Oxygen Delignification of Bagasse Kraft Pulp-Promising Approach to Combat Bleach Plant Pollution

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ABSTRACT

Surging environmental awareness and concern with mounting environmental pressure has forced the pulp and paper industry to find alternatives to reduce pollutants in general and chlorinated organics in particular. Bagasse, in addition to being eco friendly by way of forest conservation, has been very much favourable towards reduced pollutant generation owing to its low kappa number pulp. In addition, Oxygen delignification, as further step yields a bagasse pulp of ultra low kappa number. This in turn generates effluent of exceptionally low pollutants with regard to color, COD, TDS and AOX after short bleaching. The present study highlights the potential of Oxygen delignification of bagasse kraft pulp in significantly reducing the pollutants, with better pulp properties in comparison to conventional CEH bleaching. Oxygen prebleaching of bagasse chemical pulp gives us the easy approach to meet the stringent pollution standards to be met in the years to come. The approach suggested is retrofittable into conventional systems for the phase wise reduction/elimination of chlorine and its compounds in addition to lowering pollution down to incredibe levels.

INTRODUCTION

Mounting environmental pressure all over the world, has forced the pulp and paper industry to look into alternatives to reduce pollution. The bleach plant being the major source for pollution in the pulp and paper industry, significant focus has been on relooking the bleaching sequence, without sacrificing quality at the same time, meeting the ever growing trend towards higher brightness. Chlorine and its compounds, though form the major precursors for the formation of AOX, the chlorinated organic pollutant, objectionable in the effluent, it is the lignin content in the pulp , entering the bleach plant, which decided the entire pollution load in terms of color, COD, BOD, AOX, TDS etc. Hence, any attempt to reduce the lignin content to the maximum possible extent, before it enters the bleach plant, will be the most appropriate way eliminate pollution at source, rather than going for end of pipe measures.

Reduced lignin content in the unbleached pulp can be attained through several ways. The modern extended delignification techniques, enzymes prebleaching oxygen delignification are some of the most promising, commercially applied technologies world over. Among these, the oxygen delignification

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seems to be the most attractive options to reduce the brown pulp kappa entering bleaching.

The industrial application of oxygen bleaching has expanded very rapidly only in years, though the first commercial plant was started in the 1970 s. with the intensification of phasing out of chlorine and chlorine containing compounds, both technical and economic considerations have mandated the use of oxygen.

Though the oxygen delignification is not new, application of oxygen bleaching non-woods, particularly "bagasse" has attracted little attention. Bagasse, by nature produces a low kappa pulp by normal kraft process it self. Extending the same with an oxygen delignification step results in an ultra low kappa necessitating only a single stage brightening step, to reach 88% ISO brightnes targets. We have also investigated for the first time, the effect of added Hydrogen peroxide in the extended delignification stage - a facet so for not investigated for bagasse.

The paper discusses the work carried out at Tamil Nadu Newsprint and Papers Ltd, Kagithapuram, a bagasse based mill producing 1, 80,000 tons of paper annually using not less than 75% bagasse pulp in its furnish. Oxygen delignification of bagasse pulp has shown several pathways to reduce pollution significantly in comparison to existing CEH bleaching.

EXPERIMENTAL

Oxygen delignification of bagasse chemical pulp was carried out in laboratory digester. Bagasse kraft chemical pulp was collected from pulpmill, after screening, and dewatered to uniform consistency in laboratory hydroextractor.

The Plackett and Burman design of experiments was adopted to assess the influence of variables in Oxygen delignification, on the final pulp quality. Plackett and Burman design basically involves study at two levels of each variable. The high level indicated by (+) and the low level indicated by (-) are chosen enough apart so that significant response in pulp properties is expected. It is also assumed that within the high and low levels chosen, the response is essentially linear (1).

The process variables and conditions in Plackett and Burman design for Oxygen delignification of bagasse pulp is given in Table 1 and Table 2 respectively. From the results obtained from the experiments (Table 3), the influence of each variable on the properties were made. Based on the relative ranking the most influential variable on the properties was determined as per Reference (2). From the experiments an empirical equation could be arrived at to set the variables (conditions) for Oxygen delignification of bagasse kraft pulp, to reach the target values of kappa number, brightness and viscosity.

