similar fuel value show wide variations in the swelling behavior essentially due to factors as mentioned above. Swelling of the black liquor droplet during firing in to the recovery furnace determines how the liquor will behave during combustion. Higher swelling is an indication of better combustibility.

Black Liquor Sources	Gross Calorific Value, Cal/g	Swelling Volume Ratio, ml/gm
Wood	3400	25
Bamboo	3300	35
Wheat Straw	3500	11
Bagasse	3350	12
Rice Straw	2900	9

The liquor composition is clearly an important variable. Studies on the effects of liquor composition on swelling have identified the lignin to carbohydrates ratio and Ph as the major factor and inorganic content as significant contributor. The liquor which have shown to swell greatly, yielding chars with large pores showed the swelling tendency to have been decreased by high amounts of dead load inorganic.

7.0 CONCLUSIONS

1. Nature of non-wood black liquor is different as compared to wood black liquor.

2. Non- process element content in Agro residue black liquor is higher.

3. Swelling volume ratio is lower in case of non-wood black liquor. This shows its poor burning behavior.

4. Viscosity of bagasse black liquor is higher due to lignin – carbohydrate complexes. By thermal treatment of black liquor we can reduce the viscosity of bagasse black liquor.

5. Silica is the major problem in non-wood black liquor. CPPRI has developed a Desilication technology for removal of silica. More than 90% Desilication is achieved.

6. The Desilication technology developed by CPPRI has been successfully demonstrated on commercial scale in a reeds based mill.

7. The technology has been successfully evaluated on various agro based black liquor and more than 80% Desilication is achieved.

A NON CONVENTIONAL CHEMICAL RECOVERY INSTALLATION IN SHREYANS INDUSTRIES LTD - A CASE STUDY 1995-96

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Worked in J.K. Paper Mill's Pulp & paper research Institute, Jaykaypur and Star Paper Mills Ltd., Saharanpur . Published about 50 research papers in various National & International journals. He has worked in various fields such as R&D , P&D , Quality , Customer Services , ISO, Water Management , Environmental Control and Chemical recovery.

Presently working in Shreyans Industries Ltd., Ahmedgarh as Dy. G.M. and is responsible for Chemical Recovery , R&D , Quality Control and Environment.

A NON-CONVENTIONAL CHEMICAL RECOVERY INSTALLATION IN SHREYANS INDUSTRIES LIMITED A CASE STUDY (1995-96)

K.N.Tiwary

1.0 INTRODCUTION

1.1 SHREYANS EXPERIENCE

It has taken a lot of courage, patience and determination on the part of Shreyans to overcome a number of hurdles and teething problems. When we installed this Reactor only bagasse black liquor was used. Other raw materials like wheat straw etc due to high Chloride contents resulted in defluidization of the Reactor bed within few hours of operation. Since 100% bagasse pulping did not suit us,a wet cleaning system of raw materials was the remedy observed by an extensive work done in our R&D department. A number of modifications were carried out from time to time, during and after commissioning of FBR to run fluidised bed reactor successfully and smoothly. The experiences gained in operating FBR are described for the benefits of the audience and Those who are in the process of installing or intend to install fluidised bed reactor. Plant was commissioned in March.1996.

2.0 WET CLEANING OF AGRICULTURAL RESIDUES

Wherever the fluidised bed reactors are in operation and running successfully in other parts of the world, they are based on black liquor from bagasse and wood only having low chloride contents.

When fluidised bed reactor was commissioned mixed black liquor from bagasse and wheat straw was used. Sodium Carbonate Pellets of light colour of mostly above 30 mesh were obtained from the FBR, but within a short period, defluidisation of the bed started taking place. This matter was extensively investigated in R&D department of Shreyans and it was found that wheat straw had high chloride contents, as high as 1.8% as NaCl, which had resulted in high chloride contents in black liquor. It is known fact that the chloride and potassium contents bring down eutectic point of sodium carbonate resulting in agglomeration of sodium carbonate pellets, hence defluidisation.

Shreyans is situated in Punjab, where wheat straw is available in abundance and is a natural choice as raw material. Therefore, it became essential to find out the ways and means to make black liquor of wheat straw suitable for fluidised bed reactor. After conducting experiments on wet cleaning it was found that the chloride present in wheat straw is not in bound form and it is water soluble and can be removed substantially by washing wheat straw with fresh water. Based on extensive work carried out in R&D department wet cleaning plant was installed The installation of wet cleaning system proved a turning point which converted this plant to a versatile technology and almost all agro raw materials could be used in any required combination or even 100% usage without any problem .We have conducted plant scale trials even with 100% wheat straw black liquor without any problem in FBR.The plant consists of an inclined belt conveyor for feeding agro residues to hydro-pulper. From hydro-pulper, wet agricultural residues pass through decker/thickner. Where excess water gets removed at the outlet of decker/thickner, more water is added for further washing of wet agro-residues and wet material passes through Aqua separator and finally agricultural residues are squeezed in screw press to get the consistency of outlet material 30 to 40%. It was found that above wet cleaning plant was good enough, when 50-65% wheat straw was used alongwith baagasse, maintaining chloride content in mixed black liquor below 0.7%. As Shreyans intend to use more than 80% wheat straw, addition of one more hydra pulper and thickner was made in series to existing wet cleaning plant in order to process more quantity of wheat straw and to decrease chloride content in the wheat straw.

At present Shreyans does not face any problem of maintaining the desired level of chloride contents in black liquor by using upto 100% wheat straw. Trials of other agro raw materials like sarkanda and rice straw were also undertaken. It was observed that it was possible to maintain chloride content in black liquor within tolerance limits by washing the raw materials in a suitably designed wet end cleaning system. In fact wet end cleaning has made the plant versatile and has made FBR suitable to almost all agro raw materials or any combination thereof. This makes this non-conventional FBR technology, in operation at Shreyans, unique and first in the world.

3.0 MODIFICATIONS CARRIED OUT AT SITE

A number of modifications were carried out from time to time some of which are listed below.

3.1 Injection of Fines and Charcoal

Suitable eductors were designed by providing high-pressure superheated steam. Charcoal feed point was modified to a lower position to avoid overheating of upper bed.

3.2 Addition of one more cooling spray nozzle:

It was found that spray nozzle got chocked and needed replacement during running of the FBR. One additional cooling spray was provided so that nozzle can be changed and cleaned during running of FBR.

3.3 Flue gas passage from FBR to grit cyclone

Square duct flue gas discharge to grit cyclone changed to round duct. The passage chocking and jamming were completely avoided.

3.4 Eductor of grit cyclone changed to screw conveyor

a. Position change
b. Its Refractory removed

3.5 Bypass system added to grit cyclone system

This helps in preventing excessive fines intake to the venturi system thereby ensuring auto combustion when high percentage of fines are present in Sodium Carbonate pellets being discharged from product cooler.

3.6 FBR discharge point raised to 183 cms

Increase in height gave more retention time and bed becomes stable.

3.7 Metering screw

Metering screw was regulated to fixed speed and positioning also changed to the horizontal one to avoid over flowing from metering screw.

3.8 Turbo drive was changed over to Motor Drive

3.9 Height of chimney was increased from 21 M to 26 M

3.10 Multi-effect Evaporator

a. One LTV was added
b. M.S tubing changed with St. steel tubing in IIIrd #
c. Circulation system was removed (90 Kw x 2 =180 KW power saving)
d. Surface condenser recirculation pump removed (150 Kw power saving)
e. Concentrator was modified to LTV

3.11 Causticizing

Plant was operated but discontinued.

4.0 CONCLUSION

Shreyans experience demonstrates that agro based integrated pulp and paper mills can solve the water pollution problem by installing this non-conventional chemical recovery unit.

4.1 FBR is running trouble free and smoothly for the last seven years. Problem of lime sludge solid waste disposal has been completely eliminated. This is a distinct advantage over conventional system.

4.2 All the black liquor generated in pulp mill is consumed (90 TPD paper production) and effluent is free from black liquor and effluent discharged after treatment is at par with other mills having conventional recovery system.

4.3 Presently we are recovering sodium carbonate Pellets the system has the advantage of recovering Soda Ash or Caustic soda. In case caustic soda recovery is intended pallets can be dissolved and be causticized to recover caustic soda. However, to prevent build up of chloride by usage of recovered Alkali a Chloride purging plant from green liquor will have to be installed. Also arrangement to be made for disposal of wet lime sludge.

TABLE – 1

CHLORIDE CONTENT AS NACL IN VARIOUS AGRO CELLULOSIC RAW MATERIALS

Raw Material	Chloride as NaCl	
	%Age	After Wet cleaning %age
Baggase	0.1 To 0.25	-----
Wheat Straw	0.8 To 1.68	Below 0.2
Rice Straw	0.4 To 0.72	Below 0.2
Sarkanda	0.36 To 1.05	Below 0.2

TABLE – 2

A TYPICAL SIEVE ANALYSIS OF PRODUCT DISCHARGE FROM FBR

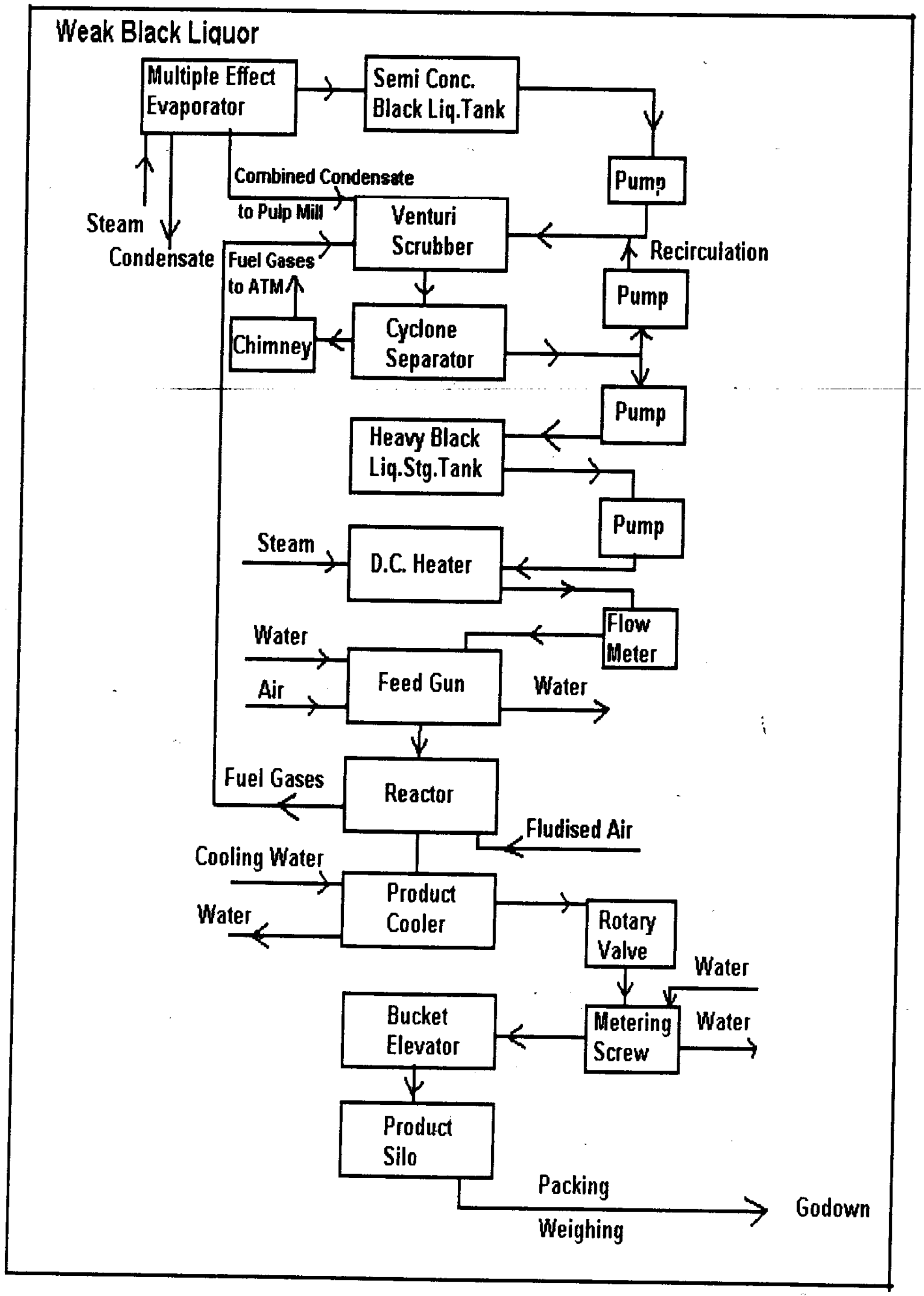
Mesh Size (mm.)	%Age Weight
+ 16	30.10
+ 22	11.30
+ 33	33.30
+ 40	14.70
+ 50	7.30
Fines	3.30

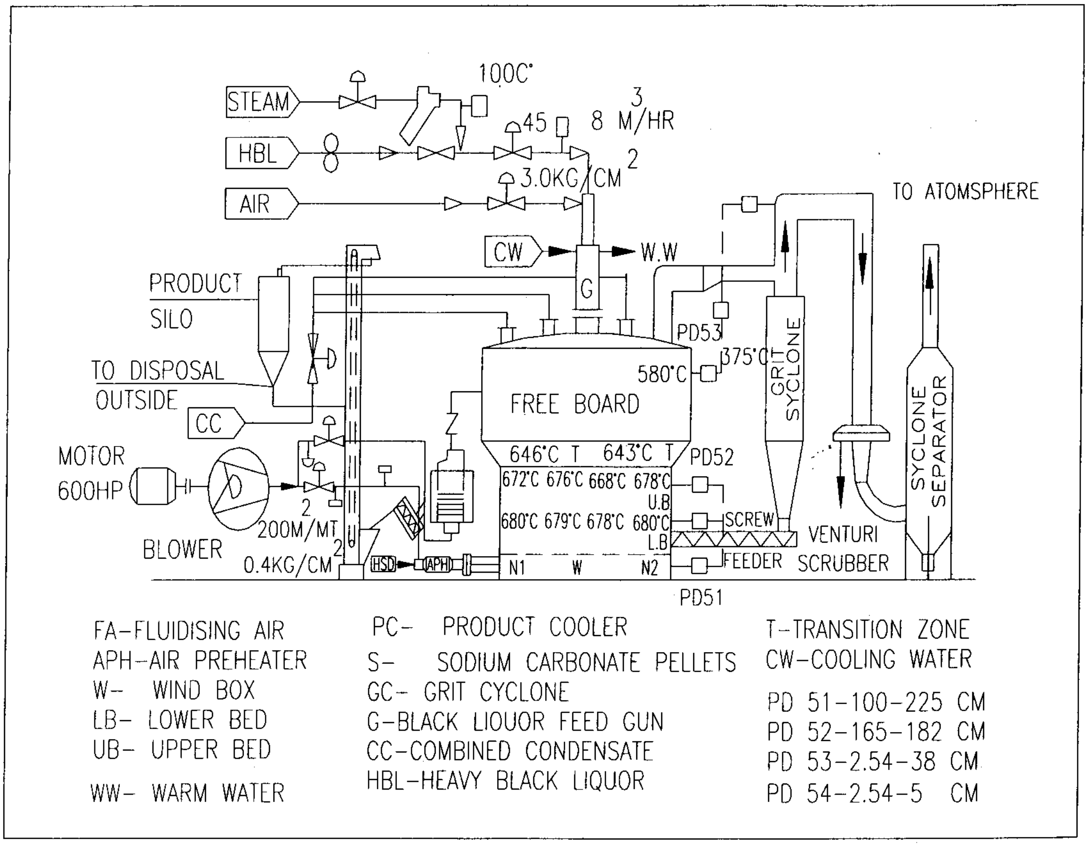
TABLE – 3

ANALYSIS OF SODIUM CARBONATE PELLETS OBTAINED FROM FBR

Chemical	Sodium Carbonate pellets Obtained From	
	Black Liquor	Mixed black liquor of wheat straw & baggasse
Volatile matters %	0.4	0.3
Total alkalinity as Na2Co3 %	94-96	90-93.4
Chloride as Nacl %	0.6	0.8
Iron as Fe %	0.1	Traces
Sulphate as Na2So4 %	0.8	0.75
Insoluble matters Which is more than 90% Silica %	2.6	4.8-6.5

BLOCK DIAGRAM OF F.B.R. SODA RECOVERY SYSTEM





FLUDISED BED REACTOR TEMPRATURE FLOW AND PRESSURE AT VARIOUS ZONES

BUILD UP OF NON PROCESS ELEMENTS IN AN AGRO BASED MILL AND THEIR IMPACT ON CHEMICAL RECOVERY OPERATIONS

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About the Author

Mr. A. K. Dixit, Scientist CPPRI, has nearly 12 years of Resource & Development experience in the area of Pulp and Paper. He holds a master degree in chemistry and recently completed his Ph. D. thesis in the area of black liquor desalination. He has done research work in the area of black liquor processing, Lignin removed for black liquor, alternative chemical recovery process and thermal treatment of black liquor. He has published more than 20 scientific papers on the area of pulp & paper. He has visited Turkey and Thailand for research trials.

BUILD UP OF NON PROCESS ELEMENTS IN AN AGRO BASED MILL AND THEIR IMPACT ON CHEMICAL RECOVERY OPERATION

A.K.Dixit & Neelam Devi

1.0 INTRODUCTION

Product quality standards as well as environmental and economic factors are increasing the interest in progressing towards low effluent, closed cycle operation in pulp and paper mill. For system closure to be realized, several problems need to be addressed (*1*). This includes chemical imbalance and build up of non-process elements such as Chlorides, Potassium, silica etc. in chemical recovery cycle. Accumulation of non-process elements (NPE's) is widely recognized as the major limitation to increased mill closure. High levels of the chloride and potassium impurities in kraft black liquors are known to accelerate recovery boiler plugging. As mills move towards higher levels of closure the current outlets for these elements are reduced. This will result in even higher chloride and potassium concentration in kraft recovery cycle. Therefore to reduce production losses due to boiler shut down control of these elements is necessary.

It is therefore necessary to critically evaluate the source and effect of non-process elements on various recovery operations and the possible methods to reduce NPE levels in recovery loop. When the NPE input is significant, their build up in the recovery cycle is very rapid and can cause severe damage to process equipment by way of plugging of flue gas passages through massive deposits. Due to a lack of adequate information, the manufacturers of recovery units do not often attach much importance to NPEs. It is therefore essential that when designing the recovery equipment, serious consideration should be given to the effects of non-process elements.

The present paper quantifies the levels of non-process elements in Indian non-wood and wood raw materials. Black liquor characterization studies show build up of these NPEs with time. Further analysis conducted on characteristics of scales & deposits formed during the chemical recovery operation highlights the need to restrict the entry of non -process elements into chemical recovery cycle.

2.0 MATERIALS AND METHODS

2.1 Analysis of Black Liquor

Tappi method T-625 CM-85 was used for analysis of black liquor.

2.1.1 Potassium and Calcium estimation

Potassium and calcium were extracted from the raw material, evaporator and boiler deposits, by acid leaching and were determined directly in black liquor using atomic absorption spectrophotometer and flame photometer.

2.1.2 Chloride estimation

A standard argentometric titration method was used for chloride estimation. Before estimating the chlorides in raw material and boiler deposits, all chloride salts were converted to their stable salts, so that chlorides are not volatilized on ignition, as it is essential to obtain a clear solution of chlorides for argentometric titration. This was achieved by treating the raw material with NaOH then ash at 500^0C. The ash was then boiled with water & filtered.

2.1.3 Estimation of Thermal properties of Black Liquor ash and Boiler Deposits

For cone slumping tests, the ASTM D 1857 cone test method was applied. Powdered black liquor and slag/boiler deposit samples were formed into a small cone. The cone was heated slowly at a heating rate of 10^0 C/min. and following physical changes were observed.

a) Sticky Temperature

The temperature at which the cone starts sweating due to the appearance of liquid in the sample.

b) Radical deformation point/smelt formation temperature

The temperature above which, the amount of liquid phase is sufficient, for the cone to start changing shape.

c) Smelting Temperature

The temperature at which, the cone is completely molten and loses its shape.

3.0 RESULTS AND DISCUSSIONS

3.1 Levels of Non Process Elements in Cellulosic Raw Materials

Non-process elements are the elements other than those elements that are normally part of pulping and recovery cycle, such as sodium, sulfur, carbon, hydrogen and oxygen. Silica, potassium, chlorides and calcium are non-process elements. Various raw materials used by Indian paper industry were analyzed for NPEs content. Results are depicted in **Table-1 & 2.**

TABLE - 1

LEVELS OF NON PROCESS ELEMENTS IN DIFFERENT CELLULOSIC RAW MATERIALS

Name of NPE	Bagasse	Wheat Straw	Rice Straw	Bamboo	Hardwood
Silica, %w/w	1.7	5.1	10.9	1.5	0.1
Calcium, %w/w	0.1	0.1	0.1	0.08	0.1
Potassium, %w/w	0.2	1.2	1.7	0.1	0.1
Chlorides, %w/w	<0.1	0.9	0.90	<0.1	<0.1

*Results are expressed as percent O.D by mass.

TABLE - 2

LEVELS OF NON-PROCESS ELEMENTS IN DIFFERENT HARDWOODS

Name of NPE	Casurina	Cashew	Poplar	Saubabool	Eucalyptus
Silica, %w/w	0.06	0.03	0.03	0.02	0.08
Calcium, %w/w	0.1	0.2	0.02	0.2	0.07
Potassium, %w/w	0.11	0.26	0.2	0.25	0.27
Chlorides, %w/w	0.03	0.03	0.02	0.04	0.02

The results show that NPE content varies significantly in different raw materials. The quantity of ash varies 2 to 17 % in non-woods though it is quite low in hardwoods. Silica content ranges from 2 to 11 % in non-woods while in hardwoods it is only 0.1%. Potassium, calcium and chlorides contents also show the same trend, higher in non-woods and around 0.1 to 0.2 in hardwoods. Quantity of calcium in raw materials is insignificant but it finds entry through process water and white liquor. Determination of non-process elements in cellulosic raw materials gives an idea about the source of these elements that enters the chemical recovery loop.

3.2 Black Liquor Characteristics vis – a -vis Chemical recovery Operations

The black liquor properties are important parameters in the design and performance of kraft recovery. Black liquor is a complex mixture of water, inorganic salts and organics and each of these components plays an important role in determining its chemical behavior and properties. Nature and proportion of various components of black liquor ultimately influence the evaporation and combustion during chemical recovery operation. The chemical and thermal recovery efficiency of non-wood black liquor is far from satisfactory as compared to wood black liquor. The primary reason is the nature of black liquor. Table 3 shows the typical comparison of wood and non-wood black liquors. Numerous articles have been published on problems of black liquor handling in chemical recovery operation but not much information is available on their characteristics.

