Modern Technological Developments Together With CPPRI Efforts In Pulping And Bleaching Can Make Paper Mills Energy Efficient And Environmental Friendly

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ABSTRACT

The pulp and paper industry is one of the large industrial sectors in India and so is a substantial consumer of energy for various process requirements. In the present scenario, the most of the large Indian paper mills are producing bleachable grade pulp of kappa around 20 (from bamboo and hard woods), and 15 (from bagasse), by kraft process in batch digesters. In general, the pulp are being bleached by conventional CEH or CEHH bleaching sequence. Number of process modifications in raw materials handling, pulping, pulp washing, bleaching have been taken place and number of new techniques for digestion ie extended delignification have been developed world wide by various agencies (like Beloit's RDH, Sunds superBatch etc). The conventional batch digester consumes Large Quantity of steam ie 2-3.5 T steam/T pulp while the energy for digestion required by these new techniques is 60-70% less than in conventional batch digestion. In addition, the kappa drop is around 50% which indirectly reduces bleaching chemicals to almost half. The effluent generated also shows very low values of BOD, COD & AOX which further reduces the energy consumption drastically for the effluent treatment to bring the values of the effluent characteristics to the limits prescribed by CPCB.

This presentation reveals the technological developments in pulping and bleaching technology specifically extended delignification and the valuable findings of the research activities carried out in the national institute on the improvement in raw material processing, quality, pulping, pulp washing and bleaching etc. and the prospects of their implementation in Indian pulp and paper industry to make them more economically viable, energy efficient and environmental friendly. By process modification and implementation of new techniqoues of extended delignification and oxygen pretreatment followed by thorough washing with minimum use of water, the pulp kappa can be brought down to every low value and this low kappa pulp could be bleached by ECF or TCF bleaching

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without the generation of heavy effluent load. By adopting this, there will be a revolution in Indian Paper Industry as for the bleaching chemical cost, energy cost and effluent load in addition to the improvement in pulp quality is concerned. To achieve this goal, the mills have to have very close cooperation with the research organization like CPPRI and with the machine manufacturers to implement these developed technologies to modify their existing facilities.

INTRODUCTION

India is a developing country with ever increasing demand of paper and boards. The main raw materials used in paper mill are bamboo, hard woods like eucalyptus, agro residues like bagasse, straws and secondary fibers/mainly waste paper. Large size paper mills based on bamboo, wood and bagasse are producing pulp with conventional kraft process and are well equipped with conventional chemical recovery system while the small and medium size paper mills based on agro residues are following soda processes and are without chemical recovery. Because of the non availability of the economically viable recovery unit for such mills, huge quantity of organics generated together with costly cooking chemicals is being drained which causes heavy pollution load. Now, these mills are increasing their capacity for putting up chemical recovery system to avoid the disposal of highly polluted organics rich black liquor to the stream and also to generate the energy.

In most of the large paper mills, bleachable grade pulp of kappa around 20 is being produced from bamboo and hard woods while still lower kappa around 15 is being produced from bagasse. The pulps are being bleached by conventional CEH or CEHH bleaching sequences to a brightness level of around 80% ISO for most of the end uses. Little doses of hydrogen peroxide in alkaline extraction stage or/and final bleaching stage is being used in some of the mills.

The Steam required in conventional pulping in batch digestion, as indicated below is quite high.

Steam consumption T/T paper: 2-3.5 T/T Pulp

The approximate effluent load generated in conventional CEH/CEHH bleaching of a 20 kappa pulp to the above mentioned brightness level is as under.

BOD (mg/1)	:	80-120
COD (mg/l)	:	300-400
AOX (Kg/T Paper)	:	4-5

Huge amount of energy and the chemicals are needed for the treatment of this effluent to bring down its values to the limits prescribed by Central Pollution Control Board.

NEED OF TODAY

Day to day increasing cost of the chemicals, energy, other utilities and very strict legislations of the Pollution Control Board, the paper industry has to think very deeply for the economical use of chemicals, energy, other utilities and reduction in pollution load generated in the paper mills. Various possibilities are open to meet out the demands of the industry. One passibility is the incorporation of the latest world wide technological developments in the field of pulping more specifically extended delignification and oxygen bleaching to our paper mills, with the possible helps of foreign and Indian machine manufacturers. Another possibility is the implementation of the valuable findings of the research activities carried out in the national institute like CPPRI, mainly on the Indian raw materials quality, specific and proper utilization, pulping, pulp washing, pulp bleaching etc., to make to the Indian paper mills more economical, energy efficient and environmentally friendly.