The following equation, for theoritically arriving at the target values were deduced

Kappa number = 5.4 - 0.6 (Alkali %-2.0) - 0.02 (Time mts - 37.5) - 0.05 (Temp °C-110)
Brightness = 57.7 +3.35 (Alkali %-2.0) + 0.355 (Temp °C-110) +0.064 (Time mts - 37.5)
Viscosity = 25.4-0.065 (Alkali %-2.0) - 0.205 (Temp °C - 110 + 0.1167 (CY - 9.0)

TABLE 1: PLACKETT AND BURMAN DESIGN OF EXPERIMENTS

Expt. NO.	X1	X2	X3	X4	X5	X6	X7
1	+	+	+	-	+	-	-
2	+	+	-	+	-	-	+
3	+	-	+	-	-	+	+
4	-	+	-	-	+	+	+
5	+	-	-	+	+	+	-
6	-	-	+	+	+	-	+
7	-	+	+	+	-	+	-
8	-	-	-	-	-	-	-

X1 TO X7 : Variables in the process
+ indicates high level of the variable
_ indicates low level of the variable

TABLE 2: PLACKETT AND BURMAN DESIGN FOR OXYGEN DELIGNIFICATION

Expt. NO.	CY	NaOH	TEMP	O_2 PRES	TIME	X6	X7
1	12	3	120	5	60	X	X
2	12	3	100	10	15	X	X
3	12	1	120	5	15	X	X
4	6	3	100	5	60	X	X
5	12	1	100	10	60	X	X
6	6	1	120	10	60	X	X
7	6	3	120	10	15	X	X
8	6	1	100	5	15	X	X

X_6 AND X_7 ARE DUMMY VARIABLES

Based on the above equations, the variable conditions can be fixed to achieve the target kappa number and in turn deduce the values of brightness and viscosity that can be obtained. The above equations were checked for their validity by substituting the conditions in the respective equations and compared with original pulp kappa achieved experimentally.

Little or no available data on extended oxygen delignification of bagasse kraft pulp, necessitated the above optimisation exercise. The above equations are valid for kappa number range of 9-10 and deviations in the kappa will definitely have influence on the theoritical value in comparison to the experimental value.

Laboratory bleaching experiments were carried

TABLE 3: BAGASSE PULP PROPERTIES AFTER O_2 EXPERIMENTS

					At 300 ml CSF		
Expt. No.	Yield	Kappa	Bri	Vis	BL	TF	BF
	%		% ISO	cPs	M		
Unbld	100	9.2	44.5	29.2	6950	60.8	45.6
1	9.1	3.3	66.6	22.8	6700	59.0	46.0
2	96.1	5.9	55.8	27.4	7200	58.0	45.2
3	96.6	5.2	56.7	24.8	6950	61.0	45.7
4	95.5	6.0	52.4	28.0	7110	57.8	46.5
5	94.3	4.6	58.9	27.3	6500	59.0	42.0
6	94.5	5.9	58.8	24.3	7000	60.0	44.0
7	95.8	5.3	62.9	21.5	7300	60.0	44.0
8	96.3	7.0	49.6	27.1	7150	59.8	47.0
AVG	95.5	5.4	57.7	25.4	7026	59.3	45.0

TABLE 4: CONSTANT BLEACHING CONDITIONS

Parameter	O	(OP)	C	E	H	D	P
Consistency %	12	12	3	8	8	8	8
Temperature °C	120	90	Amb	60	40	70	90
Time mts	60	60	30	60	120	180	240
pH	>10.5	>10.5	2	>10.5	8.5-9.5	2.5-3.5	10.0-11.0
O_2 pressure kg/cm^2	5	5	--	--	--	--	--

out using different sequences. The conditions maintained at different stages of bleaching are presented in Table 4. Oxygen delignification was performed on 500 g OD pulp while subsequent bleaching was performed on 100 g OD pulp. The effluent generated from each stage was collected and the combined effluent from the bleaching sequence was analysed for Color, COD, TDS and AOX. Chlorination, Extraction, Hypochlorite, Chlorine di oxide, Peroxide bleaching were performed in Polythene bagasse under conditions specified in Table 4. The pulps, after bleaching, were washed with water equivalent to 20 times the OD weight of pulp and the filtrate was collected for pollutant analysis. The pulp brightness, viscosity, strength and