TABLE - 3

EVALUATION OF COMPOSITION OF WOOD AND NON-WOOD BLACK LIQUORS

Parameter	Non-wood black liquor	Wood black liquor
Organics, %w/w	65-70	65-68
Inorganic as NaOH, % w/w	30-35	32-35
Hemicelluloses, % w/w	8-16	1-2
Organic acids, % w/w	10-14	15-20
Lignin, % w/w	32-38	40-42
Silica as SiO_2, % w/w	1.2-10	0.05-0.2
Potassium as K, % w/w	0.4-5.0	0.5-1.5
Chlorides as Cl, % w/w	0.2-2.0	0.1-0.5

The results shown in Table 3 indicate that wood and non-wood black liquors have different composition of important constituents, which determine remarkable difference in their characteristics, and behavior during chemical recovery operation. Non-wood black liquor are characterized by high NPEs content.

3.3 Non–process elements in black liquors

Wood and non-wood black liquors were evaluated for non-process elements. The results are shown in table 4. The results clearly show that non-wood black liquors contains higher proportion of non process elements. Being alkali soluble their level goes on building up with subsequent recovery cycle. Among the non-wood black liquors bagasse black liquor shows less concentration of NPEs.

TABLE - 4

EVALUATION OF NON-PROCESS ELEMENTS IN BLACK LIQUOR

Non-process element	Black Liquor				
	Bagasse	Wheat Straw	Rice Straw	Bamboo	Hardwood
Silica as SiO_2, % w/w	1.6	3.2	7.8	2.4	0.2
Potassium as K, %w/w	0.5	1.8	2.0	0.6	0.5
Chlorides as Cl % W/w	0.2	1.5	2.1	0.5	0.4

3.4 Problems due to potassium and chlorides in recovery boiler operations

Levels of potassium and chloride play a crucial role in the operation of chemical recovery boiler. Both potassium and chloride have a tendency to depress the ash melting temperature The analysis of various black liquor ash sample using cone test method is shown in figure 1.The results clearly indicate that ash melting temperature of straw black liquors is lower as these liquors contain higher amount of chlorides and potassium. Lowering of ash melting temperature leads to accelerated plugging in the recovery furnace and subsequent downtime required for water washing of the boiler (*2*). Due to the deposit formation, the flue gas passages are reduced which causes significant energy loss. The major concern is that these elements are alkali soluble, none of these element is naturally purging and leads build up to relatively high concentration.

3.5 Source of potassium and chlorides in a kraft pulp mill

Potassium and chlorides are alkali soluble ionic elements, which are always present in kraft pulp mill process streams. Chlorides and potassium enters the pulp mill with raw material fed to the digester and to a smaller degree with the water and makeup chemicals. These elements then pass through the system without causing significant problems and leaves the cycle with pulp and spilled liquor etc. In contrast, in pulp mills with higher degree closed water circuits, chlorides and potassium concentrations build up is to higher levels.

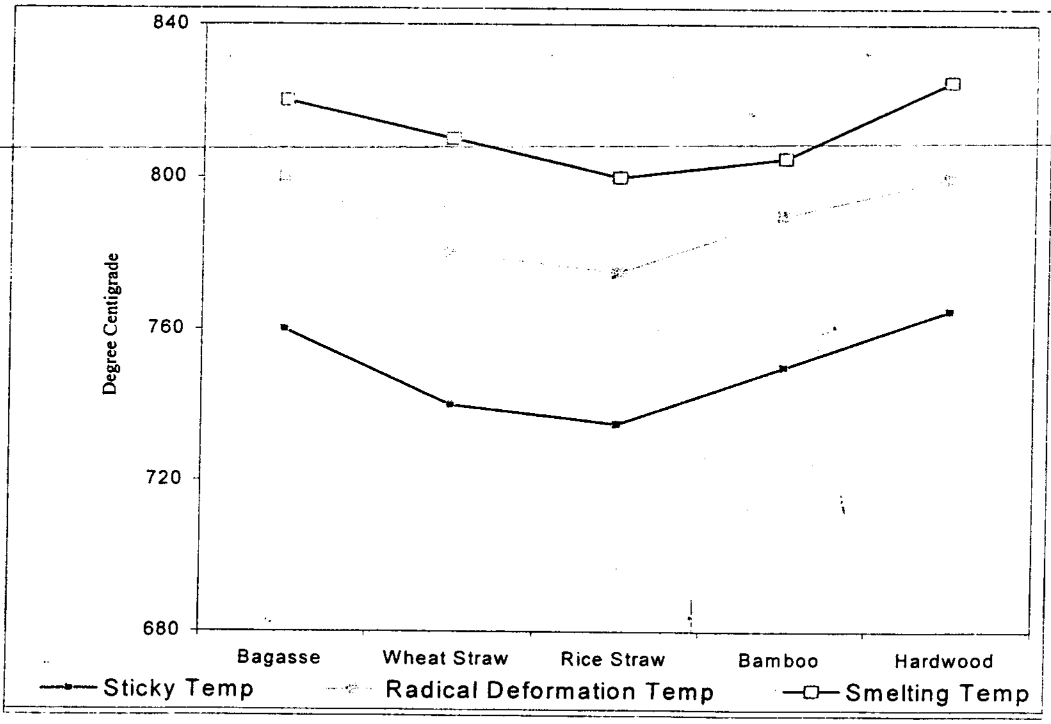


FIGURE 1 QUADRUPLE TEST FOR VARIOUS BLACK LIQUORS

Potassium and chlorides content in wood and non-wood raw material as shown in table 1 varies significantly. Non- raw material contains higher NPEs as compared to wood. In contrast to above black liquor samples collected from various Indian mills based on mixed hardwoods have shown very high levels of chlorides and potassium. Almost every mill based on hardwood is now facing problems in their recovery boiler due to high levels of these non process elements. To see the levels of NPEs in various hardwood with bark and without bark used by Indian paper industry were evaluated for non-process element. The results are shown in table 5.

TABLE - 5

EVALUATION OF VARIOUS TYPES OF HARDWOOD FOR NON-PROCESS ELEMENT

Hardwood	Chlorides, ppm	Potassium, ppm
With Bark Eucalyptus	220	3743
Debarked Eucalyptus.	63	1389
With Bark Subabul.	718	3230
Debarked Subabul.	95	2397
With Bark Casuarina	226	1958
Debarked Casuarina	130	887

The results shown in table 5 indicate that debarked hardwood contains low concentration of potassium and chlorides. This infers that efficient debarking can substantially reduce the entry of non-process elements in pulp mill cycle.

3.6 Build-up of potassium and chlorides in the chemical recovery cycle

Studies have shown that chlorides and potassium are enriched in the fume and consequently in electrostatic precipitator dust. In a kraft recovery boiler, ESP ash is recycled by mixing with heavy black liquor. In this way concentration of these elements goes on building in chemical recovery cycle.

Build up of these NPEs is further confirmed by determining the enrichment factor of potassium and chlorides in black liquor and boiler deposit samples. The results in table 6 show that there is a significant increase in the levels of NPE in the black liquor obtained using recycled white liquor compared to black liquor obtained with freshly prepared white liquor. The enrichment factor (3) is denoted by the molar ratio of potassium and chloride respectively to(Na+K), i.e. K/ (Na+K) and Cl/(Na+K). The increase in concentration of potassium and chlorides confirms their volatile nature and building up mainly through ESP dust recycling.

TABLE - 6

ACCUMULATION OF NON-PROCESS ELEMENTS IN CHEMICAL RECOVERY CYCLE

Parameter	Black liquor from fresh white liquor	Black liquor from recycled white liquor	Boiler Deposits
Silica, % w/w	3.5	3.8	0.8
Potassium, %w/w as K	3.1	4.5	14.2
Chlorides, %w/w as Cl	1.5	1.8	4.8
Cl/(Na+K) mol. %	5.1	5.9	6.7
K/(Na+K) mol. %	9.6	13.4	18.0
Chloride Enrichment Factor	Base	1.16	1.39
Potassium Enrichment Factor	Base	1.31	1.88

The reason for chloride and potassium enrichment is the higher volatility of sodium and potassium chlorides than that of other sodium compounds in the recovery boiler. Boiler operating at higher temperatures tend to have lower potassium enrichment in ESP dust although more potassium is volatilized, the relative content in the fume decreases as the amount of Na compounds increase.

3.7 Removal of Chloride and Potassium

Removal of chloride and potassium has become essential in many of the chemical recovery installation in Indian paper mills. Levels of these NPEs have gone to alarming level in black liquor in many mills and they are exploring solutions for the problem arising due to NPEs. Of various methods that are being employed or proposed, the most common is purging of precipitator dust. As shown above this dust is enriched in chloride and potassium. Therefore, chlorides are also removed by leaching precipitator, dust and discarding the chloride rich liquor. Increasing the liquor sulphidity also helps in reduction of chloride. Higher sulphur in the recovery system leads to higher SO_2 concentration in flue gas, which leads to formation of HCl according to following reactions:

$$2NaCl + SO_2 + ½ O_2 + H_2O \text{ --------- } Na_2SO_4 + 2HCl$$

$$2KCl + SO_2 + ½ O_2 + H_2O \text{ --------- } K_2SO_4 + 2HCl$$

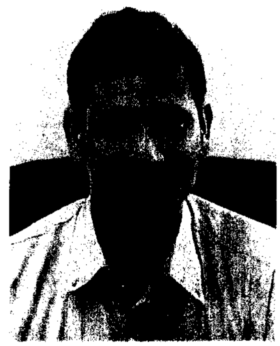
Thus chloride removes from the system by hydrogen chloride.

4.0 CONCLUSION

Presence of high levels of non-process elements in Kraft recovery cycles is a matter of serious concern. Non-wood raw materials are characterized by high level of non-process elements and there is a need to critically evaluate the chemical recovery installations based on these raw materials. Studies carried out have revealed that efficient debarking of hardwood can reduce the problem of non-process elements to some extent. Bark contains higher amounts of potassium and chloride as compared to whole wood. Both potassium and chloride cause problems in chemical recovery boiler. Since chlorides and potassium are enriched in ESP ash and their build up in recovery cycle is mainly through ESP ash re-circulation. Therefore, ESP ash is the appropriate point for reducing the build up of NPEs from recovery cycle. Studies conducted at CPPRI on reduction of potassium and chloride from ESP ash have shown encouraging results.

ENERGY & ENVIRONMENT MANAGEMENT

Energy Conservation Opportunities in Agro Based Paper Mills



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His areas of expertise are Chemical Recovery, Energy Management, Computer Simulation, Energy Audit, Benchmarking, Pinch Technology, Lignin utilization & Byproduct. He has obtained training in the area of Computer Simulation from Czechoslovakia and visited mills in Hungary and Austria. He is credited with 40 research publications in National and International Journals and 20 Technical reports in various fields of pulp & paper.

ENERGY CONSERVATION OPPORTUNITIES IN AGRO BASED PAPER MILLS

Dr. B.P.Thapliyal & Alok Kumar Goel

1.0 INTRODUCTION

The pulp and paper sector is one of the highly energy intensive industrial sectors. Though the paper industry is more than 100 years old in India, still it uses obsolete technologies and is based on diverse raw materials. Till early 70's industry was primarily based upon bamboo and subsequently it switched over to hardwoods like Eucalyptus. In the beginning of the 70's, due to increased demand of paper & board, industry was forced to utilize other resource like agro residues in order to augment shortage and sustained availability of fibrous raw materials.

Presently about 500 paper mills are in existence in India with an installed capacity of about 7.3 million tones per annum but according to an independent survey report, there are as many as 679 mills, represented mostly by small scale mills. At present there are only 23 wood based mills, which account for more than one third production. The next highest production is from recycled fiber based mills. Agro based mills also contribute significantly towards paper production and produce about 27% paper & paper products. Agro based mills are unique with respect to their technological status and play a key role in the production of pulp and paper.

Over the years there is a significant shift towards recycled fiber and most of these mills are changing their raw material furnish from agro residues to waste paper. Since a significant proportion of paper & paper products come from agro residue based mills and their importance cannot be neglected. These mills are mostly among the medium scale mills and do not have the access to latest technological developments and different technological inputs. The complexity of the agro based mills is shown in the Fig. 1, which shows that there are about 7 groups of mills with similarities in raw material, products & processes.

Raw Material: - Agro RCF
Market Pulp
Process: - Chemical Soda
Product: - Bleached
Varieties: -Writing, Printing,
No of Mills – 5

Group - I

Raw Material: - Agro, RCF,
Market Pulp
Process: - Chemical Soda
Product: - Unbleached & Bleached
Varieties: -Kraft Paper, Writing & Printing
No of Mills – 3

Group - II

Raw Material: -Agro, RCF
Process: - Alkaline Sulphite
Product: - Bleached & UnBleached
Varieties: -Writing, Printing & specialty
No of Mills - 1

Group - III

Raw Material: -Agro, RCF, Market -Pulp
Process: - Chemical Soda & Chemi-Mechanical
Product: - Bleached
Varieties: -Writing, Printing & specialty
No of Mills - 1

Group - IV

Raw Material: -Agro, RCF
Process: - chemical Soda & Alkaline sulphite
Product: - Un-Bleached
Varieties: - Kraft Paper
No of Mills - 3

Group - V

Raw Material: -Agro, RCF
Process: - chemical Kraft
Product: - Un-Bleached
Varieties: -Kraft Paper
No of Mills - 2

Group - VI

FIG.1 CATEGORIZATION OF AGRO BASED MILLS INDICATE COMPLEXITY AMONG THE SECTOR

Due to obsolete technology & inadequate process controls the paper from these agro based mills is not very good in quality. Also the cost competitiveness is poor on account of low efficiency of equipment and higher losses. This is very imortant particularly when the mills are facing serious threat from strict legislation and global market with respect to quality & cost effectiveness. Energy is one of the major cost component and accounts upto 25% towards the cost of production. Since a large part of energy is wasted due to lack of energy management practiceses and due to lower energy efficient equivalent as well as lack of process control in manufacturing processes, there is need for making adequate efforts to reduce wasteages in order to make this segment of the industry cost comptitive.

2.0 ENERGY CONSUMPTION PATTERN

There is a wide gap in energy consumption pattern among various agro based mills. They produce different varieties of products using raw material mix.

Study of energy consumption pattern in the agro based mills variation. Fig. 2 (a) and (b) show the power & steam consumption pattern by these mills. This figure shows that the power consumption ranges from 520 to 1215 kWh/t paper & 3.5 to 11.20 t steam/t of paper for producing different grades of paper. Except a few, most of the mills are not closer to the norms set up in 1996 by CII. **Table-1.**

In Fig. – 2 (a) only 2 mills have power consumption in the range of 520 to 716 kWh/t. All other mills have higher energy consumption. The lower energy consumption is mainly due to utilization of recycled fibers by these mills. These mills are using 25 to 26% of waste paper and producing unbleached varieties. In **Fig. – 2** (b) mill No. 4, 5, 11 & 12 are producing bleach and unbleached verities. The RCF utilization is 51 to 73 %. Mill No. 8 & 9 are producing unbleached varieties with 25 to 26% recycled fiber. The energy consumption pattern shows that in agro based mills energy inputs are vary high and non-uniform.

Energy is one of the input, which directly affects the cost competitiveness and the energy consumption pattern of these mills highlights the need for making serious efforts to reduce the energy consumption by these mills in order to have sustainability.

CPPRI has been actively engaged in energy conservation & management activities in agro based pulp and paper industries since 1990. The required infrastructure and facilities have been created for energy auditing in the mills. During last one decade a large number of energy audits have been conducted by CPPRI, energy audit team and useful recommendations were submitted for achieving energy conservation targets.

In this presentation major findings of the energy audits studies conducted in agro-based mills are presented to highlight the energy saving potential in agro-based mills.

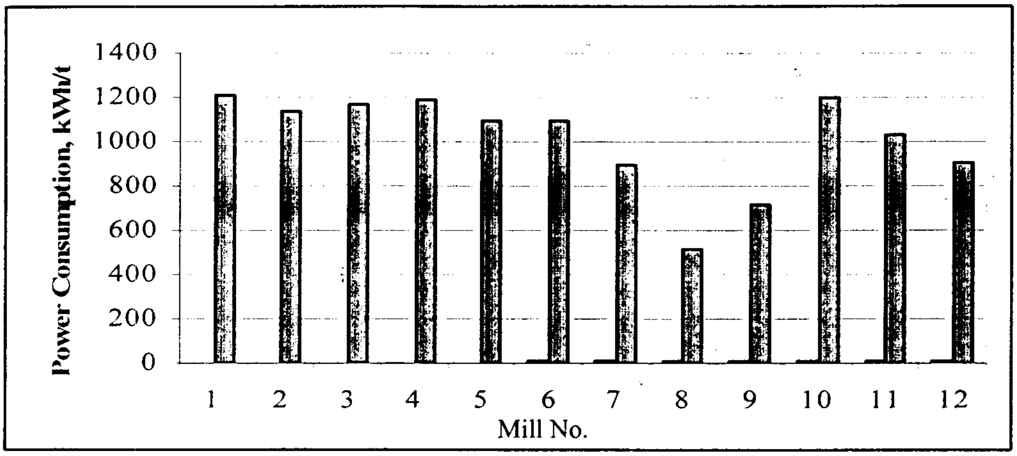


FIG. 2 (A) POWER CONSUMPTION PATTERN IN AGRO BASED MILLS

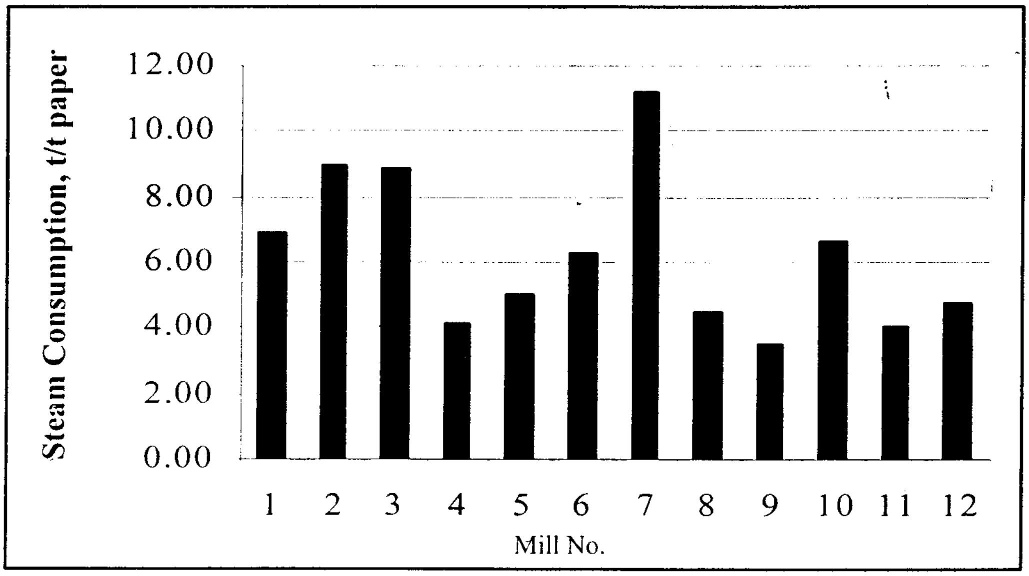


FIG. 2 (B) STEAM CONSUMPTION PATTERN IN AGRO BASED MILLS

TABLE-1

ENERGY CONSUMPTION NORMS FOR SMALL & MEDIUM AGRO BASED MILLS PRODUCING WRITING & PRINTING AND KRAFT PAPER (SOURCE – CII, 1996)

Particulars	Writing & Printing	Kraft
Purchased Energy, M kcal/t	8.7	5.5
Steam, t/t of finished paper	5.75	4.1
Power, kWh/t of finished paper	1200	650

2.0 ENERGY CONSERVATION OPPORTUNITIES

The studies conducted in large number of mills have shown potential for significant energy savings by good house keeping and by adopting small & medium term measures requiring low investment. A list of energy saving proposals in agro based pulp and paper industry is given in Table 2. The detailed case studies of the proposals are given in Annexure - I

TABLE – 2

LIST OF ENERGY SAVING PROPOSALS IN AGRO BASED MILLS

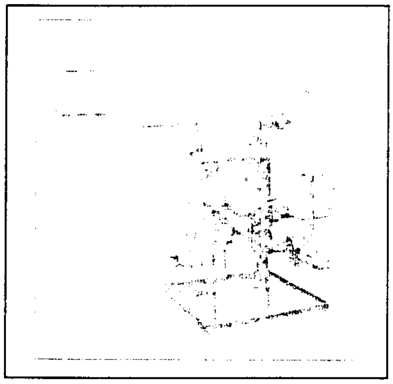
S No.	Proposals	Benefits
1	Proper washing & cleaning of raw material before feeding to digester	Less chemical consumption, clean pulp
2	Installation of Feed Controller at raw material feed Conveyor.	Uniform feeding in feeding systems
3	Installation of Drum Cleaner for the Cleaning of Wheat Straw.	Better cleaning of raw materials, Removal of impurities/dust
4	Proper insulation of Digesters, Blow Tank, Steam Pipelines, Hot Black Liquor and Pulp Lines in Pulp Mill.	Lower heat loss due to radiation losses
5	Utilization of Flash Steam of Blow Tank for Heating Water	Steam saving through waste heat recovery

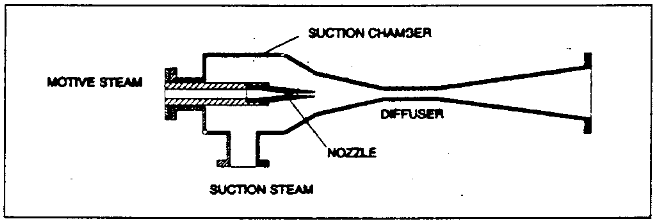
6	Installation of Magnetic Traps before Refiners in Pulp Mill	Increases the life of refiner discs
7	Cascading the Steam and Condensate System Arrangement in Drying Cylinders of Paper Machine OR Flash steam utilization using thermo compressor	Utilization of flash steam in dryers group
8	Proper insulation of Steam and Condensate Pipelines in Paper Machine.	Lower heat losses
9	Improving the Condensate Recovery from Paper Machine Drying Cylinders.	Saving the chemical & power required for generation of DM water
10	Optimization of Fuel Combustion in Boilers.	Fuel saving, higher steam generation
11	Feeding of Fuel With Uniform Moisture in Boilers.	Fuel saving, higher boiler efficiency
12	Replacement of Oversized / Under Loaded Motors with Small Sized Motors.	Power saving
13	Replacement of V-Belt Drive by Flat Belt.	Power saving

Details of the recommendations are given below

3.1 Cascading the Steam and Condensate System Arrangement in Drying Cylinders of Paper Machine or use of thermo compressors

Cascading of condensate flash steam in the 1st or 2nd group of dryers where temperature requirement is less, a very useful way to utilize the flash steam in paper machine. It has been found that in a large number of agro based mills the flash steam from condensate collection tanks is not utilized and vented out in the atmosphere. CPPRI has suggested proper cascading systems for these mills. It is also suggested that differential pressure and blow through steam must be created to drain the dryers. The steam and condensate handling system outside the dryers is responsible for creating the differential pressure and handling the blow through steam in an efficient manner. This will save the live steam and hence reduce load on boiler house. In many cases, it was also suggested that mills should use thermo-compressor to reclaim low pressure flash steam that otherwise vented or go waste. Small quantities of low-pressure flash steam are compressed to a reusable pressure using thermal vapor recompression technology





Thermo compressor

3.2. Insulation of Drying Cylinders Side Faces, Steam and Condensate Lines

Significant amount of heat energy loss takes place through the un-insulated sides of the drying cylinders, steam and condensate lines etc. in the form of radiations. Also the loss of heat from dryer surface results in lower drying capacity of dryers leading to more energy consumption or low speed of machine resulting in production loss. It is recommended to put proper insulation on the sides of the drying cylinders and steam & condensate lines to reduce the heat loss through radiation and save the energy.