WORLD WIDE TECHNOLOGICAL DEVELOPMENT

Lot of technical developments in the paper industry as a whole have been taken place in the recent years. Developments in the field of pulping and bleaching are because of the needs for

- Reduction in energy consumption
- Reduction in pollution load
- Incorporation of other technoeconomic possibility
- Increased demand of quality product
- Reduction in the use of forest based raw materials

Each of the above points pushed the developments in the specific direction but the relative importance of the above points directly relates the process economy and the mill existence.

PULPING TECHNOLOGY

Lot of technological developments in the area of different types of the pulping have been taken place world wide as indicated below.

- High yield pulping (TMP, CTMP, etc.)
- Organosolve pulping (organocell, alcell. ASAM etc.)
- Peroxyacid pulping (Milox process etc.)
- Enzymes pulping
- Additive pulping (AQ pulping, MSS AQ Pulping etc.)
- Extended delignification (Oxygen-alkali digestion, Beloit's RDH, Sunds Superbatch etc.)

Out of these above points the first is of least interest because of the high energy inputs in the high yield pulping i.e. TMP & CTMP and non existence in the country. The other three ie organosolve pulping, peroxyacids pulping and enzyme pulping, are in developing stage and are not being applied very widely on commercial scale. The fourth ie additive pulping, is also important in improving the delignification (reduction in sulphidity and pulp kappa), pulp yield and the pulp quality (viscosity) but have little impact on energy savin᧐ and environmental concerns. The last ie extended delignification, in the digester is of very great importance in saving the large amounts of energy and in reducing the pollution load drastically.

EXTENDED DELIGNIFICATION

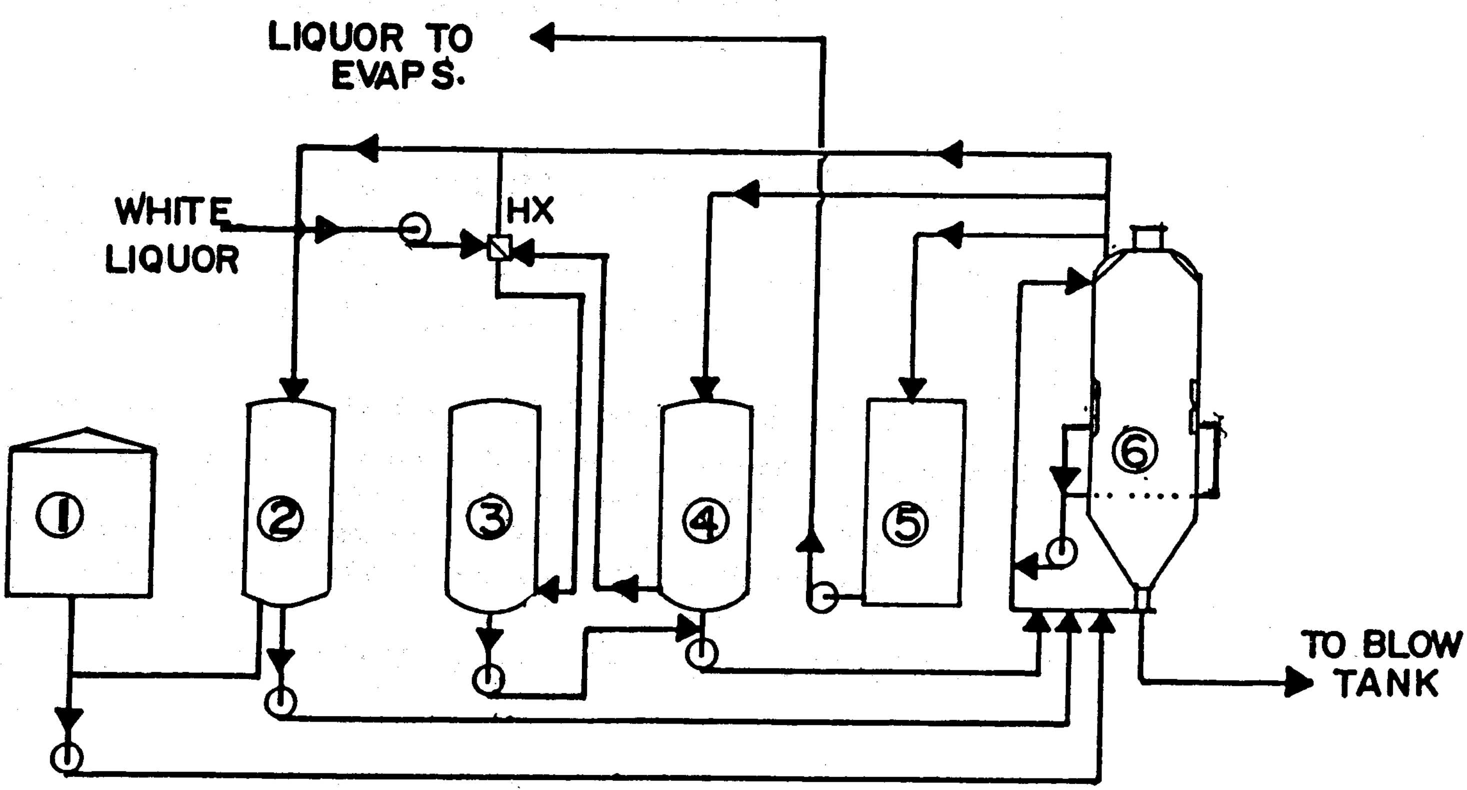
In most of the large size paper mills with conventional kraft pulping digesters, the bleachable pulps produced from bamboo, eucalyptus and other hard woods, are of kappa around 20-22, while in extended delignification in the digester using almost the same dosage of cooking chemicals, the pulp of kappa around 12-14, is obtained with the improved pulp quality (viscosity), because of the uniform distribution of the cooking chemical with the raw material through out the cooking cycle and with the drastic reduction in the steam consumption (60-70%) in cooking over the conventional batch digestion.

