Oxygen Prebleaching and Chlorinedioxide Substitution: An Emerging Need of Indian Paper Industry

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ABSTRACT

This presentation reveals the emerging need for introducing oxygen prebleaching of the pulp and the possibility of partial substitution of the chlorine and other chlorine based bleaching chemicals with the chlorine dioxide in Indian pulp and paper industry. By adopting oxygen prebleaching the pulp kappa can be brought down and the low kappa pulp can further be bleached to the required brightness ~80% ISO with the drastic reduction in the amount of bleaching chemicals and pollution load generation which indirectly results in saving of energy and other utilities required in effluent treatment. Partial substitution of the chlorine and other chlorine based bleaching chemicals with the chlorine dioxide results in high brightness i.e. +88% ISO of the eucalyptus pulp without adversely effecting the pulp quality. 50% to 100% subsitution of chlorine with chlorine dioxide in chlorination stage followed by alkaline extraction and chlorine dioxide bleaching of the oxygen prebleached pulps of bagasse, bamboo and eucalyptus showed very poor bleaching response. Use of calcium hypochlorite in extraction or after extraction stage showed an improvement in bleaching response. Still there is a need for extending laboratory bleaching studies to optimize the amount of the chlorine and other chlorine based chemical substitution with the chlorine dioxide, in order to get the maximum bleaching response of the oxygen prebleached pulps of different raw materials. By introducing system in the Indian mills, the Indian Paper Industry can think for drastic reduction in the chemical cost, energy cost and pollution load gererated. To achieve this goal the mills need to have very close cooperation with the machine manufacturers to modify their existing bleaching systems.

INTRODUCTION

Day to day increasing cost of the chemicals, energy and very strict legislation of the Central Pollution Control Board, the Indian paper industry has to think very deeply for the economical use of chemicals, energy and reduction in pollution load generation in the paper mills. Demand for the high brightness papers is also increasing to face the global competition. Pulp bleaching is an area where much attention is needed to reduce the pollution load generation during bleaching, reduction of bleaching chemicals, energy and other utilities in addition to bleach the pulp to high brightness level i.e. +88%

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ISO. There is an emergent need to consider the oxygen prebleaching of the pulp and the partial substitution of the chlorine and other chlorine based bleaching chemicals like calcium hypochlorite etc. with the chlorine dioxide.

BLEACHING PRACTICES IN INDIAN PAPER INDUSTRY

The main raw materials used in the Indian paper mills are bamboo, eucalyptus, agro-resdidues like bagasse, straws and secondary fibers mainly waste paper. Large size mills are 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 are based on agro-residues are following soda process without chemical recovery. Now these mills are increasing their capacity for putting up the chemical recovery system to avoid the disposal of highly polluted organics rich black liquor to the stream and also to generate the steam energy needed for the economical viability of the mills.

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

The AOX generation in coventional CEH/CEHH bleaching of a 20 kappa pulp to above mention brightness level is 4-5 kg/T pulp. The huge amount of energy and chemicals is wasted for the treatment of the effluent to bring down its value to the level required by Central Pollution Control Board of India i.e. 2 Kg/T paper.

EMERGENT NEED OF CHANGING BLEACHING PRACTICES IN INDIAN PAPER MILLS:

Strict legislation of the Central Pollution Control Board in the country and increasing cost of energy, chemicals and other utilities and increasing demand of high brightness paper, there is a necessesity of modification of the present bleaching practices in Indian paper mills. Oxygen prebleaching and substitution of chlorine and other chlorine based bleaching chemicals with the chlorine dioxide are being commercially exploited in developed countries. Oxygen prebleaching of the pulp results drastic reduction of pulp kappa which further reduces the bleach chemical requirement in further stages of bleaching in addition to the drastic reduction in the pollution load generated during bleaching.

Substitution of the chlorine and other chlorine based bleaching chemicals with chlorine dioxide is also well known for achieving higher brightness of the pulp in addition to the drastic reduction in the pollution load generated during bleaching of the pulp.

RESPONSE OF OXYGEN PREBLEACHING AND CHLORINE DIOXIDE SUBSTITUTION ON THE BLEACHING OF INDIAN RAW MATERIAL PULPS:

Though the oxygen prebleaching and chlorine dioxide substitution in bleaching of pulps are well stabilized in the developed countries but it is mainly on their raw material pulps. Very little informations are available on Indian raw material pulps so there is a need for laboratory studies to see its impact on widely used Indian raw material pulps, for its commercial exploitation in the country.