3.3 Optimization of Fuel Combustion in Boilers

The high oxygen level in flue gases indicates excess air during combustion. The high amount of excess air carries away with it large amount of usable heat and results in higher losses through the flue gas exit. During studies it was observed that in most of the agro based mills the boilers are operated under un-optimized conditions and this results in huge losses. Various optimization methodologies have been suggested to these mills after conducting detailed boiler efficiency analysis. In some of the mills, it was also suggested that ID and FD fans might be properly balanced to maintain the oxygen level in flue gas between 5.0-5.5% by proper control of dampers or by installation of VFD.

3.4 Replacement of Oversized / Under Loaded Motors with Small Sized Motors

The operating efficiency and power factor of under loaded motors come down resulting in unwanted wastage of energy. The motors, which are less than 60% loaded, are considered to be under loaded as these present more scopes for saving through replacement or reshuffling. However, it is essential to consider the type of application that the motor has been put to, before trying to replace it with smaller motor of optimum rating. In this regard, high starting torque requirements, frequent process control variations; frequent emergency load-increase requirements, and future plans for capacity hike/ modifications should be taken into account. Considering these aspects, and undertaking regular monitoring of under loaded motors, specific case-to-case decision should be taken to replace them with smaller motors.

CPPRI during its studies conducted detailed analysis of motor loading and motor efficiency and suggested replacement of oversized motors/ under loaded motors as well as the adoption of energy efficient motors in place of old inefficient motors.

4.0 CONCLUSION

The studies conducted in various mills have resulted in significant savings. In two mills when CPPRI energy team conducted audits recently, saving of Rs. 66.39 Lacs & Rs. 76.31 Lacs per annum could be made possible by adopting very simple measures. It is therefore necessary that mills should look into their energy consumption pattern monthly and plan a regular energy monitoring and control system. Help from external agencies can be useful for identification and implementation of the recommendations for achieving energy efficiency and cost reduction drive.

CASE STUDY – 1

Insulation of hot surfaces

Dimensions of Uninsulated pipe line: Dia of pipe=100 mm, Length = 100 meter

Surface temperature (without insulation)	: 130^0C
Surface temperature (after insulation)	: 50^0C
Ambient temperature	: 25^0C

Calculations:

Heat losses (Existing)

$S = [10 + (Ts-Ta) / 20] \times (Ts - Ta)$

Where

$Ts = 130^0C$

$Ta = 25^0C$

$S1 = [10 + (130-25) / 20] \times (130 - 25) = 1600$ k Cal/hr m^2

Heat losses (After insulation)

$S2 = [10 + (50-25) / 20] \times (50 - 25) = 280$ k Cal/hr m^2

Fuel savings:

Surface area (Existing) A1	: 3.14 x 0.1 x 100 = 31.4 m^2
Surface area (after insulation) A2	: 3.14 x 0.23 x 100 = 72.2 m^2
Total heat loss in existing system (S1 x A1)	: 1600 x 31.4 = 50240 k Cal / hr
Total heat loss in modified system (S2 x A2)	: 280 x 72.2 = 20210 k Cal / hr

Reduction in heat loss: 50240 – 20210 = 30030 k Cal / hr

Operating hours in a year	: 8640
Total heat loss (k Cal/yr)	: 8640 x 30030 = 259459200
Calorific value of Coal	: 4500 k Cal / kg
Price of fuel oil	: Rs. 20,00/- per Ton
Boiler Efficiency	: 80%
Yearly Fuel Saving	: 259459200 x 0.8 / 4500 = 46126 kg / year

= 46126 x 2 = Rs. 92,252/-

Investment of insulation @ Rs. 200 / m^2 = 200 x 72.2 = Rs. 14,440/-
Net saving: 92,252 – 14,440 = 77,812

Simple pay back (months) : [First cost / (Yearly benefits – yearly cost)] x 12
= [14440 / 77812] x 12 = 2.0 months (Approx)

CASE STUDY – 2

Optimization of excess air in FBC boiler

Basic Data

Capacity of boiler	: 10 t/hr
Average coal consumption	: 2.5 t/hr
Average calorific value of coal	: 4500 k Cal/kg
Average O_2 in the flue gas	: 11% (before air pre heater)
Flue gas temperature	: 144^{0}C
Theoretical air required	: 3.48 kg/kg of coal
Average cost of coal	: Rs. 2000/t
Heat cost based on coal	: (2000/4500) x 1000
	: Rs. 444 / million k Cal
Boiler efficiency (assumed)	: 80%

Calculation:

Excess air at an O_2 level of 11%	: (O_2 x 100) / (21 - O_2)
	: (11 x 100) / (21 - 11)
	: 110%
Excess air at recommended level of 5% O_2	: (5 x 100) / (21 - 5)
	: 31.3%
Flue gas quantity at 11% O_2:	: [(2.10 x 3.49) + 1] x 8000
	: 66,632 kg/hr
Flue gas quantity at 5% O_2:	: [(1.31 x 3.49) + 1] x 8000
	: 44,575 kg/hr
Reduction in flue gas quantity	: 66632 – 44575 = 22057 kg/hr
Heat losses	: (22057 x 0.24 x 144)/10^6

	: 0.762 million k Cal/hr
Annual saving on reducing flue gas Loss by reducing excess air	: (0.762 x 8000 x 444)/0.8
	: Rs. 33,83,280/-
Estimated investment required for close loop combustion control system	: Rs. 5.0 lakh

Simple pay back (months) : [First cost / (Yearly benefits – yearly cost)] x 12
= [5.0 / 33.83-1.0] x 12 = 1.82 months
= say 2 months

CASE STUDY – 3

Use of high efficiency pump

Basic Data

Pump flow, Q	: 0.30 m^3/s
Power absorbed, P	: 300 kWh
Suction head (Tower basin level) h_1	: +1 meter
Delivery head, h_2	: 55 meter
Motor efficiency	: 88%

Pump efficiency = (Hydraulic power, P_h / power input to the pump shaft) x 100

Where

Hydraulic power, P_h (kW) = Q x $(h_d - h_s)$ p x g /1000
Q = volume flow rate (m^3/s)
p = density of the fluid (kg/m^3)
g = acceleration due to gravity (m/s^2)
$(h_d - h_s)$ = total head in meters

Therefore

Total head, $h_2 - (+h_1)$ = 54 meters
Hydraulic power = 0.30 x 54 x 1000 x 9.81 /1000 = 158.92 kW

Actual power consumption = 300 kW
Overall system efficiency = (158.92/300) x 100 = 52.97 %
Pump efficiency = 52.97/0.88 = 60.196

If we replace the pump with high efficiency pump of 70% efficiency

The power consumption will be

(0.30 x 54 x 1000 x 9.81) / (1000 x 0.88 x 0.7) = 257 kWh

Net saving per hr. = 300-257 = 43 kWh

Savings per annum @ Rs. 4.00 per unit = 43 x 8000 x 4 = 13,76,000/-

Investment: Rs. 4.00 lakh

Simple pay back (months) : [First cost / (Yearly benefits – yearly cost)] x 12
= [4.0 / 13.76] x 12 = 3.5 months

CASE STUDY – 4

Replacement of standard motor with energy efficient motor

kW saving = kW output x [1/n_{old} – 1/n_{new}]

Where

n_{old} = existing energy efficiency value
n_{new} = proposed energy efficiency value

kW output = 50 kW

n_{old} = 87%
n_{new} = 93%

kW saving = 50 x [(1/0.87) – 1/0.93)]
= 3.703 kWh/hr

saving per annum = 3.705 x 8000 x 4.0 = Rs. 1,18,560/-

cost of new energy efficient motor = 2.25 lakh

Simple pay back (months) : [First cost / (Yearly benefits – yearly cost)] x 12
= [2.25 / 1.18] x 12 = 23 months

CASE STUDY – 5

Cascading the steam and condensate system arrangement in drying cylinders of paper machine

Existing parameters:

Total no. of dryers = 30

Paper production = 100 tpd

Steam consumption = 3.0 t/t of paper ~ 300 t/day

Proposed practice using cascade system arrangement:

Total no. of dryers = 30

Divided into three sub groups

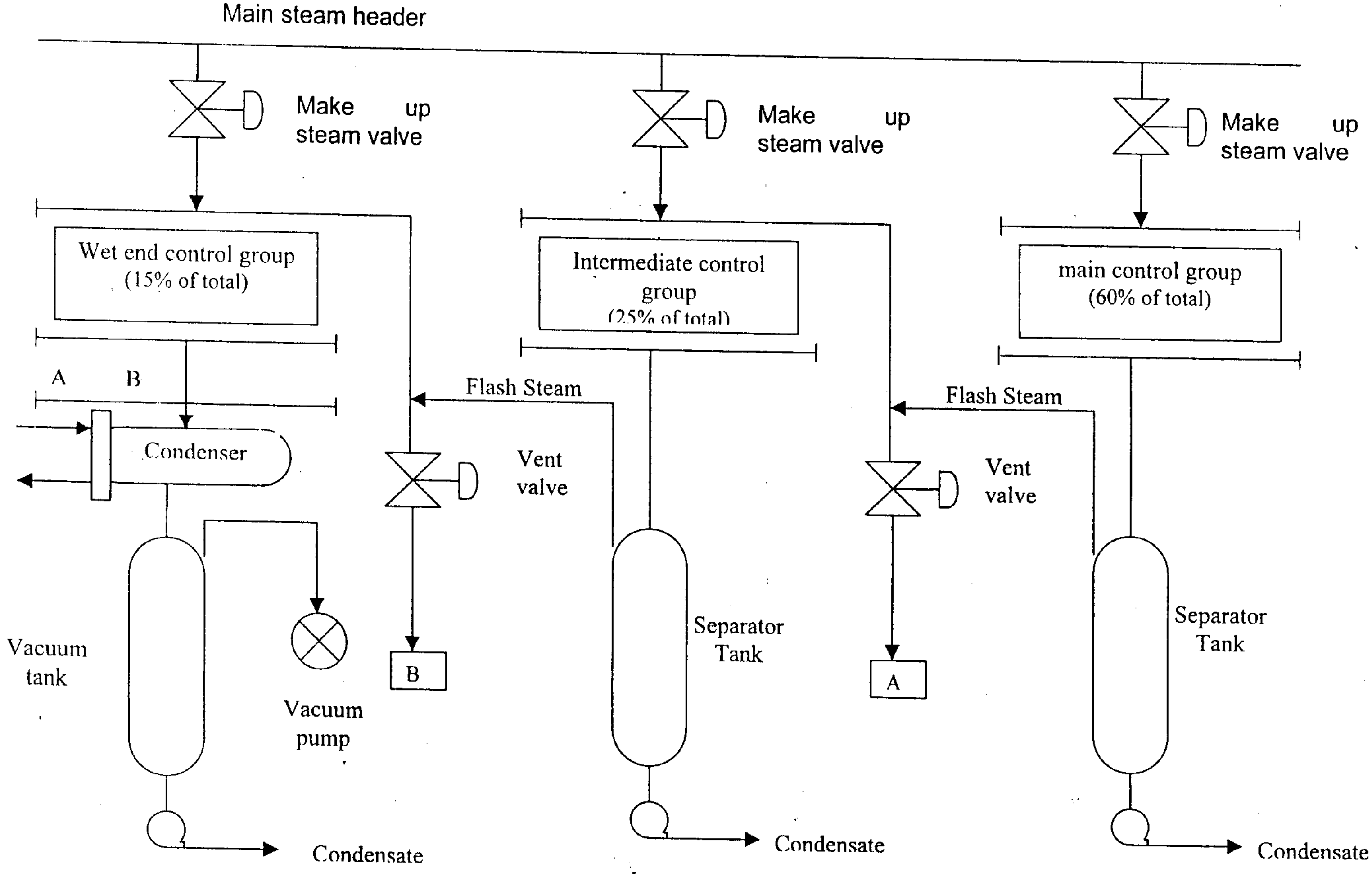
a) Main control group (60% = 19 nos.)
b) Intermediate control group (25% = 7 nos.)
c) Wet end control group (15% = 4 nos.)

Paper production = 100 tpd

Steam consumption = 3.0 t/t of paper
Steam consumption per dryer = 10 T/ day

Steam consumption in main control group = 19 x 10 = 190 T/day
Steam consumption in Intermediate control group = 7 x 10 x (20/100) =14 T/day
Steam consumption in Wet end control group = 4 x 10 x (35/100) = 14 T/day

Total Steam consumption will be = 190+14+14 = 218
Steam saving per day = 300 –218 = 82
Steam saving per annum = 82 x 330 = 27060
Steam saving in Rs. Per annum = 350 x 27060 = 94.71 Lakhs / year
Cost of cascading system = Rs. 30 Lakhs
Annual operating cost = 37 kW x Rs. 400 x 24 x 330 = 11.72 Lakhs
Simple Payback = (30/[94.71-11.72]) x 12 = 5 Months



BASIC CASCEDE SYSTEM

BIO-ENERGY RECOVERY IN AGRO BASED MILLS - A CASE STUDY

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About The Author

Dr .S. Panwar is a senior scientist working in Environmental Management Div of CPPRI for the last twenty years. He has Masters Degree in Chemistry and has Doctoral degree in Pulp & Paper Chemistry.

He has a rich and wide experience in the area of pulping & bleaching, environmental management including bioenergy recovery from wastes, performance evaluation and trouble shooting of effluent treatment plants, environmental auditing etc. He has been responsible for commissioning of full-scale biomethanation plant for recovery of bioenergy from black liquor. He has been actively associated with the projects completed on behalf of CPCB like "Development of Standards of AOX for Large and Small Scale Pulp & Paper Mills" & "Standardization of Methods for Determination of AOX in Environmental Samples".

He has undergone an advanced training at Finland and Sweden on microbial aspects and application of biomethanation technology in pulp and paper industry. He has also been actively associated with prestigious projects sponsored by UNDP, MNES, and mill associations like IARPMA, IPMA etc. He has represented CPPRI at various national & International Conferences and Seminars. He has around 30 publications to his credit and has been author/ co-author of a number of R& D reports, training and course manuals.

BIOENERGY RECOVERY FROM AGRO BASED BLACK LIQUOR THROUGH HIGH RATE BIOMETHANATION

Dr.S.Panwar, Dr.N.Endlay, A.Pandey, B.Sarangraja

1.0 INTRODUCTION

Inspite of the fact that agro based pulp & paper mills contribute to around 40 % of the total paper production of the country, thus contributing to saving of valuable forest wealth , they are facing serious environmental challenges which are endangering their sustainability. The major environmental issues associated with this category of mills is the discharge of high strength pulping spent liquor due to absence of chemical recovery system which not only increase pollution load but also results in loss of valuable organic biomass. It is estimated that the pollution load from an agro based mill without chemical recovery is almost equal to the production of the mill. Recently a few agro based mils of capacity around 100 tpd have installed chemical recovery system for handling black liquor with added advantage of meeting the environmental obligations . However the techno – economics and feasibility of its regular operation is still debatable. Specially the mills with scale of operation between 20-40 tpd are in dilemma in context of adoption of any appropriate options for treatment of black liquor as conventional chemical recovery system may not be economically viable for these mills.

2.0 MAGNITUDE OF POLLUTION LOAD

The pulping spent liquor discharged in these category of mills is difficult to treat by conventional activated sludge process and a considerable portion of organic biomass is drained which has potential to be tapped through biological route A comparative picture of pollution loads generated in small and large paper mills is given in **Table-1.**

TABLE – 1

CHARACTERISTICS AND POLLUTION LOADS GENERATED FROM LARGE AND SMALL AGRO BASED PAPER MILLS.

Parameters	Large integrated paper mill with recovery system	Agro based mill with recovery system	Agro based paper mills without recovery system
Flow, m^3/t paper	110-160	100-110	120-180

Pollution load, kg/t paper			
SS	60-155	140-150	100-175
BOD	30-225	115-120	110-260
COD	80-475	250-270	325-950

About 90% of the total water consumption is discharged as effluent by agro based mills. The pulping spent liquor is the highly polluted stream and it contributes more than 70% of total pollution load.

3.0 EXISTING EFFLUENT TREATMENT PRACTICES

Activated sludge process (ASP) is a more popular and widely used effluent treatment method in case of agro based pulp and paper mills. The ETP consists mainly of primary clarifier , aeration system and secondary clarifier. In most of these mills black liquor along with pulp washings is segregated from other effluent streams and is stored / treated in large open anaerobic lagoon .The anaerobically treated black liquor is discharged either during floods in rainy season or is mixed with other effluent for subsequent treatment by ASP. The activated sludge process suffers from the disadvantage of relatively high operational cost due to use of huge amount of energy and also the process alone is not sufficient to treat effluent rich in black liquor to the level of acceptable discharge norms. The **combination of anaerobic and aerobic** technology is now the present trend used for treatment of effluent including black liquor .In view of increased price of energy and pressure from environmental regulatory agencies some of the agro based mills have installed full scale **biomethanation plant** for treatment of black liquor to reduce pollution load with added advantage of cogeneration of energy.

In anaerobic treatment , the dissolved organics are converted to methane and carbon dioxide by anaerobic micro-organisms/ biomass . Oxygen required is obtained by the breakdown of inorganic compounds or organic compounds containing oxygen.

$$\textbf{Organics + Combined energy} \xrightarrow{\textbf{Anaerobic Bacteria}} \textbf{New cells + Energy for cells + } CH_4 + CO_2 \textbf{ + other products}$$

A comparative merits & demerts of both Anaerobic & Aerobic treatment methods is indicated in **Table –2.**

TABLE –2

ANAEROBIC V/S AEROBIC TREATMENT PROCESS

Particulars	Anaerobic	Aerobic
Bacterial growth	Slow	Fast
Carbon balance	95% CH_4+CO_2 & 5% Biomass	50% CO_2 & 50% Biomass
Energy balance	90% retained as CH_4 & 5% Biomass	60% Biomass & 40% Heat
Energy input for aeration	No	Yes
Energy required (kWh) / tonne COD reduced	15	1100

Inspite of the above advantages ,the most significant draw backs which have hampered the widespread application of anaerobic system for waste water treatment in the past were :

- Low growth rates and yields of anaerobic bacteria
- High concentration of biomass required to achieve high reaction rates
- Long startup periods needed to achieve high concentration of active biomass
- Revival of methanogenic bacteria after a toxic load is time consuming.
- Low concentration of substrate (waste water)

4.0 RECENT DEVELOPMENTS IN ANAEROBIC TREATMENT TECHNOLOGY

The development of high rate anaerobic bioreactors has enabled anaerobic treatment of dilute wastewaters since the biomass retention is no longer coupled to the hydraulic retention time. Anaerobic process was previously considered too sensitive to inhibitory compounds. The recent advances in good understanding of microbiology and process insight has made anaerobic process as proven technology to treat the complex industrial effluent including pulp and paper mills effluents.

In the last two decades, the Biomethanation technology has undergone tremendous changes especially in the design of reactor configuration to develop high rate bioreactors with compact size. These technological developments in have taken place with the following objectives:

- Flexibility in operation.
- Handling of wide variety of effluents.
- Handling of higher organic loading rate (20-40 kg COD / m^3/day).
- Biological scrubbing of biogas to remove hydrogen sulfide.
- Efficient conversion of biogas into electrical energy .

These developments can be broadly classified into two categories:

4.1 Suspended Growth System

In suspended growth system microorganisms develop in the form of dense flocks or granules are retained in the reactor.

4.2 Attached Growth System

The anaerobic microbes grow in colonies on fixed media or carrier material, which are provided. In this system the development & retention of anaerobic biomass is comparatively higher and is more resistant towards toxicity tolerance.

Some of the important high rate bioreactors based on different configurations and working on commercial scale are :

4.3 Contact Process

It is a suspended growth system which consist of a completely mixed anaerobic reactor either with mechanical mixer or recycled biogas, Contact process tolerates high concentration of suspended solids, consequently it is widely used for treatment of sludge in addition to the treatment of liquid wastes. The process has in general a lower concentration of biomass & thus requires longer contact/retention time & higher reactor volumes.

4.4 UASB Process

It is also a suspended growth system & microorganisms develop in well settling flocs or granules, consequently, the retention of biomass in reactor is very high. The wastewater is fed through specially designed distribution pipeline at the bottom. The key part of the reactor is a unique three-phase separator provided at the top of the reactor for separation of gas from liquid and sludge particles. The flow of wastewater and rising bubbles of biogas provide natural mixing & thus enhance the contact between wastewater & anaerobic microbes. The process can tolerate fairly high concentration of suspended solids without any clogging problem but these suspended solids may accumulate in the reactor & lead to the wash out of active biomass.

4.5 Expended Granular Sludge Bed Reactor (EGSB)

It is a modification of UASB reactor in which granular bed is expanded by applying high hydraulic flow velocity and high organic loading rates resulting in increased bio-mass activity and contact between biomass & organic wastes however high recirculation required to expand granular bed consumes high energy compared to UASB reactor.

4.6 Internal Circulation Reactor (IC)

It is also a modification of UASB process, consists of EGSB & UASB compartments on the top of each other. The special feature of the reactor is biogas separation in two stages. Whereby the gas collected in the first stage drives a gas lift & internal wastewater biomass circulation and the later reduces the energy demand of the process. The technical start up of this process requires an external gas supply to the reactor.

4.7 Hybrid Reactor

It is a combination of UASB and up flow fixed film reactor. In this process, the lower part of reactor (30-50%) is the UASB portion where flocculent or granular sludge develops and upper part of reactor (50-70%) is the up flow fixed film, which provides larger surface area for the development of mixed film of active biomass. The system has advantages of both UASB & fixed film reactors.

The schematic diagrams of the above configurations are indicated in **Fig 1,2&3.** The contact and UASB process are most widely applied system for treatment of Industrial effluent.