PRINCIPLE OF EXTENDED DELIGNIFICATION AND EQUIPMENT

Equipment and infrastructure needed in extended delignification as indicated in **fig.1,** is very simple. The following are the requirements to adopt the process.

- Hot black liquor storage tank (Thermostatically controlled)
- Hot white liquor storage tank (do)
- Warm black liquor storage tank (do)
- Liquors heat exchangers
- Digester fitted with displacement screens

First the digester is filled with the chips and warm black liquor of around 100°C from the storage tank is added to pre heat the chips and to remove the air. This warm black liquor replaced with hot black liquor and hot white liquor at around 160°C from hot storage tank. The temperature which is almost nearer to the final cooking temperature at this stage is raised to the final cooking temperature with very little consumption of steam energy and the cooking is carried out as usual. At the end of the cooking, the hot black liquor is replaced and stored in hot black liquor tank. This hot black liquor from the digester is replaced with the water at



LEGEND

1- WASHER FILTRATE TANK
2- WARM BLACK LIQUOR TANK
3- HOT WHITE LIQUOR TANK
4&5 -HOT BLACK LIQUOR TANK
6- DIGESTER

FIG. 1, BELOIT'S RDH SYSTEM (1)

ambient temperature with the result the final temperature of the pulp approaches slightly below 100°C. The pulp is then removed from the digester either directly or with the help of pressurised air. Heat exchangers are used to maintain the temperature of the hot liquors.

Based on the principle of extended delignification in the digester the two processes indicated below are available commercially.

- Beloits rapid displacement heating (RDH) process
- Sunds defibrator Rauma's superBatch process

BELOIT'S RAPID DISPLACEMENT HEATING (RDH) PROCESS

Commercial feasibility and the advantages of the RDH process in different part of the world are detailed in the paper by Rangan (1). Present few installations of the Beloit's RDH process are:

- Owens Illions Mills at Valdosa, Georgia
- Joutseno Pulp Oy in Joutseno, Finland

SUND'S DEFIBRATOR RAUMA'S SUPERBATCH PROCESS

Overall merits of the process and commercial installations in the different parts of the world are detailed in the literature (2). Besides energy, environmental and economical aspects, the Superbatch cooking process offers many advantages like improvement in pulp uniformity, pulp yield, pulp strength, heat economy and brown stock washing, reduction in rejects, bleaching chemicals, effluent load, in addition to high flexibility like extended cooking to kappa 10 without process modifications, simultaneous cooking of different wood species, simultaneous cooking to different kappa and easy increase in capacity. The present installations are :-