TABLE 5: OXYGEN DELIGNIFICATION OF BAGASSE CHEMICAL PULP

Ubleached pulp							
Kappa number		8.7			9.0		
Brightness % ISO		48.6			50.3		
Viscosity cPs		28.7			26.6		
Oxygen Delignification		**O**			**OP**		
Alkali as NaOH % Applied		2.00			2.00		
Consumed		1.74			1.56		
pH Initial/Final		12.7/10.5			11.3/10.9		
H_2O_2 % applied/consumed					2.0/2.0		
Kappa number		3.1			2.6		
Yield % on unbld pulp		94.4			94.9		
Brightness % ISO		65.8			73.4		
Viscosity cPs		21.7			20.8		

TABLE 6: BLEACHING DATA OF DIFFERENT BLEACHING SEQUENCES

SEQUENCE	CEH	OCEH	OH 1.5	OD	(OP)-H	(OP)-P	(OP)-D
Initial Kappa number	8.9	3.1	3.1	3.1	2.6	2.6	2.6
Brightness % ISO	49.5	66.6	66.6	66.6	73.4	73.4	73.4
Viscosity cPs	27.7	22.6	22.6	22.6	20.8	20.8	20.8
Chlorine as Cl_2 % applied	1.82	0.65					
consumed	1.72	0.54					
pH Final	2.63	3.0					
Alkali as NaOH % applied	1.00	0.50					
consumed	0.69	0.29					
pH Initial/Final	2.0/11.10	1.5/11.0					
Hypochlorite as Cl_2% applied	1.25	0.50	1.50		1.00		
consumed	0.96	0.33	1.36		0.77		
ClO_2 as ClO_2 % applied				1.14			1.14
consumed				1.10			1.13
Peroxide as H_2O_2 % applied						2.00	
consumed						1.39	
pH Initial/Final	10.0/8.5	9.8/8.3	10.8/8.0	3.5/2.5	10.2/8.0	1.2/10.8	3.5/2.7
Brightness % ISO	85.6	87.9	84.7	87.8	84.7	82.8	87.4
Viscosity cPs	13.7	13.8	14.9	20.4	20.6	17.8	20.3

optical properties were determined as per Tappi standards. The COD, TDS and color were determined as per IS 2448 and AOX according to ISO 9562 in Euroglas AOX analyser.

The experiments were performed triplicate and the average result of the three trials have been presented.

RESULTS AND DISCUSSION

The Oxygen delignification results and Peroxide reinforced Oxygen delignification results are presented in TAble 5. 0.5% Magnesium Carbonate was added as viscosity protector, prior to addition of the alkali. It can be observed from the results that the kappa reduction is to the tune of 60-65%, which is higher than the normal levels adopted for softwood and hardwoods (40-50%). Decreasing the temperature and maintaining milder conditions could contain the delignification witin 50% levels. The target of 50% kappa reduction is usually maintained to preserve the pulp from degradation as oxygen is not a specific delignifying agent. However, it can be seen that even at such high levels of kappa reduction, the strength drop is felt only in terms of tensile while there is improvement in Tear factor. The overall strength factor (3) is found to be unaffected even at such highlevels of delignification. In the Peroxide reinforced Oxygen delignification, due to the presence of Hydrogen peroxide, the reaction temperature had to be reduced to 100°C from the regular level of 120°C which is being maintained for Oxygen delignification. Under milder conditions, with 2% peroxide charge, the (OP) pulp had a brightness of 74% ISO with a kappa number as low as 2.6. The strength properties show no drop in

TABLE 7 : O_2 DELIGNIFICATION OF CHEMICAL BAGASSE PULP -PROPERTIES

CHEMICAL BAGASSE UNBLEACHED PULP

Kappa No.	8.9
Brightness % ISO	49.5
Viscosity cPs	27.7
Freeness ml CSF	480
Bulk cc/g	1.53
Breaking length M	62.15
Tear Factor	60.7
Burst Factor	37.4
Strength Factor	4.71

	OXYGEN	OXYGEN-PEROXIDE
Kappa No.	3.1	2.6
Brightness % ISO	66.6	73.4
Viscosity cPs	22.6	20.8
Freeness ml CSF	510	500
Bulk cc/g	1.48	1.46
Breaking length M	5565	6500
Tear Factor	67.6	64.2
Burst Factor	34.6	40.9
Strength Factor	4.71	5.00