5.0 STATUS OF ANAEROBIC TREATMENT IN INDIAN PULP & PAPER INDUSTRY

In Indian paper industry, till recent past , anaerobic treatment was associated with uncontrolled degradation of organic matter in big anaerobic lagoons over a long period of time followed by their discharge during the rainy season . The main problems associated with such lagoons were requirement of large space, foul odor and contribution to global warming due to release of methane into atmosphere. The development of high rate bioreactors and increased understanding of basics of biochemistry of anaerobes have resulted into successful application of biomethanation technology for treatment of wastes. A number of full scale biomethanation plants are successfully operating for treatment of pulp and paper mill effluent world wide.

6.0 APPLICATION OF HIGH RATE BIOMETHANATION SYSTEM FOR TREATMENT OF SODA BLACK LIQUOR – CASE STUDY

The first successful demonstration of treatment of high strength pulping liquor (soda black liquor) by biomethanation took place in 1997 at Satia **Paper Mills Ltd, Muktsar, Punjab** under a **MNES** sponsored project on "High Rate Biomethanation of Pulp & Paper Mill Waste" where the technical guidance was provided by **CPPRI, Saharanpur**. A schematic diagram of the plant is indicated in **Fig -4** & the salient features of the plant are described in **Table -3**

TABLE -3

SALIENT FEATURES OF THE BIOMETHANATION PLANT

S.No	Particulars	Capacity, m^3	Purpose
1.	Sump Tank	100	Black liquor from the mill is collected in the sump tank from where it is pumped to equalization tank.
2.	Equalization Tank	211	To minimize fluctuation in flow and COD concentration of black liquor.
3.	Neutralization Tank	35	For neutralizing the black liquor to a pH around 6.5 by addition of hydrochloric acid
4.	Clarifloculator	98	To enhance mechanism of flocculation
5.	Clarifier	1100	To facilitate the arresting of suspended fibers/solids and lignin as well as significant amount of silica which gets precipitated during neutralization of black liquor.
6.	Buffer Tank	840	• To ensure uniform mixing of influent with nutrients and recycled effluent. • To control and stabilize pH of influent. • It act as a hydraulic buffer for continuous and constant supply of influent to the bio reactor.
7.	Reactor (2)	2623 (each)	Handle the organic waste of 53 ton /day generated by the mill. The biomethanation process takes place in the reactor.

The biomethanation plant was commissioned and operated successfully up to 20% above the designed volumetric loading rate .The performance of the system achieved is indicated in **Table -4**

TABLE-4

PERFORMANCE OF DEMO BIOMETHANATION PLANT

Parameters	Designed	Achieved
Volumetric loading rate,kg COD/m^3/d	10.0	12.0
COD reduction, %	55-60	45-50
BOD reduction, %	70-75	75-80
Biogas Production,m^3/d	8500	11000-11500
Equivalent rice husk replacement, t/d	17-18	22-24

7.0 TECHNO-ECONOMICS OF BIOMETHANATION PLANT

A detailed study of techno-economics was carried out to evaluate the feasibility of the biomethanation system. The techno- ecnomics calculated is indicated in **Table –5**

TABLE-5

TECHNO- ECONOMICS OF BIOMETHANATION PLANT

S.No	Particulars	With Subsidy,(50%)	Without Subsidy
1.	Capital Cost,Rs.million	11.20	22.40
2.	Operational Cost, Rs.million/annum	7.00	7.00
3.	Interest on Capital, Rs.million/annum	2.00	4.03
4.	Depreciation (@ 10% in 10 years)	1.12	2.24
5.	Recurring Expenditure (B+C+D), Rs.million/annum	10.12	13.27
6.	Equivalent Fuel Saving, Rs.million /annum	14.0	14.0
7.	Indirect savings (Energy & Chemical Savings in ETP), Rs.million/annum	3.5	3.5
8.	Payback period,years	1.5-2.0	3.0-4.0

8.0 PHYSICO-CHEMICAL FACTORS INFLUENCING PERFORMANCE OF BIOMETHANATION PROCESS

The good performance efficiency of biomethanation plant can be achieved by its efficient and regular monitoring of the various physico-chemical factors influencing biomethanation process. A brief description of the important parameters & their significance is indicated in **Table –6**.

TABLE –6

PHYSICO-CHEMICAL FACTORS INFLUENCING PERFORMANCE OF BIOMETHANATION PROCESS

S.NO	Parameters*	Significance
1.	pH	The optimum pH range for maximum methane production is generally between 7.0 – 7.5, although acclimation to pH condition out side this range over a long period of time is possible. Below a pH of 6.5 to 6.8,. methane gas production will begin to drop as a result of methane bacteria growth inhibition. Below pH 6.0 and above 8.5 to 9.0, methane gas production may cease altogether.
2.	Temperature	The metabolic rate of all biological system is affected by temperature. Biochemical reactions proceed more rapidly with increasing temperature. The treatment efficiency of anaerobic process compared with aerobic process is particularly sensitive to operation below optimum temperature because of the significantly lower substrate removal rate constants .
3.	Volatile fatty acids (VFA)& Alkalinity	During biomethanation process the complex substrate is first converted to VFA by a group of anaerobic bacteria followed by its conversion to methane.The process is highly pH dependent and a low pH in the reactor can result in accumulation of unionised VFA. The unionised VFA are toxic to anerobic microbes as they are believed to penetrate the cell membrane more easily. Alkalinity is required for buffering the eventual accumulation of VFA produced during the anaerobic metabolism of the substrate and thus avoid drop in pH. Hence monitoring of VFA level and alkalinity of the system is of utmost importance for the smooth operation of the

		biomethanation plant.
4.	Nutrients	Inorganic nitrogen and phosphorous are required as macronutrients for biomass synthesis. The nitrogen requirement is approximately 11 percent of the net cell weight, based on an empirical cell composition of $C_5H_9NO_3$ where phosphorous is approximately 2 percent of the biomass. In addition to nitrogen and phosphorous, several other inorganic constituents are required in trace quantities for optimum functioning of anaerobic process. These micronutrients include Fe and Ni (1 to 5 ppm), Co,Mo,Se(approximately 0.05 ppm).
5.	Volatile suspended solids (VSS)	Determination of VSS indicate the organic matter present in the effluent as well as the organic matter and active biomass in the anaerobic sludge.
6.	Methanogenic sludge activity	To measure the potential available in anaerobic sludge to convert the organic matter into methane rich biogas.
7.	Anaerobic biodegradability	To determine the potential of the substrate to be treated aerobically. It gives an estimation of the biodegradable organic mater contained in the effluent that can be treated anaerobically.
8.	Methanogenic toxicity assay	The purpose of the toxicity assay is to determine the percent of methanogenic activity that can be lost due to inhibiting compounds. The toxicity is determined by comparing the activity of sludge fed only on substrate that with sludge fed the same substrate and the suspected toxic compounds. This assay also provide the information on adaptability of sludge to the toxic compound or waste water.
6.	Sludge profile	The amount of sludge in the reactor can be determined by a sludge profile. By knowing the quantity of sludge, it is possible to predict the maximum organic loading to the reactor, if we also know the methanogenic activity of the sludge. The sludge profile also indicates the state of sludge in the reactor i.e. whether it is building up or getting washed off as well as its distribution inside the reactor

9.0 CHARTER ON CORPORATE RESPONSIBILITY FOR ENVIRONMENTAL PROTECTION (CREP)

The introduction of **Charter on Corporate Responsibility for Environmental Protection (CREP)** by Central Pollution Control Board has brought out a time bound implementation schedule to address the major environmental issues related to pulp & paper mills failing which the mills will not be allowed to continue its operation. The major features of the CREP for small-scale agro based mills are as under:

Mill category	Environmental issues	Implementation Schedule
Small Paper Mills	Compliance of standard of BOD, COD & AOX	Either achieve the discharge Standards of BOD, COD & AOX by installation of chemical recovery system or utilization of black liquor with no discharge from pulp mill within 3 years **or** Shift to waste paper
	Upgardation of ETP's so as to meet discharge standards	Upgrade the ETP within one year so as to achieve the discharge standards
	Waste water discharge/ tonne of paper	< 150 m^3/t_{paper} within 3 years
	Utilization of treated effluent for irrigation	Wherever possible
	Colour Removal from the effluent	IARPMA to take up project with CPPRI

10.0 OPTIONS FOR BLACK LIQUOR MANAGEMENT

In the context of **CREP** requirements the limited options before the mills for management of black liquor are:

10.1 Chemical Recovery System

Small mills due to low scale of operation, higher silica and non process elements content are still looking for a techno-economical chemical recovery system for black liquor handling. Some of the mills in this category mills which have adopted chemical recovery system are unable to operate it on regular basis due to lack of sufficient quantity of black liquor on account of low scale of operation. As such before going for chemical recovery system the mills must scale up their production capacity to an appropriate level so as to enable continuous / uninterrupted operation of chemical recovery system as well as get optimum efficiency of the system.

10.2 Lignin Removal Process

Lignin present in the black liquor is biorefractory and an aerobically non-biodegradable in nature due to which it is not decomposed by microbial biomass and only contributes to increase in dead load of the sludge biomass. CPPRI has conducted extensive studies both on lab scale & pilot scale on effect of lignin removal through pretreatment of black liquor before anaerobic treatment. The results indicate encouraging improvement in the efficiency of biomethanation process by 15 - 20% (in terms of COD & BOD reduction%) after lignin removal. Lignin thus separated through lignin removal process can be used for number of industrial application like a grinding aid in cement industry, disperser in dye industry and it can also be used as a particle binder in briquetting plants for better combustion.

The mills having pulp mill with low scale of operation are now exploring the possibility of adoption of lignin separation technology for treatment of black liquor in order to comply the requirement of CREP. Some of the agro based pulp and paper mills have submitted heir action plan for treatment and utilization of pretreated black liquor after separation of lignin. The separated lignin will be sold in market for further utilization or will be used as fuel in the boiler. So the proposed lignin separation process will have dual purpose of energy generation through utilization of lignin and improved efficiency of biomethanation of pretreated black liquor.

11.0 COMBINATION OF ANAEROBIC & AEROBIC PROCESS

Inspite of the various advantages of biomethanation process, it is a fact that the reduction in pollution load by biomethanation process is moderate as compared to activated sludge process . In this perspective a combination of biomethanation process and activated sludge process is a better option to combine the advantage of both the treatment systems. In such case the effluent is initially treated by biomethanation process where most of the biologically degradable matter is reduced by anaerobic biomass along with cogeneration of bio-energy. This is followed by post treatment of an aerobically treated effluent by activated sludge process. **Table – 7** indicates that, for the same level of reduction in pollution load the energy requirement is reduced by more than 60% and chemical requirement by more than 40% in case of combination of anaerobic & aerobic treatment process as compared to only aerobic treatment process

TABLE- 7

COMPARATIVE ANALYSIS OF INPUTS IN AEROBIC & COMBINATION OF ANAEROBIC & AEROBIC SYSTEM FOR A 50 TPD MILL.

Particulars	AEROBIC	ANAEROBIC+AEROBIC
COD load,t /d	60	60
BOD load,t/d	20	20
BOD removal,%	95	95
BOD removed ,t/d	19	19
Power requirement, kWh	22800	7800
Nutrient requirement, kg/d		
• Urea	1650	1000
• DAP	950	575
Biogas generation,m^3/d	Nil	11000-12,000

The laboratory studies conducted on potential of anaerobic-aerobic processes for treatment of pulping spent liquor from agro residue indicate that the combination of anaerobic-aerobic process is effective in reducing the pollution loads i.e. BOD, COD and SS by 95%, 67% and 95% respectively which can further be increased by inclusion of lignin removal as a pretreatment step.

12.0 CONCLUSIONS

The small agro based paper mills are still looking for techno economic viable chemical recovery system and at present most of them discharge the black liquor with and without treatment causing not only environmental problems but also loosing a huge amount of organic biomass which has a potential to recover bio-energy through biomethanation process. The successful demonstration of biomethanation technology for treatment of black liquor at Satia Paper Mills has proved its enormous potential in pulp & paper mills producing chemical pulp in the range of 25-40 tonnes per day. The adoption of biomethanation process can supplement at least 15-20% of its energy requirement through High Rate Biomethanation . Moreover an integrated approach using combination of LRP, biomethanation and ASP may be the best available alternative to conventional chemical recovery system for handling of black liquor in small and medium size agro based pulp and paper mills and reduction of pollution load to prescribed discharge norms .

CPPRI has been pioneer in carrying out extensive R&D activities to understand basic fundamentals, process configuration, anaerobic biodegradability of different wastes generated in pulp and paper industry which has resulted in successful demonstration of biomethanation technology for treatment of agro residues black liquor on commercial scale. It is still actively pursuing research activities to enhance the efficiency of biomethanation process so as to make it more compatible for treatment of agro residues black liquor. Interested mills can take the technical guidance from CPPRI for evaluating feasibility of biomethanation process; LRP for treating their pulping spent liquor, installation of biomethanation plant etc. For getting the detailed information regarding financial support etc the mills may contact - **Indian Renewable Energy Development Agency Limited (IREDA), New Delhi.**

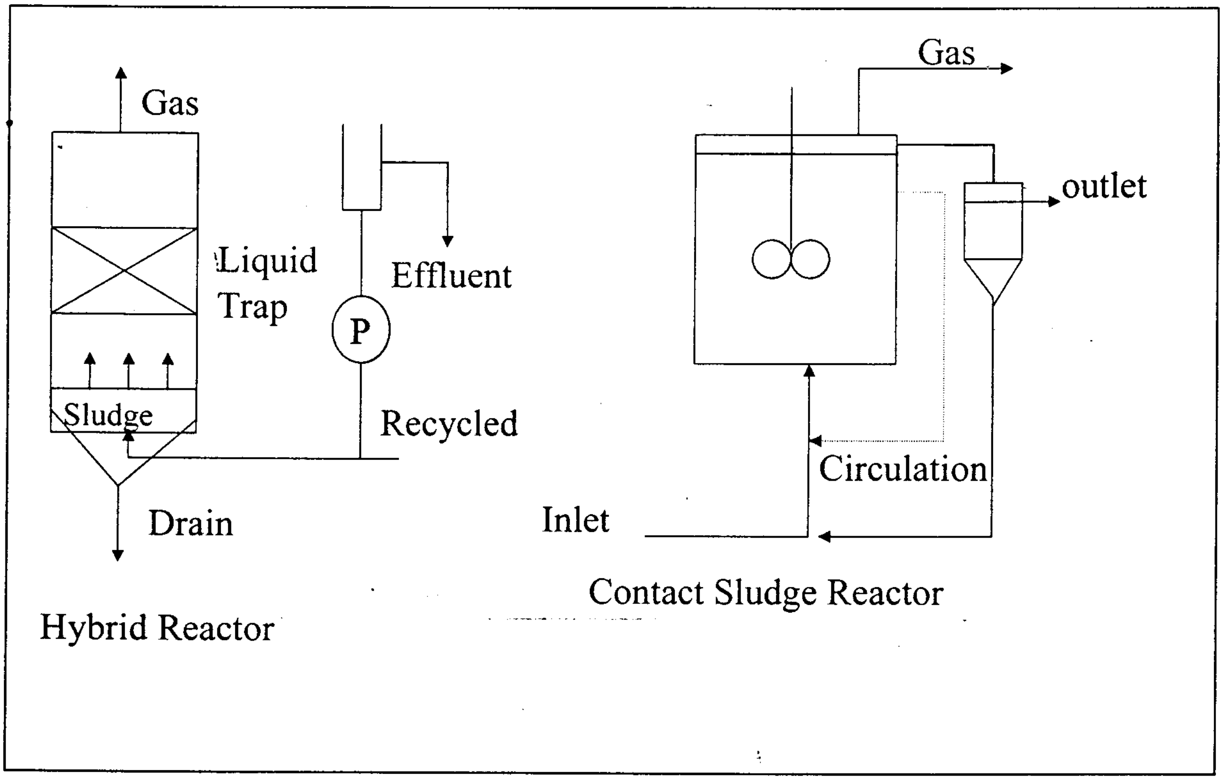


FIG -1 SCHEMATIC DIAGRAM OF HYBRID & CONTACT REACTOR

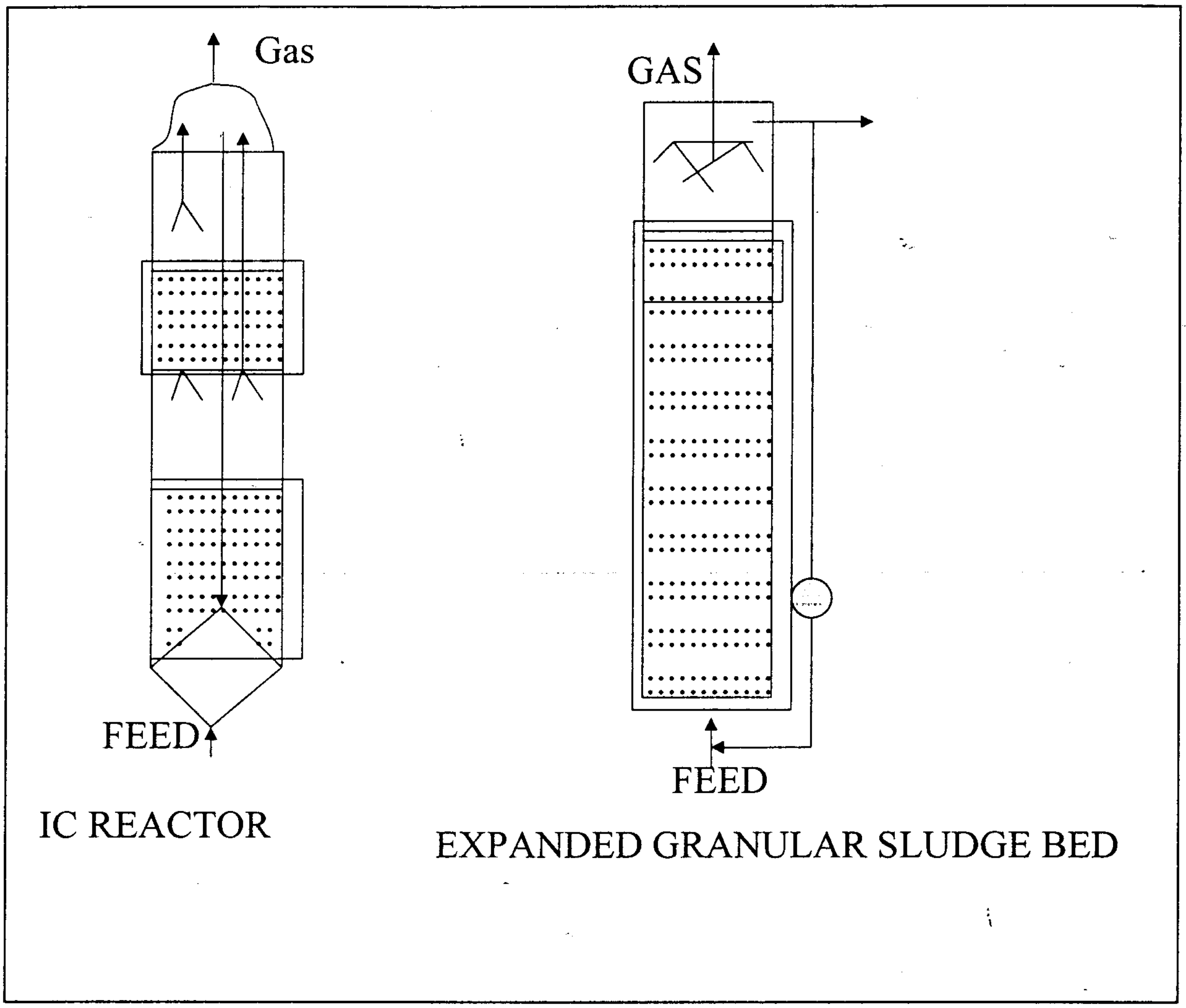


FIG- 2 SCHEMATIC DIAGRAM OF IC & EGSB REACTORS

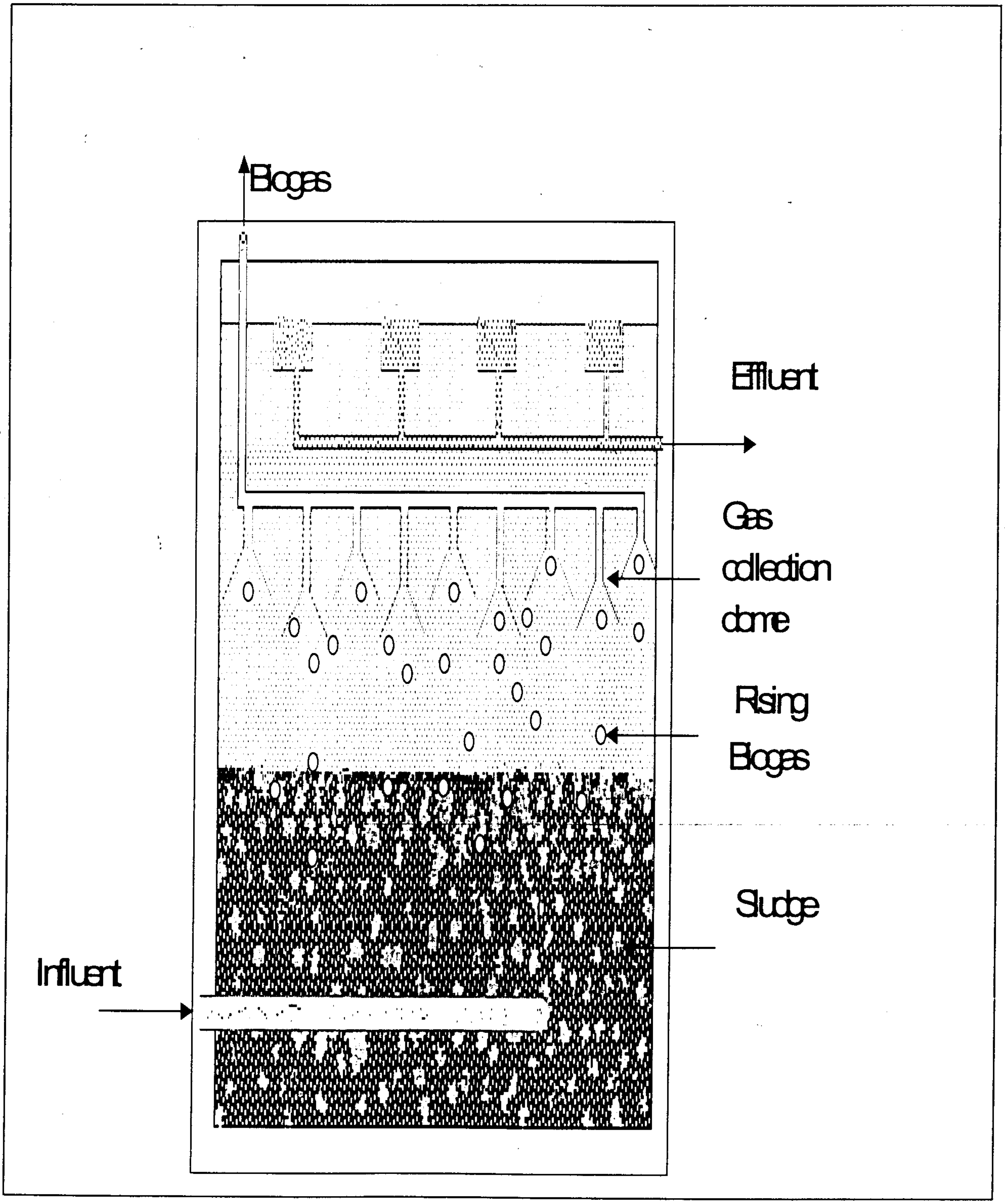


FIG –3 SCHEMATIC DIAGRAM OF UASB REACTOR

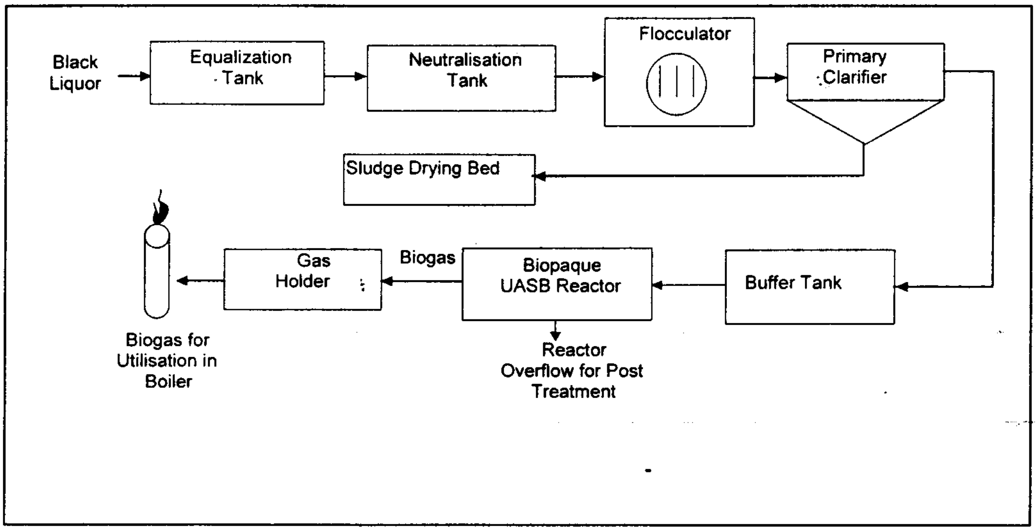


FIG –4 SCHEMATIC DIAGRAM OF BIOMETHANATION PLANT AT SATIA PAPER MILL

COLOR REMOVAL OPTIONS IN AGRO BASED MILLS

Mrs. Rita Tandon
Scientist E - I

About The Author

Presently working as a senior scientist in CPPRI, the author has a Master's Degree in Chemistry with specialization in Organic Chemistry. The author with a brilliant academic record has dedicated almost 19 years of service to the Institute working in the area: Paper testing, Papermaking, Black liquor characterization, Chemical Recovery, Secondary fibre processing, Energy & Environmental Management.