The laboratory studies on the bleaching of the pulps of the most widely used raw materials like bagasse, bamboo and eucalyptus were under taken to bleach the pulps to the targeted brightness and to see its impact on the reduction of the pollution load generated during bleaching of the pulp. The idea of the laboratory studies was to produce bleaching grade kraft pulps of kappa no. 18-20 from all the three raw materials. Parts of the pulps were to be given oxygen treatment to reduce pulp kappa. Both the pulps oxygen prebleached as well as untreated, were to be bleached by conventional CEH bleaching sequence and also by partially or fully, with chlorine dioxide. Effluent generated in different bleaching sequences from untreated and oxygen treated pulps were to be analyzed for effluent characteristics i.e. BOD, COD and AOX (TOCL @ 0.8 AOX) before and after secondary treatment of the effluent generated during bleaching.

EXPERIMENTAL:

All the three raw materials bagasse, bamboo, eucalyptus were cooked in a series digester, an electrically heated glycol bath, under following cooking conditions.

Raw material/liqour ratio - 1:3 for bamboo & eucalyptus

1:5 for bagasse

Raw material/bomboo - 400 gms. bamboo & eucalyptus 200 gms. bagasse

Sulfidity of cooking liquor - 21%

Cooking Schedule:

Time to raise to 100°C - 30 min.

Time from 100 to 168°C - 100 min.

Cooking time at 168°C - 90 min.

Pulps produced were washed, screened and analyzed for yield and kappa number etc. Pulping chemical dosage were optimized to get bleaching grade pulps of kappa no. 18-20. Optimum cooking dosage for bagasse was further adjusted to get still lower kappa no. (14-16) pulp to avoid shives.

Parts of the pulps produced above were treated with oxygen under the conditions given below and finally washed.

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.

Untreated and oxygen prebleached pulps of all the three raw materials were taken for conventional CEH bleaching to the disired brightness of around 80% ISO using optimum dosage of bleaching chemicals i.e. chlorine, alkali and calcium hypochlorite. Untreated pulp of eucalyptus and oxygen prebleached pulps of all the three raw materials were also bleached by using chlorine dioxide i.e. by OD/CED and ODED sequences where 50% and 100% of the chlorine in the chlorination stage was replaced with chlorine dioxide respectively. Because of the very poor bleaching response of the above two sequences, oxygen prebleached pulps were bleached by using calcium hypochlorite in the alkali extraction stage (i.e. E/H) followed by dioxide stage i.e. by OD/CE/HD and ODE/HD.

Unbleached and bleached pulps brightness were measured as per ISO Standard 2470 and Intrinsic viscosity cm^3/g by SCAN-C 15:62 method.

Effluent generated during bleaching by different seqences were analyzed for BOD, COD and AOX

TABLE 1: Pulping data of Bagasse, Bamboo & 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 gm	200 gm
Raw material to higher 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	

before and after the secondary treatment as per standard procedures.

FINDINGS:

Quality of the Unbleached Pulps Produced:

Table 1, indicates the pulping data of the three raw materials i.e. bagasse, bamboo and eucalyptus. By using optimized cooking chemical dosage 14, 17.5 and 16% Na_2O for bagasse, bamboo and eucalyptus respectively and corresponding kappa number of the pulps were 14.6, 18.2 and 19.2. Bagasse was cooked to the lower kappa number (14.6) than the targeted kappa number (18-20) to avoid more shives. Pulps yield, unbleached pulp brightness and viscosity are also indicated in the Table 1.

Effect of Oxygen Prebleaching on Unbleached Pulps Quality:

Table 2, indicates the effect of oxygen prebleaching on the three pulps. It is evident from the table that by using an oxygen pressure of 5 kg/cm^2 for 30 min at 120°C, the bagasse, bamboo and eucalyptus pulp kappa no. were reduced from its initial values 14.6, 18.2 and 18.2 to 5.6, 9 and 9.7 respectively or in other words, the oxygen prebleaching reduced the kappa number of the bagasse pulp by 60% while that of bamboo and eucalyptus by 50%. Respective brightness of the unbleached pulp was also improved from 26, 23.1 and 21.1% ISO to 37.1, 32.3 and 37.6% ISO. There was no drop in the viscosity of bagasse pulp while there was very little drop in the viscosity of bamboo and eucalyptus pulp on oxygen prebleaching.