	OXYGEN: CEH	OXYGEN: H1.5	OXYGEN: D3.0	OXYGEN-PEROXIDE: H1.0	OXYGEN-PEROXIDE: P2.0	OXYGEN-PEROXIDE: D3.0	UNBLEACHED: CEH
Kappa No.	3.1	3.1	3.1	2.6	2.6	2.6	8.9
Brightness % ISO	87.9	84.7	87.8	84.7	82.8	87.4	85.6
Viscosity cPs	13.8	14.9	20.4	20.6	17.8	20.3	13.7
Freeness ml CSF	410	400	500	435	420	485	380
Bulk cc/g	1.40	1.47	1.43	1.45	1.41	1.37	1.40
Breaking length M	5980	6390	5640	6430	6550	6565	6430
Tear Factor	61.7	59.7	69.8	63.0	62.3	65.6	55.7
Burst Factor	36.1	38.8	33.6	42.5	41.3	39.5	38.4
Strength Factor	4.66	4.74	4.81	4.88	4.90	5.03	4.60
Colour kg/t	1.57	0.00	0.40	0.00	0.00	0.35	26.22
TDS kg/t	41.97	43.28	14.5	42.78	20.56	17.1	87.00
COD kg/t	15.79	11.68	5.44	8.74	16.54	6.72	39.83
AOX kg/t	0.42	1.03	0.17	0.60	0.00	0.16	2.21
POLLUTION REDUCTION							
Redn (%) w.r.t. CEH sequence							
Colour	94.02	100.00	98.47	100.00	100.00	98.67	
TDS	51.76	50.25	83.33	50.83	76.37	80.34	
COD	60.36	70.68	86.34	78.06	58.47	83.13	
AOX	80.97	53.48	92.40	72.85	100.00	92.62	

Strength factor = SORT (Km x dN) ; Km - Br. Length in KM and dN is tear strength in Decinewton comparison to unbleached pulp. It is known that Oxygen delignification in presence of Peroxide, has improved selectivity (4) and this is rightly proved by the results. The strength properties at lower kappa number are better than Oxygen delignified pulp and show an improved tear over the unbleached pulp. The overall strength factor shown an improvement over the unbleached pulp, in the case of Peroxide reinforced Oxygen delignification, while it remains unaffected in Oxygen delignification. Both the cases show a significant improvement in Tear factor over the unbleached pulp.

The pulp yield is 94.4% in case of Oxygen delignification and 94.9% in cse of Peroxide reinforced Oxygen delignification.

The overall pulp properties are little affected by Oxygen delignification and in fact better with regard to Tear.

Bleaching to target brightness levels of 85-88% ISO was carried out for the unbleached decker pulp as well as the Oxygen delignified pulps. Several short sequences were tried for the Oxygen delignified pulp and compared with the conventional CEH bleaching of unbleached pulp. The summary of bleaching experiments carried out presented in Table 6 show that, as expected, the bleach chemical requirement for achieving the same brighness level is substantially lower in comparison to that of CEH bleaching of unbleached pulp. Alternatively, a single stage bleaching with either Hypo or Chlorine di oxide is sufficient and this results in significant reduction in pollutant concentrations as well as pollutant volume.

Total chlorine free (TCF) bleaching of the chemical bagasse pulp was carried out. The sequence (OP)-P with 2% Hydrogen peroxide charge could not however reach 85 + Brightness target and even with 3% peroxide the brightness could not be raised above 83% ISO. However, this brightness level is suitable for making low bright Printing and writing papers.

O-CEH bleaching was also carried out and the pollutant generation was compared with the conventional CEH sequence. The brightness of O-CEH pulp was the highest even with very little dosage of bleach chemicals. Though reduction in effluent volume cannot be envisaged with O-CEH in comparison to CEH, the pollution reduction was substantial.

The Oxygen delignified pulp and the Peroxide reinforced Oxygen delignified pulp were bleached using a single stage Hypochlorite and also a single stage Chlorine di oxide, as the kappa number of the pulps were as low as 2.6-3.0. The values are similar to those obtained in the conventional Extraction stage of the CEH bleaching. The single stage bleaching could easily meet the target brightness levels.