She has a wide experience in the area of chemical recovery and secondary fibre processing. Has completed two projects on waste paper namely **"Technological Treatment Of Waste Paper"**, sponsored by AISPMA and **"Availability And Utilization Of Waste Paper"** sponsored by IPMA under which **an indigenous gradation system has been evolved** and proposed for implementation. Currently working on project **"Identification, Characterization And Removal Of Contaminants From Recycled Fibre"** under a plan scheme.

She was associated with development of Desilication technology also and currently working on development of color removal technology for liquid effluents.

She has undergone two months extensive training on **"Energy Management in Pulp & Paper Industry" in Cia Suzano Mill in Brazil under UNIDO fellowship training programme**. She has around 30 publications to her credit and author/co-author of number of R&D reports, training & course manual.

COLOR REMOVAL OPTIONS IN AGRO-BASED MILLS

Rita Tandon, Satya Dev Negi, Subodh Singh

1.0 INTRODUCTION

Pulp & paper industry is one of the highly polluting industries generating significant quantity of organic and inorganic pollutant having high color loads. Till recently, color as an industrial waste had received only little attention from environmentalists. However in recent times color reduction in mill effluent has become a prominent issue due to increasing public awareness changes in local regulation and aesthetic considerations.

Color interferes with aquatic life by limiting light transmittance and also contributes to taste problems and increases stability of some bivalent metal ions by chelation. The color bodies in pulp mill effluents consist primarily of lignin components and lignin, which are highly colored and quite resistant to biological attack resulting in their long persistence in the environment.

The effluent color loads however varies from mill to mill depending upon the size of the mill, raw material used, process employed, type of end products and extent of system closure practiced in a mill. Conventional methods of effluent treatment, such as primary sedimentation clarifiers followed by biological methods (aerated lagoons or activated sludge treatment), are effective in reducing biological oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and suspended solids. However, these methods do not have any significant effect on effluent color. Process modifications and/or end-of-pipe treatment methods for color removal are becoming necessary to satisfy pollution discharge limits.

2.0 CHEMISTRY OF COLOR BEARING COMPOUNDS

In the Pulp & paper Industries, the concern is predominantly about the colors of organic origin, the so called "chromophores", the groups which generally absorb ultra-violet (UV) light through their functional groups having excess electrons such as the C=C, -C≡C-, six carbon aromatic rings, nitro, sulfur and oxygen containing groups and heterocyclic compounds containing oxygen, nitrogen, or sulfur as a member of cyclic ring. Those compounds, which absorb light in a visible range also contain the same high electron density functional groups, but usually arranged in a long chain. The length of the chain and the nature of the electron rich group dictate the shade of the color. Cleavage of one of these groups break the molecular chain and generally shifts the color from the visible spectrum to either UV or IR range.

The soluble color-bearing portion of the Pulp mill effluent is composed primarily of wood extractives and lignin degradation products, which are formed during pulping and bleaching. It is established that the condensation and oxidation reactions taking place during cooking, chlorination or extraction stage results in the formation of quinonoid structure may be conjugated with carbonyl and ethylenic groups which contribute for the color absorbance in the visible spectrum. Secondly the color bodies are polydisperse and a single effluent may contain species ranging in molecular weight from less than 400 upto 150,000 mass units with an average molecular weight of about 6000 mass units.

3.0 SOURCES AND MAGNITUDE OF COLOR IN PULP & PAPER MILL EFFLUENT

Preliminary findings and review of sources of color indicate that approximately 30% to 50% of the color in the effluent may result from the pulp mill. Depending on the pulping process (Kraft, neutral sulfite semi-chemical, sulfate, mechanical, or thermo-mechanical) and the bleaching process being employed at the mill, the effluent color load can vary significantly and is directly proportional to the extent of lignin extraction during pulping. The pulping process contributes between approximately 50% and 70% of the color load in the effluent. The remaining color usually results from bleaching operations and spills. The various sources for generation of colored effluent in pulp & paper industry are shown in **Table-1**.

The color in effluent is mainly due to presence of organic components, which are released during pulping and bleaching operations from the raw materials used for papermaking. The pulping process employed has a profound influence on magnitude & intensity of color generated in liquid effluents, as summarized in **Table-2**. It has also been observed that primarily the chemical composition of raw material used has more pronounced effect on generation of color in effluents.

TABLE-1

VARIOUS SOURCES FOR GENERATION OF COLORED EFFLUENT IN PULP & PAPER INDUSTRY

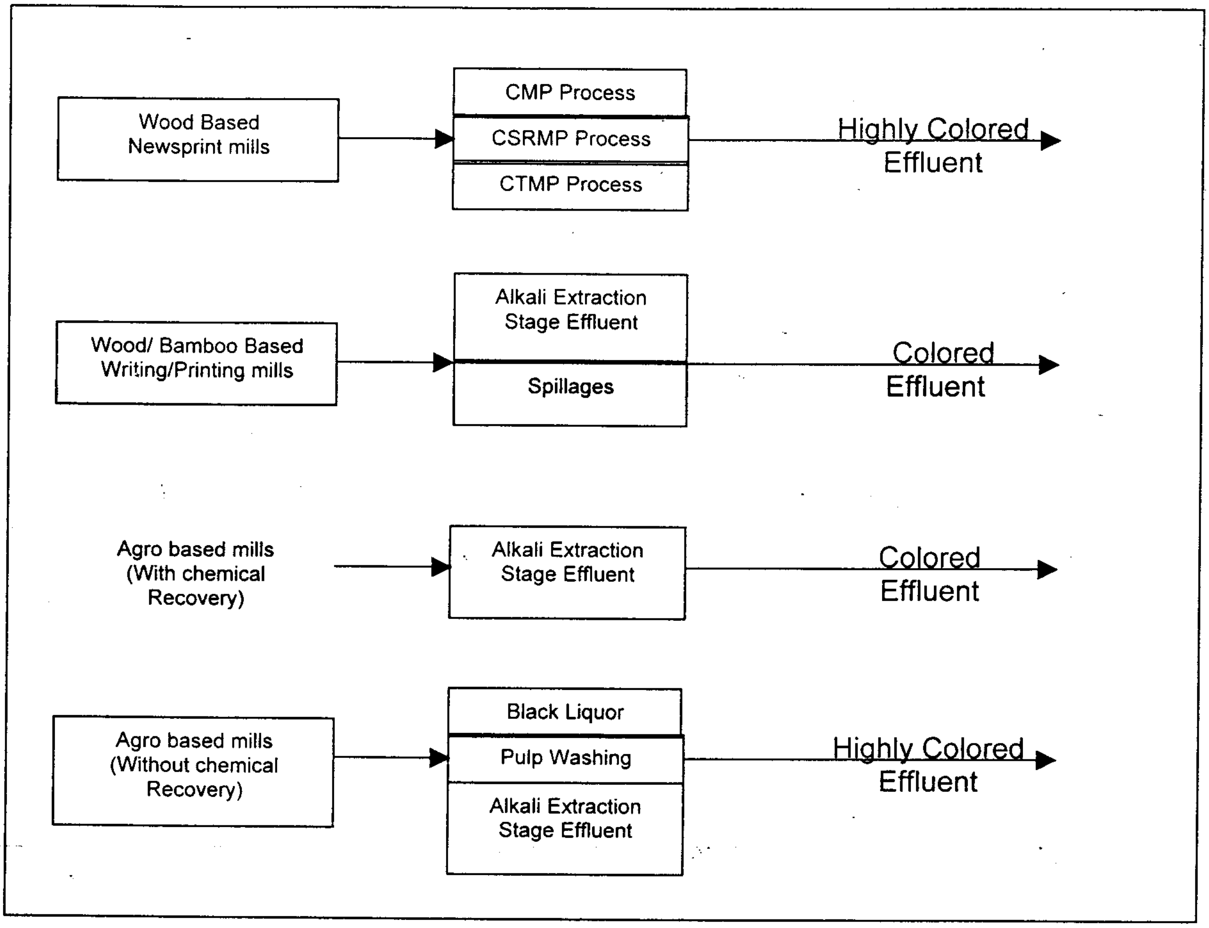


TABLE-2

MAGNITUDES OF COLOR LOAD IN DIFFERENT EFFLUENT STREAMS

Streams	Color in PCU (1% TS)	Chromophores
Combined Bleach Effluent (Bamboo, Chemical Pulping)	2771	Chlorolignins
Treated Effluent (Bamboo, Chemical Pulping)	2993	Degraded lignin products
Mechanical Pulping Effluent (Eucalyptus)	13,888	Extractives (Poly phenols & tannins)
Mechanical Pulping Effluent (Acacia)	8,488	Extractives (Poly phenols & tannins)
Mechanical Pulping Effluent (Bagasse)	8928	Extractives (Poly phenols & tannins)
Effluent from Agro based Mill	14,808	Lignin & Its degraded products

Source – CPPRI Data

4.0 PROBLEM OF EFFLUENT COLOR IN AGRO BASED MILLS

The presence of color in industrial effluents is due to presence of chemical components, which carry chromophoric groups as functional groups. In pulp & paper mill effluent the soluble color bearing portion is composed primarily of extractives and lignin degradation products, which are formed during pulping and bleaching operation of papermaking.

In large wood based mills, due to presence of chemical recovery installation, the discharged effluent color loads are significantly lower than agro based mills .In agro-based mill the discharged effluent contains black liquor, which is a colloidal mixture of phenolic compounds ranging from low molecular weight monomeric to high molecular weight polymeric substances i.e. lignin and its derivatives. These lignin-based compounds contribute to higher pollution loads in terms of COD and color. It is estimated that the quantity of lignin going through spent liquors varies from 300-400 kg/t, generating a color load of about 1400-1500 kg PCU

(Platinum, Cobalt Unit) per ton of pulp. It is estimated that 90% of the color is due to lignin.

The lignin present in the black liquor being discharged by agro-based mills contains high molecular weight fraction, which contributes to 70% of the total lignin. This high molecular weight fraction remains practically a recalcitrant and sometimes bioinhibitory too and passes on to the recipient stream, even after biological treatment.

During alkaline pulping, lignin condensation reactions are predominant at the end of cook, which results into high molar mass lignin entity. Comparing different molar mass components of lignins viz-in situ, the middle of pulping stages and at the end of cooking, it can be seen that the molar mass of lignin increases appreciably, which results in a complex polymeric structure of lignin in comparison to cellulose, hemicellulose and organic acids present in black liquor. The different molar masses at each stage of lignin starting from raw material to the black liquor and other organic molecule is shown in the **Table- 3**.

TABLE –3

MOLAR MASS OF LIGNIN AT EACH STAGE OF PULPING

Particulars	**Dalton**
Lignin:	
▪ In situ	1800-2000
▪ Middle of pulping	2000-30'000
▪ Black liquor	>30,000
Hemi cellulose	DR- 70-100
Degraded acids of lignin & Carbohydrates	Low molecular mass

The agro-based mills can be divided into two segments i.e. the mills equipped with chemical recovery and the mills having no chemical recovery system. In a large integrated agro-based mills having chemical recovery system, two third of the BOD load and 80- 90% of the colored substance have their origin from bleach plant, however in small agro based paper mills the major pollution load is from spent pulping liquor carrying 90 % color and 50 % COD due to presence of lignin which is almost completely bio-refractory.

5.0 REVIEW OF AVAILABLE TECHNOLOGIES FOR COLOR REMOVAL

The nature and composition of the effluent, degree of treatment required, operating costs and efficiency of treatment plants are some factors to be considered when deciding on the type of treatment needed for effluent color reduction. Various EOP treatment options, which have been tried, are confined to bleach effluents only. These methods included physico-chemical treatment method, physical separation method, UV irradiation methods, biological method etc. An overview showing the status of these technologies is summarized in **Table- 4** and is briefly discussed in following sections.

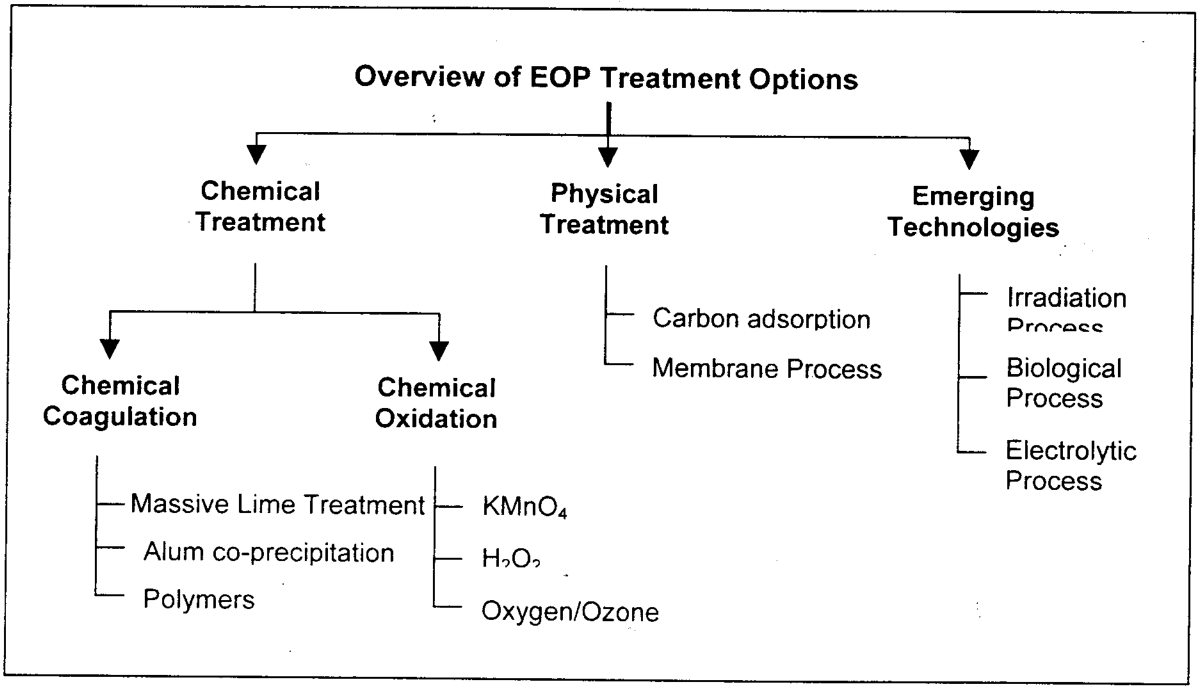


TABLE-4

STATUS OF VARIOUS EOP TREATMENT TECHNOLOGIES

TREATMENT TECHNOLOGY	STATUS
Chemical Precipitation Alum Lime Polymer addition followed by air flotation	**Full Scale application** On mill effluent On bleach & mill effluent On unbleached kraft mill effluent
Membrane Filtration	Mill scale application in E-stage effluent
Ozonation	Bench scale application with bleach effluents
UV Irradiation	Bench scale trials on bleach effluents
Electro-flocculation	Lab scale trials on bleach effluents
Biological Process Mycor Process Lacasse Treatment	 Bench Scale Development trial stage

6.0 CHEMICAL TREATMENT METHODS

6.1 Chemical Coagulation

Color in Pulp & Paper effluent generally exists as negatively charged colloidal particles due to which, removal can occur by coagulation with the aid of trivalent or divalent salts such as Ca, Fe or Al or by addition of cationic- type organic polymers. The first part of the process, the charge neutralisation is called 'coagulation' while the second part involving particle growth is termed 'flocculation'. The disadvantages of these systems are necessity to maintain absolute pH control and problems encountered in sludge handling.

6.2 Massive lime treatment

Massive lime treatment was very effective in achieving 90+% color removal for effluents. Lime dosage of 10,000 to 12,000 parts per million (ppm) were reported to produce a lime organic sludge having better dewatering characteristics than sludge from lower-lime systems. However, full scale efforts were abandoned due to high lime consumption and corrosion in chemical recovery system due to chlorides.

6.3 Alum co-precipitation

Though the use of alum for color removal is relatively cheaper, the sludge is difficult to handle and cannot be disposed off directly as landfill. $Al_2 (SO_4)_3$ as well as $Fe_2 (SO_4)_3$ or $FeCl_3$, are inefficient in removing the color at lower ranges. In case of $Fe_2 (SO_4)_3$ or $FeCl_3$ increasing the dosage level in an effort to promote the color removal efficiency may actually increase the color level.

6.4 Polymers

Certain organic polymers such as polyamines have been used to precipitate color from effluents. With a 600-mg/l-polyamine dosage, more than 85% color reduction can be achieved in bleach plant effluent. On the other hand, alum dosages of 600 mg/l brought about 54% reduction in color. Precipitation of color bodies using polyamines was more effective than alum but more expensive. Again sludge handling and disposal poses problem in both.

6.5 Chemical Oxidation method

This involves alteration of the structure of the color bearing groups in such a fashion as to prevent them to absorb in the visible range, by certain chemical oxidation. The chemicals capable of removing color are $KMnO_4$, H_2O_2 and oxygen/ozone. Depending on the oxidation potential, the efficiency of such chemicals for color removal is evaluated.

Among all the ozone has the highest efficacy towards color removal. It is reported that approximately 15 to 30-ppm color/mg of ozone is removed from bleach plant effluent. However, the high cost of ozone generation and operation remains a limiting factor for commercial installation for tertiary treatment of the effluents.

7.0 PHYSICAL TREATMENT METHODS

7.1 Carbon adsorption

Color removal by adsorption /absorption is centered around the use of either a granular or powdered activated carbon. The process is effective in removing color bodies of low molar mass. Numerous studies conducted to investigate color removal with granular activated carbon on both bleach plant and entire mill effluents have shown color removal efficiency over 90% but carbon requirements were very high and full scale applications could not be tried. Anticipated problems center around economic regeneration and disposal of spent carbon in addition to difficulty in selection of a suitable adsorption medium due to wide range of high and low molecular mass color components present in the effluents.

7.2 Membrane Processes

Membrane processes include ultrafiltration, reverse osmosis, dialysis and eleoctrodialysis. The process operates by the use of pressure and a semi permeable membrane. In ultra filtration membrane operate at a low pressure (10-20psi) and the separation of high molecular mass color materials depends on pore size of the membrane. Reverse osmosis can be visualized an extension of ultra filtration and operates at higher pressure (500-1000 psi). For color removal applications, the membranes size would nominally fall in the ultra-filtration range. Currently there are several full-scale applications of membrane technology at pulp and paper mills and removal efficiencies ranges from 80-95% however pre-filtration is required to remove the residual solids.

8.0 EMERGING TECHNOLOGIES

8.1 Irradiation Processes

Irradiation of the effluents in the presence of oxygen and/or hydrogen peroxide has been found to be promising for significant reduction in effluent color and toxicity levels (TOCl) in bleach plant effluents. Effectiveness is demonstrated by bench scale studies. Extensive research is being carried out to explore the feasibility of this process for industrial applications.

8.2 Biological processes

Decolorisation through the use of white rot fungi, or the mycelial color removal (MYCOR) process has been shown to be effective in removing color. Again, the longer treatment time requirement and the short active time of the reactor were constraints for continuous operation .In an other study it has been found that in the presence of the laccase enzyme, aeration transforms the phenolic compounds into an insoluble form, thereby precipitating them by alum or lime. Through the process in at developmental stage but may find applications, provided the enzyme can be produced an acceptable cost.

8.3 Electrolytic Process

Electro-coagulation and electro-flocculation are two techniques involving the electrolytic addition of coagulating metal ions directly from sacrificial electrodes. These ions coagulate with pollutants in water, in a similar manner to the addition of coagulating chemicals such as alum and ferric chloride and allow the easier removal of the pollutants. There is no addition of anions meaning no increase in salinity of the treated water. The system produces half to one third of the sludge. Greater activity means less metal ions required and a wider range of pollutants can be removed. In electro-flocculation the pollutants are removed by the bubbles, which are generated during the process, capturing the coagulated pollutants and floating to the surface.