EFFECT OF OXYGEN PREBLEACHING OF PULPS ON CONVENTIONAL CEH BLEACHING:

Table 3, indicates the data of the coventional CEH bleaching of the three pulps with and without oxygen prebleaching. Conventional CEH bleaching of the pulps without oxygen pretreatment consumed very high bleach chemicals. As evident from the table, bagasse pulp of kappa number 14.6 consumed 3% chlorine, 1.5% calcium hypochlorite, bamboo pulp of kappa 18.2 consumed 4% chlorine and 4% hypochlorite and eucalyptus pulp of kappa number

TABLE 2: Oxygen Prebleaching Pulp of Bagasse, Bamboo & Eucalyptus

	Bagasse	Bamboo	Eucalyptus
Unbleached Pulp:			
Kappa Number	14.6	18.2	19.2
Brightness % ISO	26.0	23.1	21.1
Intrinsic viscosity Cm^3/g	840	830	510
Oxygen Treated Pulp:			
Kappa Number	5.6	9.0	9.7
Brightness % ISO	37.1	32.3	37.6
Intrinsic viscosity, Cm^3/g	840	730	470
% Reduction in Kappa Number by oxygen prebleaching	61	60.5	49.6
% Drop in pulp viscosity by oxygen prebleaching	0	12.0	7.8

Constant Conditions:

Pulp consistency %	=	10
Oxygen pressure Kg/Cm^3	=	5
Treatment temp °C	=	120
Treatment time, Min	=	30

TABLE 3: Conventional CEH Bleaching of Bagasse, Bamboo and Eucalyptus Pulps with and without Oxygen Prebleaching

	Bagasse		Bamboo		Eucalyptus	
	Original untreated pulp	Oxygen treated pulp	Original untreated pulp	Oxygen treated pulp	Original untreated pulp	Oxygen treated pulp
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 %	1.5	0.6	2.0	1.0	2.0	1.0
(End pH above 10.5)						
Hypochlorite Stage:						
Ca-hypochlorite as available						
Chlorine %	1.5	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	78	78	78	77	80
Bleached pulp viscosity, Cm^3/g	520	630	300	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

19.2 consumed 4% chlorine and 2% hypochlorite as available chlorine to achieve a brightness target of around 80% ISO. Because of the reduction in kappa number and hence the lignin content in the pulps on oxygen prebleaching, the bleach chemicals consumption had also reduced drastically for all the three pulps. Oxygen prebleaching of the pulps has reduced chlorine consumption from 3% to 1.2%, 4% to 2% and hypo consumption for 1.5% to 0.5%, 4% to 1%, 2% to 1% in case of bagasse, bamboo and eucalyptus pulps respectively or in other words oxygen prebleaching has reduced the total chlorine consumption per ton of pulp by 50% in case of eucalyptus and by around 60% in case of bagasse and bamboo pulp bleaching to the same brightness level.

It is also evident from table 3 that there was drastic drop in pulp viscosity on CEH bleaching of untreated pulps i.e. without oxygen pretreatment. Pulp intrinsic viscosity, (cm^3/g) dropped from initial 840 to 520, 830 to 300 and 510 to 280 for bagasse, bamboo and eucalyptus pulp respectively. Oxygen prebleaching has reduced the drop in pulp viscosity during CEH bleaching. Intrisic pulp viscosity (cm^3/g) dropped from initial 830, 830 to 490 and 510 to 350 for bagasse, bamboo and eucalyptus pulp respectively. In other words oxygen prebleaching have reduced the drop in pulp viscosity during CEH bleaching from 38% to 25%, 64% to 41% and 45% to 31% for bagasse, bamboo and eucalyptus pulp respectively.