- **Enocell oy Finland:** Enocell Superbatch installation is the biggest pulp digester plant in existence with the production rate of 2000 tons per day. The cooking system comprised of 10 digesters each of 300 m^3 with the capability of simultaneously producing hard- and softwood pulps of kappa 10 to 12. The system was installed in 1992.
- **Sepap Steti, Czech Republic:** The plant at Steti mill in Czech Republic is designed for 500 ADT/d softwood (pine and spruce) pulp production of kappa around 12. The plant is consisted of four digesters each of 300 m^3 and started up in 1993.
- **Phoenix Pulp and Paper Co. Ltd. Thailand:** Superbatch digesting plant at Phoenix Pulp and Paper Co. Ltd., Khon Kaen, Thailand was designed for 370 ADT/d pulp of bamboo and eucalyptus of kappa around 18. The plant consisted of three digesters each of 200 m^3 capacity and started up in 1994.
- **PT Riau Andalan Pulp and Papers, Indonesia:** Sunds Defibrator supplied all the process equipments for wood handling and fiber line systems for a completely new pulp mill. The new mill started for 2000 ADT production of fully bleached market pulp a day. The plant is comprised of 12 digesters each of 350 m^3 and will use eucalyptus and acacia as raw materials. The plant was started in 1994.
- **Potlatch Corporation, Cloquet, Minnetosa, USA:** The Sund Defiberator is supplying new fiberline process technology to Potlatch Corporation's Cloquet plant including Superbatch cooking, brown stock washing, oxygen delignification etc. The plant was to be started in 1996 to produce 1280 ODT/d pulp.

NEED OF QUALITY IMPROVEMENTS OF INDIAN RAW MATERIALS & PROCESS

Most of the development activities took place in the developed countries on the technological developments like extended delignification etc. and that too on the forest based raw materials available in those countries. Little efforts have been done by these countries on the understanding of agrobased raw materials, their behavior, processing and suitability for different types of products.

INDIAN RAW MATERIALS SCENARIO

Developed countries are rich in superior quality raw materials like soft woods and hard woods while we have very much limited availability of such raw materials. Due to heavy deforestation in past, the availability of forest based raw materials specially bamboo and hard woods have gone very low. Use of agro based raw materials like grasses, rice straw, wheat straw and mainly bagasse are encouraged to meet out the increasing demands of the paper and boards in the country.

BEHAVIOR OF AGRO RESIDUES

The agro based raw materials are quite different from the woody raw materials as for their composition, fiber qualities, behavior during processing, pulping, pulp washing, pulp bleaching and paper making is concerned. Almost negligible informations are available on such matter and a lot of research activities are needed for the better utilization of the agro residues. Lot of research efforts are going on mainly in the developing countries like China, India etc. In India, these development activities are going on mainly in the national institute like CPPRI and other organizations. Some of the interesting findings based on research at CPPRI on these materials are detailed below:-

RESEARCH ACTIVITIES OF CPPRI

Lot of research work have been done in CPPRI, to understand the agricultural residues, their composition, behavior, pulping, pulp washing, bleaching, paper making, chemical recovery. Some of the valuable informations detailed below, can make the Indian paper industry more economical, energy efficient and environmental friendly.

MECHNICAL PROCESSING OF RAW MATERIALS

Agroresidues mainly rice straw, wheat straw and grasses are consisted of lot of dust adhered in addition to the large quantity of fines developed during thrashing and chopping. This dust and fines consumes lot of the costly chemicals in pulping. During pulping operation, these dust and fines go with black liquor and pose various problems in chemical recovery system, in addition to the pulp quality deterioration due to the part going with the pulp.

Experiments on mechanical processing in a disc mill were performed on rice and wheat straws and valuable information has been collected (3). The principle is very simple. The chopped material is given a mechanical treatment by adjusting the disc clearance in the disc mill to loose the dust and fine materials. This treated material is passed through a horizontal barrel fitted with the screen zones starting from fines to coarse with the help of a conveyer. Different fractions can easily be separated depending upon the requirement.