The process has been successfully tried on small industrial scale for waste water treatment containing pollutants like fats, oils, grease (POG's) suspended solids, dissolved solids, bacteria, algae, heavy metal, cations, anions, BOD's, nutrient etc. However, lab scale experiments were conducted by Allan.M.Springar. etal and Kerala Pollution Control Board on bleach plant effluents using electro-flocculation process, which has resulted in color reduction to the tune of more than 85% with operational costs relatively much lower than any other treatment process. CPPRI has extensively worked employing this technique and very encouraging findings have been obtained. Based on laboratory and bench scale trials a Demo Pilot Plant of $1m^3/hr$ is being fabricated to study the techno economic feasibility of the process.

9.0 COLOR REMOVAL OPTIONS FOR AGRO-BASED PULP & PAPER MILLS-WORK CARRIED OUT AT CPPRI

The dark brown color of black liquor is mainly due to presence of lignin and degraded lignin compounds present in the liquor. The color generated in the black liquor from alkaline pulping of agricultural residues is substantial and only possibility of reducing the color remains with removal of lignin using suitable techniques. At CPPRI extensive work has been carried out on lignin removal from black liquor employing following processes-

- Chemical precipitation process
- Electro-flocculation Process.

9.1 Chemical Precipitation of lignin

The process involves treatment of black liquor with a coagulating and flocculating agent, which destabilized the lignin macromolecule present in black liquor as large colloidal macromolecule, which tends to settle down from the resultant liquor devoid of lignin. The precipitated lignin is very fluffy & slow settling and requires flocculating agent to make the precipitate settle down by agglomeration. Based on this technology developed by CPPRI a pilot plant of $10m^3/day$ for removal of lignin from black liquor has been installed at M/s Satia Paper Mills, Muktsar Punjab. Results of some trials undertaken are shown in **Table – 5**.

TABLE-5

CHARACTERISTICS OF BLACK LIQUOR, OVERFLOW AND SLUDGE VOLUME

Characteristics	Trial I			Trial II		
	Black Liquor	Over flow	Redn. %	Black Liquor	Over flow	Redn. %
Total Solids, % w/w	2.62	1.79	32	3.16	1.92	39
COD, g/l	24.88	10.95	56	26.5	12.44	53
Lignin, g/l	8.8	2.19	75	11.3	3.30	71
Color, PCU	49500	10200	79	52300	1046	80
Sludge Volume in underflow, %	18			19		

9.2 Color reduction of black liquor employing electro-flocculation process

Extensive work has been carried out during last three years in the area of color reduction employing electro-flocculation process, which has shown promising results for treating bleach effluent, black liquor including mechanical pulping effluent. The process has been studied in detail in laboratory and bench scale. Now a demo plant of 1m^3/hr is under fabrication to demonstrate the technology on continuous basis to find out its techno-economic feasibility. This project is being financed by Central Pollution Control Board.

9.3 Process Description

The process involves application of low voltage DC current to sacrificial metal electrodes having coagulating properties., like Al, Fe or Mg generating metal ions and gas bubbles simultaneously. The metal ion released combines with pollutant and gas bubbles generated captures the coagulant agglomerates resulting in most of the pollutant being floated to surface.

Reaction Mechanism

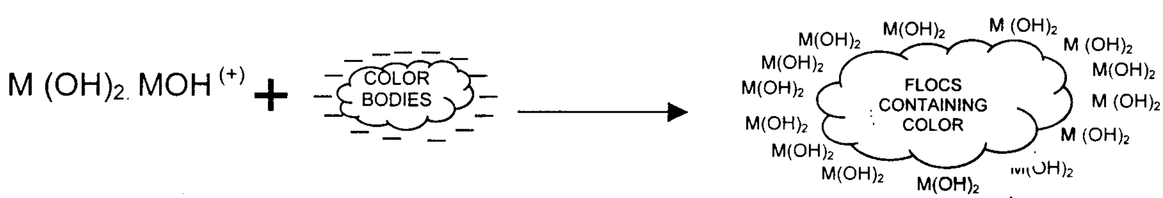
The total process is accomplished in three steps as shown below.

1st Step **At Anode** $M \xrightarrow[\text{Dissociation}]{\text{Electrolytic}} M^{2+} + 3\,e^-$

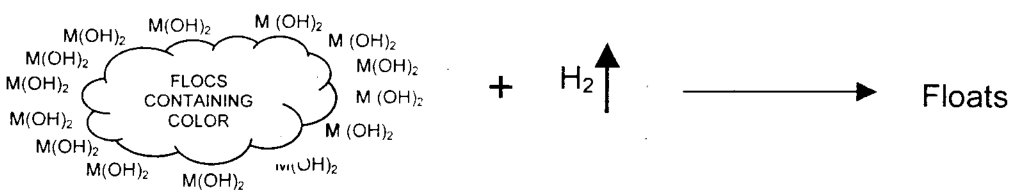
At Cathode $2e^- + 2\,H_2O \xrightarrow[\text{Dissociation}]{\text{Electrolytic}} 2OH^- + H_2\uparrow$

2nd Step $M^{2+} + OH^- \longrightarrow M\,(OH)_2.\,MOH^+$

Insoluble metal hydroxide



3rd Step



The results of bench scale studies using different mill black liquors are summarized below in **Table – 6** and **Table – 7**.

TABLE - 6

ELECTROFLOCCULATION OF BLACK LIQUOR CHARACTERISTICS OF TREATED & UNTREATED BLACK LIQUOR

Particulars	Mill I (Unbleached) (Bagasse Black Liquor)			Mill II (Bleached) (Mixed Black Liquor- Wheat Straw, Bagasse, Sarkanda)		
	Untreated	Treated	Red, η	Untreated	Treated	Red, η
pH	7.9	8.9	-	6.4	9.0	-
Conductivity, ms/cm	5.8	6.0	-	6.9	7.1	-
Total Solids, g/l	13	8	38.4	9.0	6.7	25.6
Lignin, g/l	3.87	0.98	74.6	2.83	0.28	90.1
Silica, g/l	0.415	0.06	85.5	0.21	0.046	78.1
R_2O_3, g/l	0.0012	0.002	-	0.22	0.053	76.0
COD	9801	5894	39.9	8250	2300	72.1
BOD	4622	3485	24.6	2460	2120	13.8
Color, PCU	6333	450	92.9	13163	300	97.7

TABLE - 7

ELECTROFLOCCULATION OF BLEACH EFFLUENT

characteristics of treated & untreated effluent

Particulars	Mill III (Bleached) Bleach Effluent (Mixed Hardwood)		
	Untreated	Treated	Red, η
pH	7.74	8.85	-
Conductivity, ms/cm	1.84	1.88	-
Total Solids, g/l	2.16	0.85	60.6
Lignin, g/l	0.23	0.017	92.6
Silica, g/l	0.034	Nil	100.0
R_2O_3, g/l	0.110	Nil	100.0
COD	1158	69.4	94.0
BOD	402	23	94.3
Color, PCU	1310	28	97.9
AOX	55	6.5	88.2

10.0 ECONOMICS VIABILITY OF THE PROCESS FOR TREATING BLACK LIQUOR AND COMBINED BLEACH EFFLUENT

To evaluate the power consumption for treating black liquor by electro-flocculation process batch trials were conducted, using different volumes of black liquor, based on the values obtain in actual a regression curve was obtained. From the regression curve it was analyzed that power varies logarithmically with respect to volume of black liquor taken. Based on the regression curve analysis following equation has been derived:
Power = 0.0232 Ln (Volume) + 0.0605 (Regression coefficient R^2 = 0.9832).
According to equation power required for treating 1 m^3 of black liquor is 0.22 Kwh. Cost analysis for mill producing unbleached kraft paper is shown in **Table–8**

TABLE - 8

Pulp Production, tpd	40
End Product	Unbleached kraft
Black liquor generated, m^3/day	1600
Solid Concentration, gpl	13.0
Lignin Concentration, gpl	3.8
Initial Color, PCU	6333
Optimum pH	6.0
Optimum Color Reduction Efficiency, %	94.0- 96.0
POWER	
Power Consumption, Kwh/m^3	0.22
Power Consumption, MWh/day	0.35
Power Cost, Rs./day (@ Rs. 4.00/kwh)	1408
Power Cost, Rs./ ton of pulp	**35.2**
CHEMICALS USED	
H_2SO_4 required, kg/m^3	0.3
H_2SO_4 required, kg/day	480
Cost of H_2SO_4, Rs./ton of pulp (@ Rs. 10/kg)	**120**
Iron introduced to the system, kg/m^3	0.14
Iron introduced to the system, kg/day	224
Cost of Iron, Rs./ton of pulp (@ Rs. 25/ kg)	140
Total cost of treatment, Rs./ton of pulp	**295.2**

Similarly to evaluate the power consumption for treating combined bleached effluent by electro-flocculation process batch trials were conducted, using different volumes of bleached effluent, based on the values obtain in actual a regression curve was plotted. From the regression curve it was analyzed that power varies logarithmically with respect to volume of bleached effluent taken. Based on the regression curve analysis following equation has been derived: Power = 0.0133 Ln (Volume) + 0.0127 (Regression coefficient R^2 = 0.8645) According to equation power required for treating 1 m^3 of bleached effluent is 0.041 Kwh. Cost analysis for mill producing writing/printing paper is shown in **Table - 9**

TABLE – 9

Pulp Production, tpd	300
End Product	Writing/printing
Black liquor generated, m^3/day	5000
Solid Concentration, gpl	2.6
Lignin Concentration, gpl	0.18
Initial Color, PCU	1133
Optimum pH	6-7
Optimum Color Reduction Efficiency, %	96-98
POWER	
Power Consumption, Kwh/m^3	0.041
Power Consumption, MWh/day	0.20
Power Cost, Rs./day (@ Rs. 4.00/kwh)	820
Power Cost, Rs./ ton of pulp	**3.00**
Iron introduced to the system, g/m^3	0.3
Iron introduced to the system, kg/day	1.44
Cost of Iron, Rs./ton of pulp (@ Rs. 25/ kg)	**0.90**
Total cost of treatment, Rs./ton of pulp	**4.00**

11.0 CONCLUSION

The problem of color in liquid effluent is a major cause of concern for Indian Paper Industry. Under CREP Directives notified by MoEF & CPCB the industry has been asked to contain the color loads in discharge effluent by 2008. Currently there is no technology available commercially which is economically viable. Moreover the issue of color in effluents is more pronounced in India due to the presence of chloro-organics in bleach effluent and discharge of black liquor by agro-based mills which do not have Chemical Recovery system. CPPRI in its endeavor has taken up the challenge and is working on the problem for last three years. A number of available technologies were evaluated.

It has been found that color reduction efficiency of each technology is highly influenced by the molecular size of the organic pollutant in the effluent. For treating black liquor, which contains lignin as a macromolecule, it is found that the reduction efficiencies are better with electroflocculation process than lignin removal process, however the economic viability of electroflocculation has yet to be established on pilot scale. Under CPCB sponsorship a project is in execution by CPPRI to demonstrate electroflocculation process on pilot scale of 1 m^3/hr capacity. The fabrication of the plant is in process and shortly the plant will be installed in Century Pulp & Paper Mills, Lalkuan, which is our industrial partner and has contributed Rs. 10 Lacs (30% of project cost) to this project.

STATUS OF EFFLUENT TREATMENT PRACTICES IN AGRO BASED PAPER INDUSTRY

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About the Author

Dr. M.K. Gupta is a senior scientist working in the area of Environmental Management for the last thirteen years.

He has a wide experience in the area of environmental management including bio-energy recovery from wastes, performance evaluation and trouble shooting of effluent treatment plants, environmental auditing etc. He has been associated as a team member with the commissioning of full-scale biomethanation plant for recovery of bio-energy from black liquor. He has also been actively associated with CPCB, IARPMA, and IPMA, sponsored projects

He has undergone an advanced training at Netherlands on anaerobic treatment of pulp & paper mill effluent. With around 20 publications to his credit, he has also been involved in preparation of a number of R& D reports, training and course manuals.

PRESENT PRACTICES OF EFFLUENT TREATMENT IN AGRO BASED PAPER MILLS

M.K.Gupta,S.Mishra,Mohd.Farid,Charu Sharma

1.0 INTRODUCTION

Indian paper industry is one of the oldest and core industry in India. It has made tremendous growth in last 50 years. Initially the industry was based on woody raw material but a severe shortage of paper and forest based raw materials in 1970 has led to establish a number of mills based on locally available non conventional agro residues raw materials. Presently more than 600 mills are in existence in India. The Indian pulp & paper industries are generally categorized into large, medium and small scale depending on the scale of operations & fibrous raw materials used as indicated in **Table-I**

TABLE – 1

CATEGORY OF INDIAN PULP & PAPER MILLS

Category	Scale of operation, tpd
Small	5-30 (Mostly recycled fiber (RCF) based)
Medium	30-100 (Mostly agro residues and RCF based)
Large	Above 100 (mostly wood based)

At present the installed capacity of Indian pulp & paper industry is around 7.5 million tonnes and the present level of paper & board production is about 5.8 million tonnes. The production of paper and paper board in India is shown in **Table-2.**

TABLE –2

PRODUCTION OF PAPER & PAPER BOARD IN INDIA

Raw material	No. of mills	Installed capacity (million tonnes)	Production (million tonnes)	Prod. %
Wood based	28	2.85	2.26	39
Agro based	178	2.40	1.80	31
Others (RCF etc.)	418	2.25	1.74	30
Total	624	7.50	5.80	100

From **Table 2** it is clear that agro based mills are playing a significant role in fulfilling the demand of paper in the country. Now time has come to have more and more dependence on agro based raw materials and recycled fibers primarily due to limited availability of wood based raw materials.

2.0 ENVIRONMENTAL LEGISLATION FOR AGRO BASED MILLS :

The discharge standards in are generally stipulated for small & large pulp & paper industries based on size of mills, quality of end products as well as mode of discharge of effluent. The standards for discharge of effluent for pulp & paper industry under Environmental Protection Rules 1986 prescribed by Central Pollution Control Board (CPCB) are given in **Table 3**.

Table –3

LIQUID DISCHARGE STANDARDS FOR INDIAN PULP & PAPER MILLS

Parameters	**Discharge standards**	
	Small Mills	**Large Mills**
Volume , m^3/t paper	Agro based : 200 (150) Waste paper 75 (50)	Writing & printing : 200 (150)* Rayon grade/ newsprint : 150
pH	5.5 – 9.0	7.0 – 8.5
BOD $_5$ at 20^0C , mg/l	30 (if discharged into inland surface water) 100 (if discharged on land)	30
COD, mg/l	Not specified	350
SS, mg/l	100	50
TOCl, kg/t $_{paper}$	Not specified	2.0
SAR	26	0

***figure in bracket are for new mills set up after 1992**

With the present status of technology, these discharge norms are practically unachievable in most of the agro based mills, particularly in mill where chemical recovery system is not in practice due to some technical and economical reasons.

3.0 CORPORATE RESPONSIBILITY FOR ENVIRONMENTAL PROTECTION

With the introduction of open market economy in the country and ever increasing **"environmental challenges"** the small agro based mills are at crossroads as far as its survival is concerned. In view of changed environmental scenario & magnitude of pollution problems **Ministry of Environment & Forests** have proposed the concept of **"corporate responsibility"** which aims at time bound joint efforts by industry as well as regulatory authorities to make these agro based mills environmentally compatible. The main areas in these category of small mills is as follows-

- Installation of chemical recovery system for bleached grade of paper for compliance of standard of BOD, COD & AOX
- Upgradation of effluent treatment plant (ETP)
- Conservation of water
- Utilisation of treated effluent for irrigation
- Colour removal (Only for mills discharging into surface waters)

4.0 ENVIRONMENTAL ISSUES BEFORE AGRO BASED MILLS

The various process operations right from raw material handling to finished product, paper-manufacturing process exerts environmental pressure in one way or the other. The magnitude of pollution load generated from different agro based mills vary considerably and depends on the size of mill, raw materials used, process technology employed etc. With increasing public awareness and stricter environmental legislations coming into force, small mills are facing serious challenges for their sustenance and existence and as such environment compatibility has become the top agenda of these mills for their sustenance.

The major environmental issues associated with these mills and which needs immediate attention are:

- Discharge of pulping spent liquor in absence of chemical recovery system.
- High volume of effluent.
- High level of colour in effluents.
- Discharge of high level of AOX related chlorinated phenolic compounds

- Inadequate effluent treatment facilities
- Solid wastes disposal

5.0 WATER CONSUMPTION IN AGRO BASED MILLS

The consumption of water in agro based pulp and paper industry is relatively high and varies from 150-225 m^3/ton of paper and out of which 85-90 % is discharged as effluent. The reasons for high consumption of water in agro based mills are: -

- Use of mixed fibrous raw materials.
- Poor drainage characteristics of agro residues pulp.
- Poor washing efficiency of existing pulp washing system.
- Use of obsolete technology and equipments and multiple number of paper machines.
- Ease of water availability.
- Use of second hand imported machines, which are not designed for Indian law materials.
- Frequent changes in paper quality on machines.

Besides above specified technical reasons for high consumption of water in agro based mills, some other reasons which play a major role in undue increase of water consumption are: -

- Poor water management system
- Lack of personal interest & individual responsibility
- Carelessness & negligence.
- Non acquaintance

Reduction in water consumption and wastewater generation can be achieved by adopting a systematic approach, adequate supervision, motivation, incentives & setting of targets etc. The establishment of wastewater accounting system will help in developing and implementing an integrated water usage programme. Moreover the discharge norms stipulated and promulgated by environmental regulatory authorities for Indian industries are still on the basis of the concentration of pollutants not directly on the basis of the pollution load discharged per ton of product. Some of the basic approach for reduction of wastewater generation are: -

- Minimization of generation through in plant control measures
- Segregation of streams
- Reuse & recycling of effluents

6.0 MAGNITUDE OF POLLUTION LOAD

The agro based pulp and paper mills in one way are environment friendly in terms of nature of raw material used by them and help to conserve the forest based woody raw material, and promote afforestation but on the other hand they are associated with discharge of high magnitude of pollution load. The major contribution comes from pulping spent liquor, which is discharged either without treatment or partial treatment along with other wastewaters. The pollution loads generated in agro-based mills are given in **Table - 4.**

TABLE – 4

THE CHARACTERISTICS AND POLLUTION LOADS GENERATED IN AGRO BASED PAPER MILLS

Parameters	**Agro based mill with recovery system**	**Agro based paper mills without recovery system**
Flow , m^3/t paper	150-200	175-225
pH	6.5- 9.5	6.0-9.0
SS, mg/l	100-1250	1200-1800
BOD_5 at 20^0C, mg/l	300-500	800-1200
COD, mg/l	1000-1500	2500-4000
COD : BOD ratio	3.0-3.3	3.0-3.3
Colour, PCU	400-800	8000-12000
Pollution loads, kg/t paper :		
SS	150-200	250-400
BOD	50-100	150-250
COD	120-250	500-800

The pulping spent liquor is the highly polluted stream and it contributes more than 70% of total pollution loads. The treatment of pulping spent liquor is one of the major problems as it contains lignin compounds (200-500 kg/ton paper), which are almost biorefractrory in nature. However, pulping spent liquor contains an appreciable amount of biodegradable organic matter like carbohydrates, organic acids etc.

The bleach plant effluent also contributes a significant amount of pollution load and is a major source of pollution particularly in mills having chemical recovery system. Generally bleach plant effluent is considered most toxic stream due to presence of chloro-organic compounds formed during bleaching of pulp with chlorine containing chemicals. In India most of the agro based pulp mill are still continue the use of elemental chlorine for bleaching of high kappa no. pulp due to some economical reason, which results in generation of high level of AOX compounds. The level of AOX in agro residue based mills ranges from 3 to 7 kg AOX/ton pulp. Therefore, bleach plant effluent is not considered suitable for the treatment by anaerobic process. The only way to treat bleach plant effluent is aerobic treatment process.

The paper machine back water is comparatively less polluted and a major part of it is recycled after its clarification. The pollution load generated from three main sections are given in **Table - 5**

TABLE –5

CHARACTERISTICS AND POLLUTION LOADS OF MAJOR STREAMS IN AGRO BASED PAPER MILLS (50 TONNES/ DAY)

Parameters	Different waste water streams		
	Pulping	Bleaching	Paper machine
pH	8.0-10.0	6.0-7.5	5.0-6.0
Temperature, ^{0}C	50-60	30-40	30-40
Flow, m^3/d	4000-4500	3500-4000	2500-3500
Total solids, mg/l	12000-15000	4000-6000	3000-4000
SS, mg/l	2500-3000	1500-2000	2000-3000
BOD, mg/l	3500-4000	800-1200	250-350
COD, mg/l	10000-14000	3000-4000	600-1000
AOX, mg/l	-	50-80	-
Pollution loads generated:			
SS, kg/day	10000-13500	5250-8000	5000-10500
BOD, kg/day	14000-20500	2800-4800	625-1225
COD, kg/day	40000-63000	10500-16000	1500-3500
AOX, kg/day	-	150-300	-

7.0 EFFLUENT TREATMENT PRACTICES IN AGRO BASED MILLS

The overall situation of agro based mills without chemical recovery is not very satisfactory because these mill are not able to recover pulping chemical from their pulping spent liquor which causes a major threat to environment. This pulping spent liquor contribute more than 70% pollution load in terms of COD, BOD etc and it also exerts more than 80% colour load from these mills. Generally these mills have segregated this most polluting stream from rest of effluents and if these mills are having no limitation of space, then storage of this black liquor for 8-9 month is in practice and these mills discharge this black liquor during flood/in rainy season reduce its impact on receiving stream to a greater extent. For the treatment of other streams, these mills have conventional treatment system consisting of aerated lagoon or activated sludge process. But performance efficiency of the effluent treatment system is normally observed below optimum level due to:

- Relatively high operation cost due to huge consumption of electricity and chemicals (Nutrients, Urea & DAP)
- Overloading and/or shock loading to aerobic bacteria
- Negligilance in operation of ETP due to non productive nature of ETP
- Usually ETP's are treated as a liability.