EFFECT OF OXYGEN PREBLEACHING OF UNBLEACHED PULPS ON THE QUALITY OF THE CEH EFFLUENT:

Table 4, indicates the characteristic of the CEH effluent before and after secondary treatment for the oxygen prebleached and untreated pulps of bagasse, bamboo and eucalyptus. Results indicate that the effluent characteristic particularly TOCI (80% of AOX) of the effluent generated in CEH bleaching of untreated pulps followed by secondary treatment of the effluent for bamboo pulp (kappa 18.2), eucalyptus pulp (kappa 19.2) and bagasse pulp (kappa 14.6) were quite in the tolerance limit prescribed by Central Pollution Control Board. Oxygen prebleached of the pulps have further reduced the pulp kappa number and also the effluent characteristics. The CEH effluent generated for all the above three pulps, before the secondary treatment were quite near to the limits prescribed by CPCB. The values of BOD, COD and TOCI effluent were in the prescribed limits.

Discharge Limits of Final Discharge

BOD	mg/1	-	30
COD	mg/1	-	250
TOCI	kg/T Paper	-	2.0

(Effluent volume 175 m^3/T paper)

Values approached to very low level by the secondary treatment of the effluent as evident from the table.

CHLORINE DIOXIDE BLEACHING RESPONSE ON UNTREATED EUCALYPTUS PULP:

Table 5, indicates the clhorine dioxide bleaching response over conventional CEH bleaching of untreated eucalyptus pulp. It is quite clear from the table that the untreated eucalyptus pulp of around 20 kappa

TABLE 4: Characteristics of CEH Bleach Effluent* of Untreated and Oxygen Prebleached Pulps

		Bagasse		Bamboo		Eucalyptus	
		Original untreated pulp	Oxygen treated pulp	Original untreated pulp	Oxygen treated pulp	Original untreated pulp	Oxygen treated pulp
I) Before treatment:							
i)	BOD Kg/T. Pulp	11.3	8.8	12.8	5.3	8.8	4.8
	(or mg/1)	(113)	(88)	(128)	(53)	(88)	(48)
ii)	COD Kg/T. Pulp	40.5	20.4	43.5	20.4	33.0	16.3
	(or mg/1)	(405)	(204)	(435)	(204)	(330)	(163)
iii)	AOX Kg/T. Pulp	2.93	0.86	4.53	1.32	4.18	1.27
	(TOCI=0.8 AOX)	(2.34)	(0.69)	(3.68)	(1.05)	(3.34)	(1.02)
II) After treatment:							
i)	BOD Kg/T. Pulp	5.8	2.4	4.8	0.4	2.1	0.6
	(or mg/1)	(58)	(24)	(48)	(4)	(21)	(6)
ii)	COD Kg/T. Pulp	33.9	13.9	32.0	9.7	23.0	7.75
	(or mg/1)	(339)	(139)	(320)	(97)	(230)	(775)
iii)	AOX Kg/T. Pulp	1.84	0.50	2.54	0.84	2.10	0.72
	(TOCI=0.8 AOX)	(1.47)	(0.4)	(2.03)	(0.67)	(1.70)	(0.58)

* Bleach Effluent Vlume 100 m^3/T Pulp

TABLE 5: Chlorine and Calcium Hypochlorite Substitution with Chlorine Dioxide in Conventional CEH Bleaching of Eucalyptus Pulp.

Kappa Number		21.8
Pulp Birghtness % ISO		26.6
Pulp Intrinsic viscosity Cm^3/g		560
Bleaching sequence	CEH	D/CEHD
Chlorination stage:		
Clo_2/Chlorine %	0/4.8	1/3.8
Alkali Extractions stage:		
Sod. Hydroxide %	2.0	2.0
(End pH abvoe 10.5)		
Hypochlorite stage:		
Ca-hyopchlorite as		
available chlorine %	2.5	1.5
Sod. Hydroxide as Buffer, %	0.5	0.4
Chlorine dioxide stage: Clo_2%	-	1.0
Bleached pulp Brightness, % ISO	78.2	87.5%
Bleached pulp viscosity, Cm^3/g	320	395
Yield loss during bleaching	6.2	6.0
Total Bleaching chemical used Kg/T Pulp:		
Chlorine	73	73
Sod. Hydroxide	25	24

could be bleached to brightness level of around 80% ISO by conventional CEH bleaching sequence. Partial replacement of chlorine (20%) with the chlorine dioxide in chlorination stage and partial replacement of calcium hypochlorite with chlorine dioxide in final bleaching stage, the oxygen untreated eucalyptus pulp could be bleached to ~ 88% ISO brightness level.