Table-1

Yield and Ash Content Of Different Rice Straw Fraction Obtained During Disc Mill Treatment

Fraction No.		Disc Clearance	
		0.65 mm	0.75 mm
	Yield	Ash%	Ash%
1	15	19.8	18.0
2	10	16.8	17.2
3	6	15.0	15.8
4	3	14.8	15.4
5	66	14.9	14.8

(Ash in original raw material : 15.9%)

Table-1, indicates the ash content of original rice straw and in different fractions from the disc

Table-2

Pulping trials of rice straw treated in disc mill

Particulars	Original Rice straw			Rice Straw treated in disc mill		
Cooking chemical, %	8	10	12	8	10	12
Unscreen Pulp yield, %	58.1	55.3	51.9	59.4	52.5	50.9
Screen rejects %	3.2	2.7	1.5	1.0	1.0	0.8
Kappa number	28.5	22.5	18.6	17.2	14.5	14.1
RAA (gpl)	5.0	8.0	9.8	6.9	8.4	11.4

Table-3

Effect of pretreatment in disc mill on pulp properties

Property	Rice Straw		Wheat Straw	
	Original	Treated in Disc mill	Original	Treated in Disc mill
-200 BM fraction %			34.7	18.4
CSF (ml)	325	325	350	310
Drainage Time (s)	8.4	10.6	7.3	7.0
Apparent Density (g/cm³)	0.68	0.65	0.68	0.76
Burst (K.Pa.m/g)	2.5	2.0	2.0	3.1
Tensile (N.m/g)	39	35	32	53
Tear (m Nm/g)	4.9	4.6	7.3	6.1

mill. The original rice straw contains 15.9% ash while the finest fraction (ie. 15% at a disc clearance of 0.65 mm) 19.8%.

Table-2, indicates the result of pulping experiments of original rice straw and after disc milling where the fine material (~15%) is removed. The 12% NaOH is required for original rice straw as against 8% for getting same kappa pulp (around 18), in addition to the better pulp yield of 58.4% against 54.4% of original rice straw.

.**Table-3,** indicates the pulp quality of original rice straw and wheat straw and that of the disc milled. In case of the wheat straw, there is a marked improvement in the physical strength properties particularly burst and tensile of the disc milled straw pulp as against the original raw material pulp.

CHEMICAL PROCESSING OF RAW MATERIALS

On agroresidues particularly straws and grasses, the dust is adhered while the silica is imbibed inside the structure of the raw materials and can not be separated by mechanical treatment or by simple washing.

Presence of silica in the raw materials causes lot of problems in the system more particularly in the recovery of the chemicals. A mild alkaline treatment in warm condition (60-70°C) can easily remove lot of silica present in the raw materials. Detailed studies have been carried out on silica removal from bagasse and fruitful results were obtained (4).

Table-4, indicates the some of the results of pulping experiments performed on original and extracted bagasse. Just 2% NaOH treatment at 60°C for 2 hrs could remove 75% of the silica present in the original bagasse (ie around 1%). Better delignification took place in extracted bagasse (pulp kappa 13.8) compared to that in original bagasse (pulp kappa 20) by using 0.5% Na_2O less to that in the original bagasse, without adversely affecting the pulp quality.

PROPER USE OF RAW MATERIALS

Some of the raw materials like rice straw contains very high silica and their black liquor is not suitable for recovery point of view in addition to the poor quality pulp produced. Such raw materials can be diverted for the production of unbleached kraft paper where much of the pulp

Table-4

Kraft Pulping of Unextracted and Extracted Bagasse

Particulars	Unextracted bagasse	Extracted bagasse
NaOH used in extraction, %		1.5
Silica removed on ext, % (at 60°C, 2 hrs)		75
Cooking chemical used in pulping as Na_2O %	16	14
Total pulping chemical	16	15.5
Pulp yield	51.0	48.34
Kappa of unbleached pulp	20.0	13.8

Table-5		
Vapor Phase Pulping of Agroresidues (Wheat Straw)		
Particulars	**Liquid Phase**	**Vapor Phase**
Steam consumption t/t od pulp	4.8	1.7
Bath ratio	1:5	1:3.5
Black liquid solid, w/w, %	9.6	18.4
Black liquid m/t pulp	15.5	7.3

processing is not needed. Using unconventional N,P,K based pulping chemicals like urea etc, suitable grade kraft paper can be produced with the generation of sodium free spent liquor, suitable for irrigation.

A detailed studies on urea pulping of rice straw have been carried out in CPPRI and encouraging results were obtained (5,6). Unbleached kraft pulp of +20 burst factor could be produced almost at half the cost of chemicals compared to the conventional soda process with the additional advantage of diverting whole of the sodium free spent liquor to the agricultural fields and without the generation of any pollution load.