The general layout of existing ETP in these category of mills is given in **Figure-1**

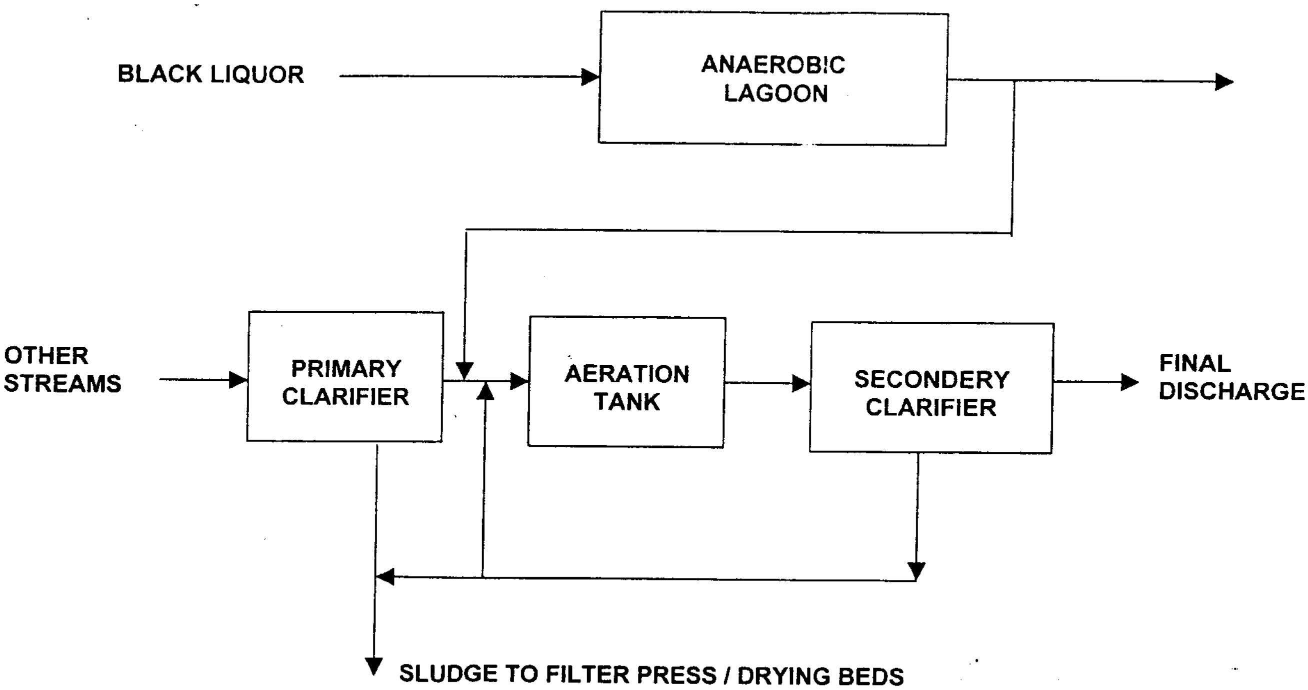

FIG-1: PRESENT PRACTICES OF EFFLUENT TREATMENT IN AGRO BASED PAPER MILLS

8.0 EFFLUENT TREATMENT PROCESSES

Due to increased public awareness & pressure from environmental regulating agencies now it has been become mandatory for agro based mills to treat their effluent in well defined manner to achieve the stipulated discharge norms. Various treatment processes used by agro based mills are described below:

8.1 Primary Treatment Processes

Primary treatment processes are used for removal of coarse and suspended materials. Manual or mechanized bar screens are used for removal of coarse materials while sedimentation tank or clarifiers are used for removal of suspended material. The efficiency of settling tank / clarifier depends on settling behavior of suspended particles as well as on surface overflow rate (SOR) and residence time. Usually a retention time of 4-6 hrs is required with a surface overflow rate of 15-20 m^3/m^2/day for efficient operation of settling tank / clarifier.

9.0 SECONDERY (BIOLOGICAL) TREATMENT PROCESSES

Biological treatment processes are primarily used for removal of dissolved & colloidal organic matter from waste waters. Usually biological processes are preceded by sedimentation to physically remove suspended particles. Biological processes are divided into two groups based on their oxygen requirement.

- **Aerobic biological treatment processes** take place in presence of oxygen. The oxygen may be supplied to system through aeration equipments.
- **Anaerobic biological treatment processes** take place in absence of oxygen. Mostly reactions take place in a closed vessel except anaerobic lagoon, which are open to atmosphere.

10.0 AEROBIC BIOLOGICAL TREATMENT PROCESSES

Aerobic biological waste treatment involves the utilization of a mixed population of micro organisms to convert organic contaminants to new cellular material. At the same time a portion of the organic contaminants is oxidized to carbon dioxide and water. Number of biological processes has been developed for the treatment of wastewaters. Among them only aerated lagoon & activated sludge process are in application for the treatment of agro based mills effluents.

11.0 AERATED LAGOON

An aerated lagoon is a stabilization pond that depends on mechanical or diffused aeration equipment. Two types of aerated lagoon may be considered for use, completely mixed and partially mixed.

Completely mixed aerated lagoon keeps all of the incoming solids and biological solids produced from waste conversion in suspension. The essential function of this type of aerated lagoon is waste conversion. Depending on the detention time, the effluent may contain about one third to one half the value of the incoming BOD in the form of all tissue. Settling is required prior to discharge in a receiving stream. Partially mixed aerated lagoon employ aeration devices to maintain aerobic conditions in the upper zone of the ponds. A large portion of the incoming solids and the biological solids from waste conversion settle to the bottom where they eventually undergo anaerobic decomposition. Partially mixed ponds are designed to maintain a minimum of 2-3 mg/l dissolved oxygen in the upper zone of the liquid.

12.0 CONVENTIONAL ACTIVATED SLUDGE PROCESS

The process consists of an aeration tank; a secondary clarifier and sludge recycle line. The process utilizes a mixed microbial population in the aeration tank to convert the organic matter into cellular material, which can be subsequently separated from its suspended liquor in the secondary clarifier. The cellular material in the aeration tank is called the activated sludge or mixed liquor suspended solids **(MLSS)**, which consists of an activated mass of different species of microorganism. A portion of the settled sludge in the clarifier is recycled to the aeration tank while the excess sludge is wasted at a rate proportional to the rate of new cellular production. The flow diagram of conventional activated sludge process is given in **Figure-1.**

Design criteria for conventional activated sludge treatment facilities are:

- Organic loading :0.2 -0.5 kg BOD_5/kg MLSS/day
- Volumetric loading :0.4-1.8 kg BOD_5/m^3/day
- Sludge retention time :5-15 days
- Hydraulic Detention time :6-8 hrs
- MLSS concentration :2000-4000 mg/l
- Sludge return ratio :25-100% of process effluent
- Water depth :3-5 meter
- Oxygen requirement :1.2-1.5 kg O_2/kg BOD load
- Sludge production :0.5-0.7 kg/kg BOD_5 removed

13.0 FACTORS AFFECTING THE PERFORMANCE OF ACTIVATED SLUDGE PROCESS

13.1 Sludge volume index (SVI)

The sludge volume index (SVI) is the unit volume of the activated sludge (in ml/g) after a half an hour settling of the mixed liquor in a one liter Imhoff Cone. The volume of. SVI in various treatment cases are, generally in the range of 30-40 ml/g. With higher SVI values a difficulty arises in the performance of the secondary clarifier. One of the frequent cause of activated sludge bulking is excessive growth of filamentous microorganism in a mixed culture.

$$SVI = \frac{\text{ml settled sludge} \times 1000}{\text{suspended solids, mg/l}}$$

If	SVI <50	settling excellent
	Up to 100	settling quite well
	<150	settling reasonably well\

13.3 F/M ratio (food to microbes ratio)

The low F/M ratio (up to 0.7 gm BOD/gm MLSS/d) is applicable for activated sludge process with a high degree of BOD (90%) removal. At high F/M ratio (up to 5.0 gm BOD/gm MLSS/d), BOD (53-75%) removal is low and under such cases the demand of dissolved oxygen is quite high.

$$\text{F/M ratio} = \frac{\text{BOD load, kg/day}}{\text{MLSS content in Aeration Tank, kg}}$$

13.4 MLSS (Mixed Liquor Suspended Solids)

Mixed liquor suspended solids are composed of active microbial mass, non active microbial mass, non biodegradable organics and inorganics mass. The level of MLSS varies widely for various modification of activated sludge process and under various modes of operation of the same modification. Generally, the higher levels of MLSS call for higher oxygenation capacities in the system and require large secondary clarifiers. Optimization analysis indicates that the most economical and attractive range of MLSS exists between 2000-4000 mg/l.

13.5 Dissolved oxygen

Activated sludge treatment plant operates at high oxygen levels, normally around the saturation point. For consistently good treatment result it is important to maintain the required level of dissolved oxygen concentration in the aeration tank. The D.O. levels in aeration tank affect the net sludge production.

13.6 Sludge age

In activated sludge treatment of waste water, mean solid residence time (SRT) in aeration tank, is more important than waste water aeration time. The sludge age must be maintained at a level which is greater than a maximum generation time of the microorganism. Normally sludge age for pulp and paper industry waste water treatment are 5-10 days.

$$\text{SRT (in days)} = \frac{\text{Total weight of solids in biological system}}{\text{Total weight of solids leaving the system/day}}$$

14.0 OPERATION & MAINTENANCE OF ACTIVATED SLUDGE PLANT

- A minimum dissolved oxygen level 1 mg/1 preferably 2 mg/1 should be maintained throughout the aeration tank. Excess dissolved oxygen does not adversely affect the performance of the system. It should be checked at various point in the aeration tank at least twice a day.

- It is essential to check and adjust the concentration of MLSS to the required level at least twice in weak.

- Regular wasting of sludge should be carried out to maintain a desired concentration of MLSS in aeration tank. This can be achieved by a continuous or batch wasting of sludge from sludge return line.

- The 30 minutes sludge settling test should be carried out daily. Any variation in settled sludge volume indicate a change in quantity and quality of MLSS in the aeration tank. An increase in the settled volume would indicate that either the sludge concentration is increasing and some sludge wasting is required or the quality of sludge is deteriorating. The sludge volume index (SVI) can also be determined to characterize the compactness and settlability of the sludge flocs. A good settling sludge has an index of less than 100 ml/g.

- Periodic inspection and replacement of worn mechanical parts, regular cleaning, oiling and greasing of aeration devices, compressors, pumps etc are essential to maintain stable, reliable and efficient operation of the treatment plant.

15.0 ANAEROBIC TREATMENT PROCESSES

Anaerobic treatment system is not considered until recently as viable technology for water pollution control in pulp and paper sector because of following reasons'.

- Too dilute waste water for feasible anaerobic treatment
- The often low strength in soluble COD .
- The assumed low anaerobic biodegradability of this COD
- The presence of toxic chemical such as chlorophenolic compounds which are thought to inhibit anaerobic degradation

The development of high rate anaerobic treatment systems has enabled anaerobic treatment of dilute wastewaters since the biomass retention is no longer coupled to the hydraulic retention time. Anaerobic process was previously considered too sensitive to inhibitory compounds. The recent advances in good understanding of microbiology and process insight make anaerobic process as proven technology to treat the complex industrial effluent including pulp and paper mills effluents. The anaerobic treatment processes offer several economical advantages making system more attractive. These include the following :

- lower production of biosolids per unit of organics removed.
- lower requirements of nutrients (nitrogen & phosphorous) as a consequence of less biosolids are produced.
- No aeration is required, significantly reducing over all treatment system power requirement.
- The biogas produced is recoverable as a by product (fuel source) typically 0.35- 0.40m^3/kg COD removed.
- Anaerobic system can be left dormant without feed for long periods of time without severe deterioration in biomass properties and can be brought back into operation at normal treatment efficiency within very short period of time.

- Very high active biomass densities (3 % to 5% and higher) can be achieved under favorable conditions in anaerobic reactors.
- Increased resistance to organic shock loads.
- Less capital investment.
- Less land requirement.

The most significant drawbacks which have hampered the widespread application of anaerobic system for waste water treatment are related to the following:

- Low growth rates and yields of anaerobic bacteria.
- High concentrations of biomass is required to achieve high reaction rates.
- Long startup periods needed to achieve high concentration of active biomass. Revival of methanogenic bacteria after a toxic load may be time consuming.

15.1 Anaerobic Treatment Systems Configuration

The anaerobic treatment system may consist of anaerobic lagoons or different kind of high rate reactors. As discussed above the rate of cell synthesis is low in anaerobic processes and a long retention time is required. In agro based paper mill anaerobic lagoon, contact reactor and UASB reactors are in application for treatment of pulping spent liquors.

15.2 Anaerobic Lagoon

In anaerobic lagoon usually high strength streams are discharged. A long retention time of 15 to 30 days is usually required. But if the wastewater contains easily degradable substances, a lower retention time may be effective. A typical design criteria for anaerobic lagoon is given below:

Retention time, days	: 30-60
Volumetric loading rate, (VLR, Kg COD/m3/day)	: 0.3-0.5
COD reduction, %	:20-30
BOD reduction, %	:40-50

15.3 Contact Reactor

These consists of a continuously stirred tank reactor and a sedimentation stage, where suspended solids are removed and recycled to the anaerobic reactor. Efficient sludge separation can pose a problem, since the sedimentation is often disturbed by the production of methane. This can be improved by degasification and flocculation of the effluent before sedimentation. The system is sensitive to high inlet concentration of suspended solids and temperature variations. Lamella clarifiers are often better than normal clarifiers because it has shorter sludge retention time.

15.4 UASB Reactor

The upflow anaerobic sludge blanket reactor utilizes an upward hydraulic flow, through a bed of anaerobic biomass. It employs solid liquid separation system at the top of the reactor surface. The rising waste water stimulates microbial growth. Baffles under the sedimentation zone deflects the gas to collector areas and allow the liquid to enter in this zone without being disturbed by the gas. The sludge particle separate and settle back to the reactor by gravity.

16.0 TERTIARY TREATMENT PROCESSES

To meet the stringent discharge norms, now it has been become essential for agro based mill to treat their effluent more efficiently. Since common practices used for treatment of effluent consisting of primary clarifier, activated sludge process has limitation for removal of colour, COD & AOX due to presence of biorefractery compounds like lignin and its derivatives. Tertiary treatment which consists of physico chemical process is quite effective in removal of these pollutants at a higher cost of treatment. Major limitations in application of tertiary treatment in Indian paper industries are:

- Increase in the level of dissolved solids, which may affects the quality of recipient stream.
- Disposal of chemical sludge is more difficult.

17.0 CONCUSIONS

The survival of agro based mills has become very difficult particularly for the mills which have low scale of operation and unable to go for chemical recovery system. The option left for such mills is to use recycled fibre in greater extent to meet the discharge norms laid by regulatory agencies. The quality of indigenous recycled fiber is not sufficient to make quality papers. On the other hand rising prices and uncertainty in supply of uniform quality of imported recycled fiber limits the economical use of imported recycled fiber in fiber furnish in these agro based mills. The present practice of effluent treatment i.e. activated sludge process preceded by primary clarifier is capital intensive and not sufficient to meet discharge norms with black liquor laden effluent. .Hence it has become necessary to make effluent treatment system more effective through combination of anaerobic and aerobic process and implement schemes for water recycling in larger extent to reduce the pollution load at source. Recycling of water not only reduce the water consumption but also help in improving the performance of effluent treatment system through implementation of secondary and tertiary effluent treatment processes in more effective manner .

TESTING METHODS

ENVIRONMENTAL MONITORING - NEED & SIGNIFICANCE OF WASTEWATER, AIR & SOLID WASTE ANALYSIS

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ENVIRONMENTAL MONITORING - NEED & SIGNIFICANCE OF WASTE WATER, AIR & SOLID WASTE ANALYSIS

N.Endlay ,S.Mishra ,S.Gaur & S.Panwar

1.0 INTRODUCTION

Environmental monitoring (Effluent, Air & Solid Waste) is an important tool for evaluation of performance of the process, control systems (ETP, Cyclone, ESPs etc), identification of areas for resource conservation and utilization as well as assessment of overall environmental status of the mill and its impact on the surroundings. The present article discusses in brief the important pollutional parameters usually measured in environmental monitoring.

2.0 EFFLUENT MONITORING

2.1 Sampling

The starting step of wastewater monitoring is sampling. Representative sampling is of utmost importance for accuracy, reliability and reproducibility. The methods of effluent sampling can be classified as:

- **Grab**
- **Composite**

Grab sample represent the composition of the source at particular time and place. Usually employed when the source is fairly consistent /constant in composition. Composite sampling includes a mixture of garb samples collected at different time from the same source

Sampling can be carried out manually, mechanically or automatically. The advantage of manual sampling is that personnel can observe visible changes in the effluent and can monitor the ETP more effectively.

2.2 Flow measurement

Flow measurement is of utmost importance to monitor the pollution load as well as prevent over loading of ETP. Flow measurement also helps in quantifying the pollution load. With emphasis being given on calculating the pollution load per tonne of paper in new discharge standards, accurate flow measurement has become important. Various manual techniques for flow measurement include-

- Float velocity method
- Weirs
- Notch (V / Triangular / Rectangular)
- Prashall Flume

The details of these methods can be referred from any standard book on effluent treatment or **Standard Method for Examination of Water & Waste Water (APHA-AWWA-WPCF)**..In addition various automatic ultrasonic / flow measurement devices are available

2.3 Preservation of samples

Sample preservation is difficult as almost all preservatives interfere with some of the tests. Storage at low temperature (4°C) is the best option to preserve the sample up to 24 hrs. Methods of preservation are limited to Ph control, chemical addition, refrigeration & freezing. The methods are generally intended to retard biological action, hydrolysis of chemical compounds and complexes, volatily etc. Some of the preservation methods are indicated in **Table -1**

2.4 Pollution parameters

The pollution parameters can be classified into:

2.4.1 Physical Parameters

These include Temperature , Suspended Solids, Dissolved Solids, Color,Odor

2.4.2 Chemical Parameters

These include Organic/Inorganic, BOD, COD, TOC, pH, Acidity,Alkalinity, Heavy Metals, Oil &Grease ,Hardness etc

2.4.3 Biological Parameters

These include Toxicity, Pathogenic organism

The significance and the principle of some of the important physico-chemical & biological pollutional parameters is discussed as under:

a. pH VALUE

Significance

Measurement of pH is one of the most important and frequently used test in waste water analysis . Practically every phase of water supply, waste water treatment & corrosion control is pH dependent. At a given temperature the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion activity.

b. Total Suspended Solids (TSS)

Significance

Presence of high concentration of TSS may adversely affect the effluent quality both from aesthetic considerations and also from point of view of its discharge into the recipient bodies. The suspended solids when discharged into streams get degraded over a period of time under aerobic conditions resulting in depletion of dissolved oxygen in water while when degraded under anaerobic conditions methane generation may take place which is toxic to aquatic life. Similarly when discharged on land they may clog the soil pores adversely affecting the soil properties and making it unsuitable for cultivation. The level of suspended solids in clarifier overflow is also indicative of the performance of primary / secondary clarifier.

Principle

A well-mixed sample is filtered through a weighed standard glass-fiber filter and the residue retained on the filter is dried to a constant weight at 103 to 105°C. The increase in weight of the filter represents the TSS. If the suspended material clogs the filter and prolongs filtration, the difference between the total solids and the total dissolved solids **(TDS)** can be considered as an estimate of the total suspended solids.

$$\text{TSS mg/l} = \frac{(A - B) \times 1000}{\text{Sample volume, ml}}$$

Where, A= Weight of filter + dried residue (mg) & B= Weight of filter (mg.)

c. Chemical Oxygen Demand (COD)

Significance

The chemical oxygen demand **(COD)** is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For sample from a specific source, COD can be related empirically to the Biological Oxygen Demand **(BOD)**, organic carbon, or organic matter.

Principle

A sample is refluxed with sulphuric acid and a known volume of potassium dichromate **($K_2Cr_2O_7$)** and is finally titrated with ferrous ammonium sulfate **(FAS)** to determine the amount of $K_2Cr_2O_7$ consumed. The oxidizable organic matter is Calculated in terms of oxygen demand by the following formula.

$$\textbf{COD as mg } O_2/l = \frac{(A-B) \times N \times 8000}{\text{ml sample}}$$

Where, A = ml FAS used for blank., B= ml FAS used for sample and

N = Normality of FAS.

d. BIOCHEMICAL OXYGEN DEMAND (BOD)

Significance

BOD is the measure of degradable organic material present in a water sample and can be defined as the amount of oxygen required by the microorganisms in stabilising the biologically degradable organic matter under aerobic conditions at specified conditions. Generally the incubation period in for BOD determination is 5 days at 20° C, in Scandinavian countries it is 7 days. Recently CPCB has approved BOD determination with incubation period of 3 days at 27° C.

Principle

The BOD test is performed in the laboratory by diluting the waste water sample with water containing sufficient amount of dissolved oxygen and nutrients, and measuring the depletion in dissolved oxygen after a fixed incubation period at a particular temperature. In BOD process the organic matter present in the sample is metabolized primarily by bacteria in the early stages. Some of the organics are oxidized which can cause oxygen uptake and remainder are transformed into new bacterial cell. As the supply of external substrate become scare, some bacteria die out of starvation and other predate on living and dead bodies present. If protozoan are also present, they can also contribute to the removal of organic matter present in the sample. As the food resources of bacteria diminish to small amount because of predation, protozoan population will eventually become dominant. The original organic matter is recycled through a number of organisms with oxygen being consumed as the organic matter is metabolized for each biomass transformation. Oxygen is utilized for metabolism until it is exhausted or the amount of organic matter decreases to negligible amounts and the last aerobic microorganism die.The phenomenon is depicted in **Fig.-1**.

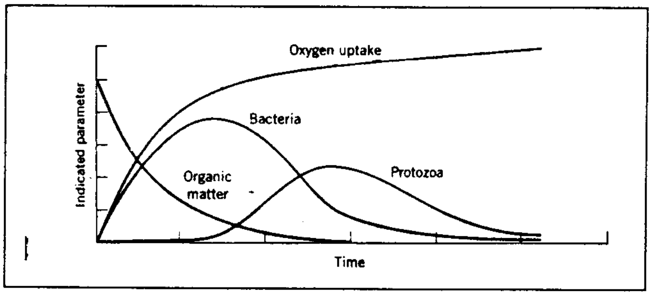

FIG-1

The determination of BOD is carried out by following formula

$$\text{BOD mg/litre} = \frac{(D_1 - D_5) - (B_1 - B_5)}{\%\text{ of sample.}} \times 100$$

Where:

D_1-D_5 = Depletion in dissolved oxygen of the sample during the incubation period.

B_1-B_5 = Depletion in dissolved oxygen of the blank during the incubation period.

e. COLOR

Significance

Measurement of colour as a pollutional parameter has not been given due importance till recent past. Even no discharge limits for colour have been specified by regulatory authorities. However in recent times color reduction in mill effluents has become a prominent issue due to increasing public awareness, changes in local regulations and aesthetic considerations. Color interferes with aquatic life by limiting light transmittance and also contributes to taste problems and increases stability of some bivalent metal ions by chelation.

Principle

The Platinum-Cobalt method of measuring color is the standard method, the unit of color being that produced by 1 mg Platinum / l. in the form of chloro-platinate ion. Colour is determined by spectrophotometer at 465nm wavelength and estimated by the following formula:

$$\text{Color, PCU} = \frac{\text{Sample absorbance at 465 nm x dilution x std. color values}}{\text{Absorbance of std. sample at 465 nm.}}$$

f. Chloride

Significance

Chloride anion is generally present in waste waters. The presence of chloride in natural waters can be attributed to dissolution of salt deposits, discharge of effluents from industries. The salty taste produced by chloride depends on the chemical composition of the water. A concentration of 250 mg/l may detectable in some water containing sodium ions. On the other hand , the typical salty taste may be absent in water containing 1000 mg/l chloride when calcium and magnesium ions are predominant. A high chloride content also has a deleterious effect on metallic pipes and structures as well as on agricultural plants.