CHLORINE DIOXIDE BLEACHING RESPONSE ON OXYGEN PREBLEACHED PULPS:

Table 6, indicates the chlorine dioxide bleaching response on the oxygen pretreated pulps of bagasse, bamboo and eucalyptus where 50% and 100% of the chlorine in the chlorination stage is substituted with chlorine dioxide followed by alkaline extraction and chlorine dioxide bleaching stages i.e. OD/CED and ODED bleaching of the pulps. In OD/CED and ODED bleaching of pulp, the brightness level of 8t of ~88% ISO could not be achieved in any of the three pulps. In case of bagasse, by using 1.2% chlorine (half chlorine dioxide) in chlorination stage, 0.6% sodium hydroxide in alkali extraction stage and 1% chlorine dioxide and available chlorine in final stage, the brightness achieved was 71.3%, in case of bamboo, 2% chlorine (half chlorine dioxide), 1% sodium hydroxide in alkali extraction stage and 1% chlorine dioxide as available chlorine in the final stage, the brightness achieved was only 54.4% ISO while in case of eucalyptus pulp by using same bleaching chemicals dosages as in case of bamboo pulp, the brightness achieved was 67% ISO. In other words, the bleaching response of D/CED sequence was very poor as compared to that of CEH bleaching sequence for oxygen prebleached pulps of bagasse, bamboo and eucalyptus. Bleaching response in ODCD bleaching sequence was much poorer than in OD/CED sequence. However, by using little calcium hypochlorite in the alkaline extraction stage, bleaching response was improved a little as evident from the table 7.

Still there is a need of extending laboratory studies on the bleaching of oxygen prebleached pulps of different raw materials in order to optimize the amount of the chlorine and other chlorine based

TABLE 6: Chlorine dioxide Bleaching response of Oxygen Pretreated Pulps:

	Bagasse			Bamboo			Eucalyptus		
Original untreated pulp:									
Kappa Number		14.6			18.2			19.2	
Pulp Brightness % ISO		26.0			23.1			21.1	
Pulp Intrinsic viscosity Cm^3/g		840			830			510	
Bleaching sequence	OCEH	OD/CED	ODED	OCEH	OD/CED	ODED	OCEH	OD/CED	ODED
Chlorination Stage:									
Chlorine %	1.2	0.6/0.6	0/1.2	2/0	1/1	0/2	0/2	1/1	0/2
Alkali Extractions stage:									
Sod. Hydroxide % (End pH above 10.5)	0.6	0.6	0.6	1.0	1.0	1.0	1.0	1.0	1.0
Hypochlorite stage:									
Ca-hypochlorite as available chlorine %	0.5	-	-	1.0	-	-	1.0	-	-
Sod. Hydroxide as Buffer, %	0.2	-	-	0.2	-	-	0.2	-	-
Chlorine dioxide stage:									
Chlorine dioxide as available chlorine %, applied/consumed	-	1.0/0.6	-	-	1.0/0.63	-	-	1.0/0.68	-
Bleached pulp Brightness, %ISO	78	71.3	-	78	54.4	-	80	67	-

bleaching chemical substitution with the chlorine dioxide for the better bleaching response.

POSSIBILITY OF IMPLEMENTATION OF OXYGEN PREBLEACHING IN INDIAN PAPER MILLS:

based on the results of the laboratory studies on the conventional CEH bleaching of oxygen prebleached pulps of bagasse, bamboo and eucalyptus, it is quite evident that the pulps could be bleached to around 80% ISO brightness level with the drastic reduction of bleaching chemicals requirement, pollution load generation and saving of energy and other utilities needed for effluent treatment in addition to the pulp quality improvement as compared to the CEH bleaching of the oxygen untreated pulps. There is an emerging necessity for introducing oxygen prebleaching in Indian paper mills. It is only possible by close cooperation of the mills with the machine manufacturers.

CONCLUSIONS:

1. Bleachable grade pulps of kappa number between 18/20 could be prepared from bamboo and eucalyptus by using 17.5% and 16.0% Na_2O respectively. 18.0 kappa number pulp produced from bagasse was quite shivy so lower kappa pulp (14.6) free from shives could be prepared by using 14.0% Na_2O.