IMPROVEMENT IN PULPING PROCESS

Conventional pulping with the direct steaming consumes more energy. Vapor phase pulping experiments, carried out in CPPRI (7), showed drastic reduction in steam consumption in addition to the many other advantages like high black liquor solids, less energy requirement for evaporation of the black liquor etc., as evident from the **Table-5.**

IMPROVEMENT IN PULP WASHING

Agroresidues pulps are quite different to the wood pulp as far as washing is concerned. Effective washing of the pulp results in lower soda loss, less carry over with pulp, less black liquor volume, lower energy demand for evaporation of black liquor and less expenses on effluent treatment. Conventional counter multistage drum filter washing have many disadvantages for the washing of agroresidue pulp such as high D.F., large filter surface, high energy consumption, low consistency of filter cake, high frequency of filter surface cleaning etc.

A systematic study on the subject was carried out in CPPRI by using Andritz Double Wire Washer for agroresidues and lot of problems stated above could get solved (8).

OXYGEN BLEACHING

Lot of technological developments have been taking place from time to time in the field of pulp bleaching. Use of oxygen in pulp bleaching is of great importance in reducing energy, bleaching chemicals demand and effluent load. Today in the developed countries oxygen is being used in pre bleaching stage to reduce the pulp kappa and in alkaline extraction stage to improve the pulp quality (viscosity).

Sufficient efforts are going on with the countinuous use of the oxygen as a bleaching chemicals in prebleaching stage as well as in alkaline extraction stage. Very recently, laboratory

Table-6			
Pulping Data of Bagasse, Bamboo and Eucalyptus			
	Bagasse	**Bamboo**	**Eucalyptus**
Cooking chemical as Na_2O%	14	17.5	16
Unscreened pulp yield %	51.2	44.3	41.9
Screen Rejects	Nil	0.38	0.12
Kappa Number of Unbleached pulp	14.6	18.2	19.2

Constant Conditions:

	Bamboo & Eucalyptus	Bagasse
Raw material filled in each bombs, gm	400	200
Raw material to liquor ratio	1:3	1:5
Sulphidity of cooking liquor %	21	21

Cooking Schedule-

Time to raise temp to 100°C, min	=	30
Time to raise temp 100°C to 168°C	=	100
Cooking time at 168°C, min	=	90

Oxygen Pretreatment Conditions:

Pulp consistency	-	10%
Sodium hydroxide	-	2% for bamboo & eucalyptus 1.2% for bagasse
Oxygen pressure	-	5 kg/cm²
Treatment temp.	-	120°C
Treatment time	-	30 min

Table-7						
Conventional CEH Bleaching of Untreated and Oxygen Pretreated Bagasse, Bamboo and Eucalyptus Pulps						
	Bagasse		**Bamboo**		**Eucalyptus**	
Unbleached Pulps: (Before & After O_2 Pretreatment)						
Kappa Number	14.6/5.6		18.2/9.0		19.2/9.7	
Pulp Brightness % ISO	26.0/37.1		23.1/32.3		21.1/37.6	
Pulp Intrinsic Viscosity, Cm^3/g	840/840		830/730		510/470	
Bleaching sequence	CEH	OCEH	CEH	OCEH	CEH	OCEH
Chlorination stage:						
Chlorine	3.0	1.2	4.0	2.0	4.0	2.0
Alkali Extractions Stage:						
Sod. Hydroxide % (End pH above 10.5)	1.0	0.6	2.0	1.0	2.0	1.0
Hypochlorite stage:						
Ca-hypochlorite as available chlorine %	1.0	0.5	4.0	1.0	2.0	1.0
Sod. Hydroxide as Buffer, %	0.3	0.1	0.8	0.2	0.8	0.2
Bleached pulp Brightness,% ISO	82.0	78	78	78	77	80
Bleached pulp viscosity, Cm^3/g	520	630	430	490	280	350
Yield loss during bleaching	4.2	6.2	3.6	4.3	3.9	6.6
Total Bleaching chemical used Kg/T Pulp						
Chlorine	45	17	80	30	60	30
Sod. Hydroxide	18	7	28	12	24	12