The pulp properties and the pollutant generation are presented in Table 7. As evident from the table, there is no significant loss in strength, even at such high delignification to the tune of 65%. The strength factor determined by Sqrt (kN x dN) (3) clearly shows no change. The freeness and Tear factor have improved with slight reduction in Tensile in some cases. All the bleached pulp stength properties are better than CEH pulp strength, particularly in terms of Tear factor. The bleachability also improves after Oxygen delignification. The Peroxide reinforced Oxygen shows better strength properties as expected, as it improves the selectivity.

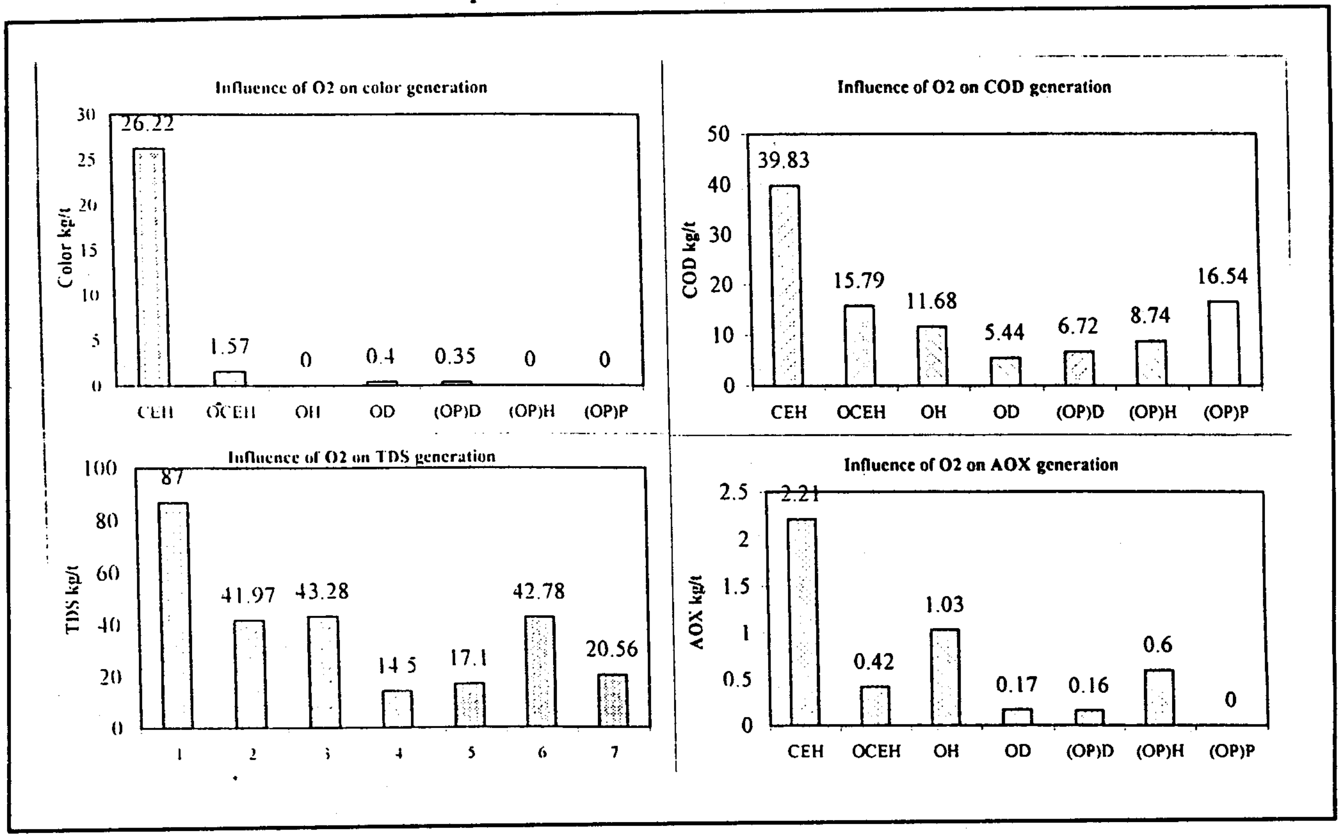
SHIVE REDUCTION

Oxygen delignificatin is efficient in removing shives during bleaching (5). The shive content was found to reduce from 0.96% to 0.08%. In another case, the shive content of 3.48 % got reduced to 0.32% with Oxygen delignification. Thus the shive content gets reduced by over 90%. This paves way to go for high kappa pulping, with slightly higher amount of rejects, which can easily be taken care during Oxygen delignification. Thus the reduction in rejects will be reflected as accepts and pulp throughput increases.