2. Oxygen prebleaching of the pulps (5 kg/cm^2 oxygen pressure, 30 minutes, 120°C) could reduce the pulp kappa number to almost 50% without much drop in pulp quality i.e. pulp viscosity.

3. Untreated as well as oxygen prebleached pulps

TABLE 7: Effect of Calcium Hypochlorite on Oxygen Prebleached Pulp Bleaching with Chlorine Dioxide

	Bagasse			Bamboo			Eucalyptus		
Original untreated pulp:									
Kappa Number		14.6			18.2			19.2	
Pulp Brightness % ISO		26.0			23.1			21.1	
Pulp Intrinsic viscosity Cm³/g		840			830			510	
Bleaching sequence	OCEH	OD/CE/H	ODE/H	OCEH	OD/CE/H	ODE/H	OCEH	OD/CE/H	ODE/H
Chlorination Stage:									
Chlorine %	1.2/0	0.6/0.6	0/1.2	2/0	1/1	0/2	0/2	1/1	0/2
Alkali Extractions stage:									
Sod. Hydroxide % (End pH above 10.5)	0.6	0.6	0.6	1.0	1.0	1.0	1.0	1.0	1.0
Hypochlorite stage:									
Ca-hypochlorite as available chlorine %	0.5	0.6*	0.6*	1.0	1.0*	1.0*	1.0	1.0*	1.0*
Sod. Hydroxide as Buffer, %	0.2	- -	-	0.	-	-	0.2	-	-
Chlorine dioxide stage:									
Chlorine dioxide as available chlorine dioxide %, applied/consumed	-	0.6/0.5	0.6/04	-	1/0.6	1/0.5	-	1/0.7	1/0.5
Bleached pulp brightness, % ISO	78	80.5	72	78	76	64	80	82	75
Bleached pulp viscosity Cm³/g	630	780	810	490	670	--	350	430	440
Total yield loss in bleaching %,	6.23	6.51	4.49	4.26	4.17	4.46	6.55	5.51	4.23
Total Bleaching chemicals as available chlorine Kg/T. pulp (Chlorine, Hypo. & chlorine dioxide)	17	24	24	30	36	36	30	37	36
Total Sod. Hydroxide used	7	6	6	12	10	12	10	10	10

*** Calcium hypochlorite added in alkaline extraction stage.**

of three raw materials could be bleached easily to around 80% ISO brightness level by conventional CEH bleaching.

4. Oxygen prebleaching followed by CEH bleaching has reduced the bleaching chemicals dosage to almost half compared to CEH bleaching of untreated pulp.

5. Oxygen prebleaching also reduced the drop in

pulp viscosity during CEH bleaching of pulps.

6. Oxygen prebleaching of the pulps has resulted the marked dropped in pollution load particularly AOX in conventional CEH bleaching of pulps. Values of the AOX in the effluent generated as quite within the range prescribed by the Central Pollution Control Board.

7. Partial subsitution of chlorine and other chlorine based chemicals with chlorine dioxide in CEH bleaching of untreated eucalyptus pulp responded good. Untreated eucalyptus pulp could be bleached to ~88% ISO brightness level.

8. 50% substitution of chlorine in chlorination stage followed by alkaline extraction and chlorine dioxide bleaching of oxygen prebleached pulp showed poor bleaching response. Pulp of bagasse bamboo and eucalyptus could be bleached to 71.3, 54.4 and 67% ISO brightness level. Response was much poorer where substitution with chlorine dioxide was 100%.

9. In chlorine dioxide bleaching of oxygen prebleached pulp, the use of calcium hypochlorite even in alkali extraction stage, helped in increasing the brightness to some extent. Targeted brightness of around 80% ISO could be achieved for all the three pulps by OD/CE/HD sequence while it was difficult to achieve in case of bagasse and bamboo.

10. Viscosity drop in OD/CE/HD bleaching sequence was even less than the drop in OCEH sequence.

11. Reduction in pollution load (BOD, COD and TOCl) was further reduced compared to that in OCEH sequence for all the three pulps.

12. To introduce oxygen prebleaching in Indian paper mills, a close cooperation of machine manufacturers is required.

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