Table-8						
Characteristics of CEH Bleach Effluent of Untreated & Oxygen Pretreated Pulps.						
	Bagasse		**Bamboo**		**Eucalyptus**	
	Original Untreated pulp	**Oxygen treated pulp**	**Original untreated pulp**	**Oxygen treated pulp**	**Original untreated pulp**	**Oxygen treated pulp**
Before Secondary Treatment:						
BOD_5 Kg/T. Pulp	11.3	8.8	12.8	5.3	8.8	4.8
(or mg/l)*	(113)	(88)	(128)	(53)	(88)	(48)
COD Kg/T.Pulp	40.5	20.4	43.5	20.4	33.0	16.3
(or mg/l)*	(405)	(204)	(435)	(204)	(330)	(163)
AOX Kg/T.Pulp	2.93	0.86	4.53	1.32	4.18	1.27
(TOCl=0.8 AOX)	(2.34)	(0.69)	(3.68)	(1.05)	(3.34)	(1.02)
* Bleaching effluent volume 100 m^3 per tonne of pulp						

studies have been carried out in CPPRI on the use of oxygen in bleaching of widely used Indian raw materials like bamboo, bagasse, and eucalyptus pulps and very encouraging results were obtained (9).

As indicated in the **Table-6&7** the oxygen pretreatment of the pulps can reduce the pulp kappa by 50-60% without effecting the pulp viscosity. This reduction in kappa could further reduce the consumption of bleach chemical like chlorine, alkali and calcium hypochlorite by about 50-60%.

As indicated in **Table-8,** the effluent load generated in CEH bleaching was of very high BOD, COD and AOX which could not meet the limits prescribed by CPCB, even after secondary treatment. Oxygen pretreatment of unbleached pulp followed by CEH bleaching reduced the value of BOD, COD, and AOX in the effluent drastically. This effluent after secondary treatment **(Table-9),** could meet the limits prescribed by Central Pollution Control Board as indicated below:

Limits For Final Effluent Discharge

BOD mg/l	30
COD mg/l	250
AOX kg/T paper	2

(Limiting effluent discharge 125 m^3/T Paper)

So oxygen pretreatment of the unbleached pulp is the best tool for Indian paper mills to drastically reduce the pulp kappa, the bleaching chemicals, the amount of the energy specially in effluent treatment and the effluent load generated in pulp bleaching.

Most important part is that the experiments were performed in laboratory digester with some arrangements for mild mixing of oxygen with the pulp at medium consistency. Similar mixing arrangements can also be thought of for the existing digesters in the mills for performing oxygen pretreatment of unbleached pulps.

POSSIBILITY OF INCORPORATION OF TECHNICAL DEVELOPMENTS

Incorporation of technical developments in pulping and bleaching, more specifically the idea of extended delignification during pulping and the results of various process modification activities including, oxygen pretreatment, followed by through washing of the pulp with the minimum quantity of water and then bleaching can revolutionize the Indian paper industry. It is very hard and impossible for the Indian paper mills to replace the whole pulping system to the new imported extended delignification system from out side as being done by many other developed and developing countries. On the other hand, there is a possibility of incorporation of the technological developments in the existing system of

Table-9

Characteristics of CEH Bleach Effluent of Untreated & Oxygen Pretreated Pulps.

	Bagasse		**Bamboo**		**Eucalyptus**	
	Original Untreated pulp	**Oxygen treated pulp**	**Original untreated pulp**	**Oxygen treated pulp**	**Original untreated pulp**	**Oxygen treated pulp**
After Secondary Treatment:						
BOD_5 Kg/T. Pulp	5.8	2.4	4.8	0.4	2.1	0.6
(or mg/l)*	(58)	(24)	(48)	(4)	(21)	(6)
COD Kg/T.Pulp	33.9	13.9	32.0	9.7	23.0	7.75
(or mg/l)*	(339)	(139)	(320)	(97)	(230)	(77.5)
AOX Kg/T.Pulp	1.84	0.5	2.5	0.84	2.1	0.72
(TOCI=0.8 AOX)	(1.47)	(0.40)	(2.03)	(0.67)	(1.68)	(0.66)

* Bleaching effluent volume 100 m^3 per tonne of pulp

the paper mills with close cooperation and necessary helps of the machine manufacturers and without much investment. Machine manufacturers at this juncture have to play a vital role in achieving this goal.

By incorporation of extended delignification and fruitful findings of research organization, the present kappa around 20 of the pulp being produced will come down to almost 10 with the drastic reduction of the energy inputs in pulping. This pulp kappa can further be reduced to around 4-5 after oxygen pretreatment and pulp can further be bleached to the final brightness target without the use of elemental chlorine (ECF) or without the use of chlorine based compounds (TCF) as the GREENPEACE movement demands. The final effluent discharge from the mill will be almost negligible and there will not be any energy inputs for the effluent treatment in addition to the better quality of the pulp produced.

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