POLLUTANT REDUCTION

The main advantage of Oxygen delignification is felt only at the effluent stage. The comparative pollutant generation presented in Table 7 shows, though there is only 60% reduction in kappa, the color reduction is significant, which is as high as 90-93%. This is one of the major advantages with Oxygen. The color reduction is not proportional to kappa reduction but much more. It may be noted that in the case of single stage bleaching with Hypochlorite, the color reduction is 100% in comparison to CEH bleach effluent color. The COD and TDS reduction, as shown, show significant reduction, which is the need of the hour. Reduction in TDS can be obtained only through reduced bleach chemicals. There is no other way to reduce the TDS as an end of pipe measure. Only Oxygen facilitates this TDS reduction in effluent, through reduced bleach chemical demand. The COD reduction is also significant. The effect of Oxygen prebleaching on pollutant generation is shown pictorially in fig 1. The

Fig. 1 : Influence of Oxygen Delignification on Pollutant Generation in Different Bleaching Sequences of Chemical Bagasse Pulp



reduction of pollutants in comparison to CEH bleaching is shown in fig 2.

The advantage of COD reduction and color reduction can be felt only if the Oxygen stage effluent is taken into the recovery cycle, through the Brown stock washing loop. Taking Oxygen stage into the recovery not only reduces the Color and COD load but also improves the recovery efficiency. The overall recovery load will increase by 5% due to Oxygen delignification. (6)

AOX REDUCTION

AOX in the effluent, the main compound dictating the usage of Chlorine and its compounds for bleaching, is the talk of the day. The restrictions in the usage Chlorine has come into force only due to the formation of adsorbable organic halogen compounds. The usage of chlorine for bleaching is again governed by the incoming kappa to the bleach plant. Hence as the incoming kappa reduces, the AOX reduces. Hence Oxygen delignification is the best route to reduce the AOX formtion, through reduced chlorine. The AOX generation and reduction in comparison to CEH given in Table 7 clearly shows significant reduction. The chlorine di oxide bleaching shows the maximum reduction.

The reduction in pollutants in terms of color, COD, TDS and AOX, is the most attractive feature of the Oxygen delignification, in addition to its low running cost. Though installation of Oxygen requires capital investment, the returns in terms of environment is far more than the investment. The returns on a long run are very attractive.