Principle

Chloride is determined in a natural or slightly alkaline solution by titration with standard silver nitrate, using potassium chromate as a indicator . Silver chloride is quantitatively precipitated before red silver chromate is formed.The chloride content is calculated as under

$$\text{Chloride mg/l} = \frac{(A-B) \times N \times 35.45 \times 1000}{\text{Ml of sample}}$$

Where A= ml $AgNO_3$ required for sample, B= ml $AgNO_3$ required for blank

N= Normality of $AgNO_3$ used

g. Hardness

Significance

Hardness in water poses problem of scale formation in boilers. It is also objectionable from view point of water use for laundry and domestic purposes since it consume a large quantity of soap. Ordinarily salts of Ca and Mg contribute to hardness.Hardness may be classified as (1) Carbonate and non-carbonate hardness, (2) Calcium and magnesium hardness and (3) Temporary and permanent hardness.

Principle

In alkaline condition EDTA react with calcium and magnesium to form a chelated complex. Ca and Mg ions develop wine red colour with eriochrome black 'T' under alkaline condition. When EDTA is added as a titrant the Ca and Mg divalent ions get complexed resulting in sharp change from wine red to blue which indicates the end point of the reaction.

$$\textbf{Total Hardness mg/l} = \frac{(A-B) \times N \times 1000}{\text{ml of sample}}$$

N= Normality of EDTA

In case the treated effluent is used for irrigation purpose, determination of following parameters in addition to above are also required.

h. Electrical Conductivity (EC)

Significance

It is indicative of the concentration of total soluble salts, which are mostly inorganic in nature. It is a measure of salinity. Effluents having EC in the range of 0.75-2.25m.mhos/cm are suitable for irrigation of land for cultivation of crops.

i. Sodium Absorption Ratio (SAR)

Significance

The presence of excess concentration of sodium in water used for irrigation leads to an adverse impact on soil structure and permeability SAR is a parameter used to estimate the suitability of effluent for land application

$$\frac{[Na^{+}]}{\sqrt{\{[Ca^{2+}] + [Mg^{2+}]\}/2}}$$

In general effluent having SAR value less than 20 are considered suitable for land application

j. Toxicity

Significance

Toxicity of waste water is important to assess the suitability of the effluent for discharge in recipient stream. The common method for determination of toxicity is LC 50 bioassay test using fish.In recent times Microtox toxicity has also been introduced which measures the effect of toxic compounds on bioluminescent bacteria.

k. Absorbable Organic Halides(AOX)

Significance

AOX measures the amount of chlorine associated with the organic compounds, which is adsorbable on to the activated carbon. At present reduction and control of this parameter is on the top agenda of every pulp & paper industry as CPCB has issued time bound implementation schedule to reduce AOX.

Principle

The organicHalide adsorbed on the activated carbon are incinerated in presence of oxygen at 1000± 50°C.Hydeogen Chloride thus formed is precipitated by sliver ions in microcoulometric titration cell contatining acetic acoid. The silver ions consumed during titration are replaced electrochemically and thecurrent generated is integrated and displayed digitally as chlorine in test sample

Other Parameters

Apart from above physico –chemical parameters there are additional parameters which indicate the status / performance of biological treatment process viz Activated Sludge Treatment Process & Biomethanation Process. Some of these parameters are

Process	**Parameters**
Activated Sludge Process	**MLSS,SVI & Sludge age**
Biomethanation Process	**VFA, Alkalinity, VSS, Methanogenic Sludge Activity , Anaerobic Biodegradability, Sludge Profile**

The significance of the above parameters is already discussed in other environmental related papers of the manual.

I. Microbial Population

The activated sludge is made up of bacteria, fungi, protozoa, rotifers and other higher forms of life as indicated in **Fig-1.** The bacteria are the most important group of microorganism as they are responsible for stabilization of the organic matter and formation of the biological flocs. In the sedimentation process these floc particles from larger aggregates, which can be readily removed by gravity sedimentation. The presence of protozoa and rotifers is essential as they feed on small particles that have not been entrapped in the sludge floc. In that way they contribute to good wastewater quality. Fungi are not desirable as they tend to be present as filamentous forms, which prevent good floc formation. A growth pattern of these higher forms and bacteria are compared in **Fig-2.** A general indicator of microscopic sludge analysis is summarized as under and depicted in **Fig-3**

Type of microbial population	**Indicator**
Small – medium floc masses with no dispersed growth	A properly functioning activated sludge
Filamentous bacteria / fungi	May be due to adverse environmental conditions like high organic load, low Ph , nutrient deficiency, low DO level,etc.
Small flagellates and strings extending out of and mixed in the floc	Underoxidised young sludge
Small floc with crisp edges and many large rotifiers	Old sludge

3.0 AIR MONITORING

Air pollution can be classified into two major categories:

- Primary
- Secondary pollutants.

3.1 Primary Air Pollutants

Following are the five primary pollutants which together contribute more than 90% of total global air pollution:

- Carbon monoxide
- Oxides of nitrogen (NO, NO_2, N_2O_5)
- Hydrocarbons (C1-C5)
- Sulfur dioxide
- Particulate Matter

3.2 Secondary Air Pollutants

After being released in to the atmosphere, these primary pollutants react with the atmospheric constituents and with themselves thus producing secondary pollutants. In most of the cases, the pollutants so generated are more harmful and highly toxic to the biosphere. One of the most common secondary air pollutant is photochemical smog. Likewise, sulfur dioxide in certain conditions can result in acid rain.

The air pollutants can be classified into two major groups viz., inorganic gases, organic gases and particulates as under:

Groups	Sub class	Constitutes of class
Inorganic gases	Oxides of Nitrogen	Nitric oxide, Nitrogen dioxide
	Oxides of Sulfur	Sulfur Dioxide, Sulfur trioxide
	Oxides of carbon	Carbon monoxide, Carbon dioxide
Organic gases	Hydrocarbons	C1-C5
	Aldehydes and Ketones	Formaldehyde, Acetone
	Other organic	Organic acids, Alcohols
Particulates	Solids	Fume, Dust, Smoke, Ash, Carbon, Lead
	Liquid	Mist, spray, oil, grease, acids

The type of gaseous pollutants found in paper industry depend chiefly on the process adopted for cooking of the raw material. Smaller mills which use only sodium hydroxide as a cooking medium usually pollute by way of emission of sulfur dioxide and nitrogen oxides from the power boiler along with a certain amount of particulates. Large integrated pulp and paper mills use a mixture of NaOH and Na_2S for cooking and therefore emit reduced sulfur gases such as hydrogen sulfide, methyl mercaptan, dimethyl sulfide, dimethyl disulfide in addition to emission of sulfur dioxide and nitrogen oxides from the power boilers.

4.0 SOURCE OF AIR POLLUTANTS

The major kinds and sources of air pollutants are indicated as under:

Particulates	Coal fired & hog fuel boilers
Oxides of sulfur	Especially fromsulfite mill operation
Oxides of Nitrogen	From all Combustion Process
TRS	Kraft Pulping & Recovery Operations
Mercaptans	Kraft Pulping, Recovery, Lime Kiln

There are three chief point source of gaseous pollution from the pulp and paper industry - the recovery boiler, the digester and the power boiler. Besides these, exhausts from the lime kiln and smelt dissolving tanks also contribute significantly to environmental load. Though water vapor is the most prominent emission from a typical pulp & paper mill ,it is considered pollutant only when the visibility is hampered or climate modified .

5.0 MONITORING OF AIR EMISSIONS

The monitoring and testing of airquality generally is of two types –

- Ambient Sampling
- Source Sampling

Measurement of ambient air quality inside and in the near by areas can help in dispelling the misconceptions about the magnitude and extent of air pollution The ambient parameters of main interest are particulates ,reduced andoxidised sulfur gases , oxides of nitrogen etc. The particulates measured are classified into three groups:

5.1 Dust Fall

Dust fall is defined as the weight of particles which are normally greater than 100 microns in diameter expressed in gm/cm ^{2}/day. These particles tend to settle down in the immediate vicinity of their generation

5.2 Suspended Particulate Matter (SPM)

These are the particulates which do not have appreciable settling velocity and therefore they tend to remain suspended in the environment for a longer duration. Suspended particulate matter is the weight of all the particles emitted from a source or present in a surrounding. It is expressed in mg/Nm^3 for stack and point source emissions and in $\mu g/m^3$ if determined in the ambient air or work surroundings.

5.3 Respirable Suspended Particulate Matter (RSPM)

This refers to the amount of all such particles which have a diameter less than or equal to 10 microns. The results are expressed in $\mu g/Nm^3$ and at present, in India, such determinations are being reported only in the ambient environment.

The principle objective of source sampling is to get a feed back information for control of emissions .It is also useful due to following reasons:

- Provide reliable emission data for formulating the control strategy.
- Assessment of status of emission compliance with respect to regulatory standard
- Determination of inlet loading for a propsed collection device
- Determination of performance efficiency of existing control equipments
- Monitoring of one or more constituents in an exit stream as ameans of process control
- Obtain specimen material for determination of physical/ chemical properties

In general the major emissions monitored in a pulp & paper mill operation include :

5.4 Stack Emissions

Stack emissions include emissions from combustion and incineartion process which are vented out from a specifically designed chimney called stack. The main stack emission sources in paper industry are recovery furnace, power house lime kiln and smelt dissolving tank.

5.4.1 Fugitive Emissions

These are the emissions encountered on shop floor such as raw material yard , chipper house , coal handling yard , multiple effect evaporators , storage tanks , bleach liquor preparation , etc and to which the mill personnel are directly exposed

5.4.2Non Condensable Gases (Mercaptans)

Kraft mill odor is principally due to four reduced sulfur gases i.e. hydrogen sulfide, methyl mercaptan, dimethyl sulfide dimethyl disulfide. They are collectively called as Total Reduced Sulfur (TRS) Emissions. These TRS along with other Volatile Organic Compounds (VOC) such as alcohols , terpenes and phenol are collectively called as Non Condensable Gases (NCG). These VOC are themselves mild odorants and their main action is to ehance the effect of sulfur gases. In recent times, with the inclusion of odor control in CREP reduction / control of has become a major issue before the Indian pulp & paper mills using kraft pulping process . The major sources of NCG emissions are digester relief , digester blow, black liquor storage vents , washer hood vent, evaporator vent , smelt dissolving tank, lime kiln etc. The threshold values of these compounds are indicated below :

Compound	Approx odor threshold
Hydrogen Sulfide	1ppb
Methyl Mercaptan	1ppb
Dimethyl Sulfide	10 ppb
Dimethyl DI Sulfide	10ppb

6.0 COMMON AIR POLLUTION MONITORING EQUIPMENTS

6.1 High Volume Sampler

High volume sampler **(Fig - 4)** is used for the determination of suspended particulate matter and gases in the ambient air. They are in widespread use all over the world to measure air pollution in the ambient environment viz. In industrial areas, urban areas, on the shop floor and other sensitive areas. The

Principle

In these samplers, air borne particulates are measured by passing air at a high flow rate of 1 to 1.3 cubic meter per minute through a high efficiency filter paper which retains the particles >3 micron. The instruments measures the volume of air sampled, while the amount of particulate collected is determined by measuring the change in weight of the filter paper as a consequence of sampling. The passage for air reaching the filter paper is designed to prevent heavier settlable dust particles from reaching the filter. Hence the high volume samplers measures only the concentration of suspended particulate matter (SPM) in the atmospheric air. Often high volume samplers are fitted with absorbers to sample gaseous pollutants. The air is passed through chemicals which absorb specific gases, and the concentration of gaseous pollutants is determined by chemical analysis of the absorbing solutions.

6.2 Respiribale Dust Sampler

Respirable dust sampler is used for the determination of respirable particulate matter, which are having size less than 10 micron. Most of the health effects are caused by respirable particulate in the size range of 0.5 to 10 micron.

Principle

Ambient air laden with suspended particulate enters the system through the inlet pipes. As the air passes through the cyclones, coarser, non-respirable dust is separated from the air steam by centrifugal forces acting on the solid particles. These separated particles fall through the cyclone conical hopper and collect in the sampling bottle placed at its bottom. The dust forming the respirable fraction of the total suspended particulate (TSP) passes through the cyclone and is carried by the air steam to the filter paper. The respirable dust is retained by the filter and the carrier air exhausted from the system through the blower.

6.3 Stack Monitoring Kit

It is used for the determination of particulate load in the flue gases. The kit basically consist of a sample probe, filter holder and sampling nozzles. The filter holder is capable of taking a paper thimble or a glass microfiber thimble. The thimble holder along with the appropriate nozzles is then fitted on the filter holder which in turn is converted to the sampling probe The sampling probe is connected to a vacuum pump via two flow meter. **Fig 5** depicts the stack monitoring kit .

Principle

Flue gases enter the system through the nozzle at the tip of sampling probe, passes through the filter thimble, where suspended particulate matter (SPM) is removed and reach the sampling train/condenser assembly in the cold box section of the instrument panel where the gas stream splits in to two sections. One section passes at low flow rate (0.5-3.0 LPM) through a train of impingers loaded with suitable reagents to absorbs gaseous pollutants relevant to the emissions source while the remaining gas stream bubbles through a distilled water impinger followed by silica gel. On passing through the cold box section, the flue gas cools down, releasing any moisture or condensable present. Relatively clean gases then pass through the flow meter and dry gas meter, so that the volume of flue gas sampled is measured and are subsequently exhausted in to the atmosphere through the vacuum pump. Mercury manometer is provided to measure the pressure drop across the sampling train assembly. Similarly the temperature of the gas stream near the flow meter inlet can be measured by thermometer provided in the impinger train. Here the flue gas volume can be measured as per gas laws.

The system allows up to three gases to be sampled simultaneously. While the volume of the gas sampled is determined from the knowledge of the sampling time and flow rate. Concentration of individual pollutants must be determined through an analysis of the absorbers.Change in weight of the filter is used to determine the quantity of dust contained in the flue gas sample while a product of the sampling rate and time is used to measure the sample volume.

6.4 Organic Vapour Sampler

Organic vapour sampler is an instrument used for the collection of organic compound on activated charcoal. Two Teflon nozzles fitted with critical orifices have been provided to facilitate two simultaneous samples otherwise one nozzle can be used for sampling of organic compounds on activated charcoal while other can be used for indicative measurement of any gaseous pollutants like SO_2, NO_2 CO and H_2S using detector tubes both in work place or in the ambient air environment.

Principle

A known volume of air passed through activated charcoal tube at constant flow rate (100 to 200 ml/minute) with minimum pressure drop (10-15 mm Hg). Volatile organic compounds(VOC's) are adsorbed on activated charcoal which is later deabśorbed /extracted using a suitable organic solvent. Extracted or desorbed solvent is used for the quantifying the organic compounds(VOC's) with the help of gas chromatography.In case of detector tube method a measured volume of air is passed at the flow rate of 100 to 200 ml/min. for 1 to 8 hrs. and colour change in indicating gel filled in detector tube is monitored.

6.5 Non Condensable Gases

The methods available to determine the non condensable gases or mercapatns are :

- Colorimetric method
- Gas Chromatographic method
- Gas Tech Tube Method

Among these the gas tech tube method **(Fig 6)** is widely used because of ease of operation. The method involves determination of concentration of individual component of non condensable gases through change in colour of the detection tubes. The detection tubes are specific for every compound .

7.0 SOLID WASTE

Different process operations during pulp & paper making results in generation of large quantity of solid waste The solid waste generated in pulp & paper industry on the basis of composition can be classified as :

- Organic
- Inorganic

Organic solid waste include ETP sludge , chipper dust ,fines etc while inorganic solid waste include mainly lime sludge , fly ash and cinder . The major quantity of solid waste in small mills is organic in nature while in large mills it is inorganic in nature . In terms of volume the biggest quantity is biosludge generated from effluent treatment plant .(ETP)

7.1 Biosludge

The rate of formation of biosludge is around 0.2-1.2 kg /kg BOD removed depending on the biological process used for treatment of mill effluent . Another estimate indicate that around 0.15-0.20 tonne of sludge is generated per tonne of paper produced . Some fraction of the biosludge is sold by mills to board manufacturers , however the major fraction is disposed off . Among the solid waste generated by pulp & paper mills , biosludge is the most difficult to handle / manage.

7.2 Lime sludge

Lime sludge is generated during causticisation of green liquor with quick lime. Some large mills reclaim lime by burning it in lime kiln . However most of the mills have been disposing lime sludge as such by dumping off /spreading in mill yards ,open fields ,low lying areas which have over the years accumulated into big heaps and also led to environmental problems in some cases . Small mills based on agro residues in general are not having chemical recovery as such lime sludge generation is negligible except from bleach plant.

7.3 Fly Ash & Cinder

These are generated from coal fired boiler due to incomplete combustion

7.4 Raw Material Waste

It is usually generated during / from raw material handling, storage , chipper house , depither etc. This is mostly organic in nature.

Besides these there are waste from stock preparation such as fillers and additives, deinked sludge (in mills using RCF for writing & printing paper) ,dregs from recovery , scraps, building and packaging waste as well as office waste . Most of the solid waste are valuable resource and there minimization / control will not only reduce the environmental pollution but will also reduce the cost of production and improve the over all economy of the mill.

7.5 Solid Waste Analysis

The major parameters analyzed in organic solid wastes are:

Parameters	**Significance**
Moisture	To estimate the actual quantity of solid waste generated on OD basis
Ash	To determine the inorganic and organic content
Calorific Value	To estimate its fuel potential for incineration in boiler

If the ETP sludge is being used for compost the additional parameters required are pH , C/N ratio , Heavy metals and AOX/EOX. With the inclusion of AOX bearing ETP sludge as a hazardous waste in notification issued by MoEF analysis of AOX/EOX in ETP sludge has become necessary .

In case of Fly ash & Cinder the general parameters are Moisture and unburnt carbon. The unburnt carobon % is an indicative of the performance efficiency/ status of combustion process in the boiler.

8.0 CONCLUSION

In all, understanding of the basic principle and significance of the various parameters related to waste water, air and solid waste analysis is necessary and important for determination and quantification of pollution load, designing and operation of control systems/ equipments to achieve the desired level of efficiency. The proper & regular analysis of these parameters helps in efficient monitoring and smooth performance of the ETP/ control equipments to achieve the discharge norms. The methodology details of analysis of the above parameters can be obtained from the Laboratory Manual of Testing Procedures prepared by CPPRI or from the Standard Method for Examination of Water & Waste Water (APHA-AWWA-WPCF) as well as operational manuals (in case of instrument specific analysis).

TABLE -1

PRESERVATION OF SAMPLES FOR DIFFERENT ANALYSIS

Determination	Container	Sample Size ml	Preservation	Maximum Storage Recommended/ Regulatory*
Acidity	P,G	100	Refrigerate	24 hrs./14d
Alkalinity	P,G	200	Refrigerate	26 hrs./14d
BOD	P,G	1000	Refrigerate	06 hrs./48hrs
COD	P,G	100	Analyze as soon as possible or add H_2SO_4 to pH <2; Refrigerate	07 days/28d
Colour	P,G	500	Refrigerate	48 hrs
Conductivity	P,G	500	Refrigerate	28days
Hardness	P,G	100	Add HNO_3 to pH <2	06 month
Oil & Grease	G,Wide mouth Calibrated	1000	Add H_2SO_4 to pH <2, Refrigerate	28 hrs
Oxygen (Dissolved)	G,BOD Bottles	300	Analyze immediately Titration may be delayed after acidification	0.5 hrs
PH	P,G	--	Analyze immediately	02 hrs
Solids	P,G	--	Refrigerate	07 days
Sulfate	P,G	--	Refrigerate	28 days
Sulfide	P.G.	100	Refrigerate, add 4 drops 2N Zinc Acetate/100ml; add NaOH to pH >9	28 days

P- Plastic Bottles, G-Glass Bottles

- **Environmental Protection Agency**

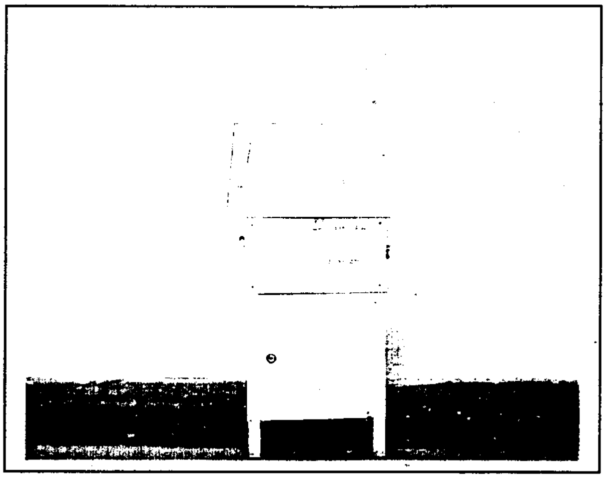

FIG.4 HIGH VOLUME SAMPLER

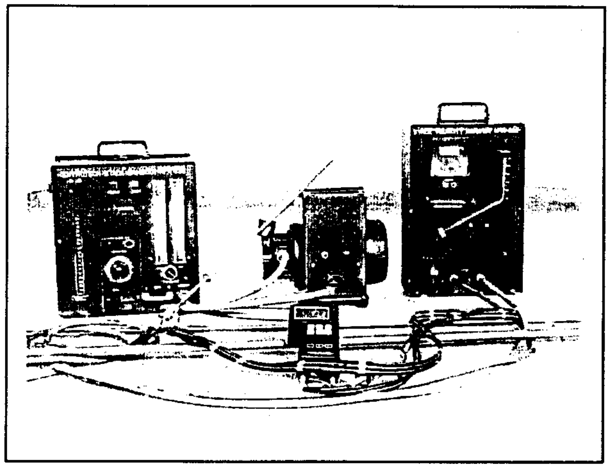

FIG.5 STACK MONITORING KIT

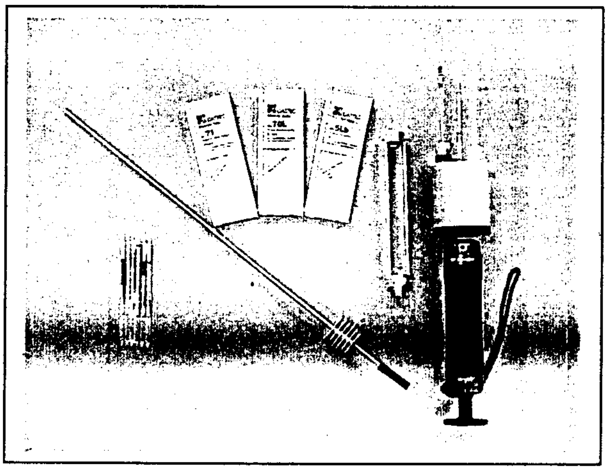

FIG .6 GAS TECH APPARATUS FOR NCG DETERMINATION