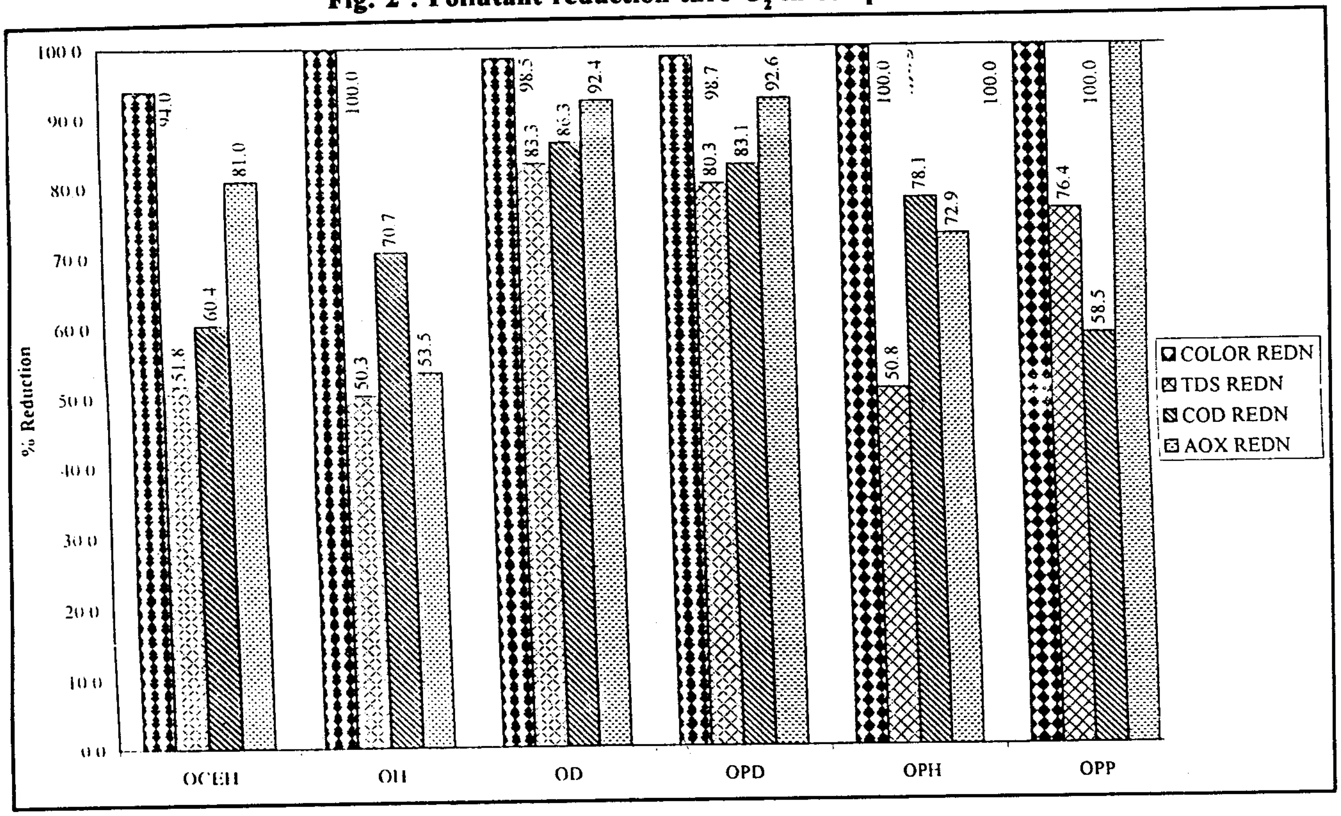
OBSERVATIONS AND CONCLUSIONS

- Oxygen delignification substantially reduces pollution load in terms of Color, TDS, COD and AOX, without sacrificing pulp quality. Pulp bleachability is improved.

- Single stage bleaching with Hypo or Chlorine di oxide enables 85-88% ISO brightness, after Oxygen delignification. This helps in significant reduction in effluent volume, in comparison to conventional CEH bleaching.

- The Oxygen stage effluent can be taken to

Fig. 2 : Pollutant reduction thro O_2 in comparison to CEH



soda recovery through the brown stock washing loop.

- Single stage hypo bleaching gives absolutely no colored effluent. Single stage chlorine di oxide stage is most attractive in all aspects.

- Peroxide reinforced Oxygen shows improved selectivity over Oxygen delignification. The TCF sequence OP-P gives slightly lower brightness. But pollutant generation is excellent with regard to color and AOX, in comparison to CEH bleaching. This sequence helps in closing the bleach plant loop.

- Oxygen delignification shows significant shive reduction, which can be promising route to high kappa pulping of bagasse to reap the benefits of higher yield and improved strength properties.

- In case of low bright varieties like Newsprint or 75% brightness grades, mere Oxygen delignification or Peroxide reinforced Oxygen alone is sufficient, doing away totally the subsequent bleach plant. This reduces effluent volume significantly.

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REFERENCES

1. Cardwell, S., Cundall, S.B., Appita, Vol 29, No. 5, March 1976. p 350
2. Mohan Rao, N.R., Mathur, R.M., Kulkarni, A.G., Pant, R., Sharma, Y.K., Rao, A.R.K., IPPTA vol 19, No.3, Sep 1982, p 38.
3. Patt, R., Odermatt, J., Yeber-Ortiz, M., Kordsachia, O., Schubert, L.-H., Workshop of emerging pulping and chlorine free bleaching technologies, 1993, N.C.State University.
4. Pulp bleaching - Principles and practice, Oxygen delignification - Thomas J McDonough, Tappi press, 1996, p 225.
5. Pulp bleaching - Principles and practice, Bleaching shives and dirt - Peter Axegard and Elisabeth Bergnor GIdnert, Tappi press, 1996, p 451
6. Pulp bleaching - Principles and practice, Oxygen delignification - Thomas J McDonough, Tappi press, 1996, p 237.