Role of Oxygen In The Preliminary Stage of Bleaching of Bamboo + Eucalyptus (70:30) Pulp Followed By Multi-Stage Bleaching Sequences

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ABSTRACT

Kraft digestions of Bamboo + Eucalyptus (70:30) were performed in order to get higher Kappa No. (29.5) and lower Kappa No. (25.2) pulps and were bleached under O/C/E/H Sequence to achieve 79-80% P.V. brightness. Effluent at each stage of bleaching was studied for physico-chemical properties. Unbleached pulp, Alkali/Oxygen, C/E/H & O/C/E/H sequence bleached pulps were evaluated for physical strength properties. In order to go for still higher brightness (84-85% PV) and retaining good physical strength properties, the lower Kappa No. (25.2), bamboo + Eucalyptus (70:30) unbleached pulp was bleached under O/C/EP/H, O/C/EP/H/P, O/C/EP/H/D Sequences. The effluent characteristics at each stage of bleaching and physical strength properties of the finally bleached pulp were evaluated.

It was observed that lower Kappa No. (25.2) pulp bleached under O/C/E/H Sequence gives higher physical strength properties and reduces pollution measuring parameters considerably as compared to higher Kappa No. (29.5) pulp bleached under similar bleaching sequence. To get higher strength properties and higher brightness (84-85% PV), Hydrogen peroxide and Chlorine dioxide were used in O/C/EP/H, O/C/EP/H/P and O/C/EP/H/D Sequences. Bleached pulp under O/C/EP/H/D sequence gives higher viscosity and physical strength properties followed by O/C/EP/H/P and O/C/EP/H sequences. AOX calculated theoritically gives an idea that the limit of Tocl, 2 Kg/ton of pulp could be achieved by incorporating Alkali/Oxygen delignification stage prior to C/E/H, C/EP/H/P, and C/EP/H/D sequences and afterwards installing A.S.P. or Aeration system at the effluent treatment plant.

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INTRODUCTION

A worldwide drive to reduce pollution from pulp bleaching plants has resulted in mill scale application of Oxygen/Alkali delignification. By partly replacing the chlorination stage by Oxygen/Alkali stage BOD, COD and Colour of effluent can be reduced considerably. The Waste liquor from washing of Oxygen pulp is recirculated and used in brown stock washing. Thus most of the organic matter dissolved during Oxygen/Alkali stage goes into the mills chemical recovery.

Although oxygen bleaching sequences consume less[1] expensive chemicals than do non-oxygen sequences. This reduction in operating cost has not been the main incentive for using oxygen delignification. Instead, the significant fact has been the ability of oxygen stages to contribute to pollution abatement. A particular feature in this regard is the fact that all types of polluting substances, including high molecular weight aromatic materials are retained to a great extent within the mill.[1] This is in contrast to biological treatment which only reduces certain easily oxidized substances and has minimal effect on the amount of total organic load in the effluent.[2]

BOD and acute toxicity are caused by biodegradable low molecular weight compounds where as high molecular weight compounds are primary cause of COD, Colour and chronic toxicity.[3,4] Generally higher molecular weight compounds are more resistant to biological degradation. Colour is not effected by biological treatment as it is caused by high molecular weight compounds that are resistant to biodegradation. Aerobic treatment reduces AOX [5,6] by 25-60%.

Oxygen delignification can reduce [7,8] colour by 70-90%, BOD by 81% and COD by 67%. The reduction is due to recycling of organic matter to recovery boiler, where it under goes combustion[9]. Considering the viability of oxygen delignification technology in the present Indian Scenerio to reduce pollution load specifically of the Chlorolignin Compounds its importance has become much more than ever before, Kraft pulps of Kappa No. 29.5 and 25.2 were produced on lab scale by using Bamboo + Eucalyptus (70:30) and bleached under C/E/H, O/C/E/H, Sequences. Further Bamboo + Eucalyptus (70:30) pulp of Kappa No. 25.2 was also bleached under O/C/EP/H, O/C/EP/H/D and O/C/EP/H/P sequences to study the pollution load created in each bleaching sequences and the pulp quality.

EXPERIMENTAL DETAILS

Autoclave Digestion

Kraft Digestions of Bamboo + Eucalyptus (70:30) screened chips were performed in a 30 litre capacity electrically heated digester having indirect forced liquor circulation arrangement. Cooking conditions were adjusted to get pulps of Kappa No. 29-30 and 24-25. Physico-chemical properties of pulp and black liquor are reported in **Table-1.**

Oxygen /Alkali delignification

Oxygen/Alkali delignification was performed in an autoclave having indirect forced liquor circulation arrangement. Unbleached pulp (800 gram) at 8% consistency, alongwith 2.5% alkali and 0.5% Magnesium sulphate was added to the autoclave. Oxygen pressure 5.25-5.5 Kg/cm^2 for 60 mts. was maintained through a non-return valve connected to an oxygen cylinder. The temperature of reaction mixture was maintained 95°C. Physico-chemical properties of pulp and Waste water are tabulated in **Table-2.** Physical strength properties of oxygen bleached pulps are compared with their unbleached pulps in **Table-3.**

Bleaching of Oxygen Alkali delignified pulp and unbleached pulps under C/E/H Sequence

Oxygen/Alkali delignified pulps and unbleached pulps of higher and lower Kappa Numbers were bleached under C/E/H Sequences. Bleaching conditions and results are tabulated in **Table-4.**

Effluent Characteristics

Effluent characteristics pH, BOD_5, COD suspended solids, Dissolved Solids, Chloride and Colour of each stage of effluent under C/E/H bleaching sequence are reported in **Table-5.**

Physical Strength Properties

Physical strength properties of Oxygen pulps and unbleached pulps bleached under C/E/H sequence are reported in **Table-6.**

Bleaching of lower Kappa No. Oxygen pulp under C/EP/H, C/EP/H/P and C/EP/H/D Sequences

Alkali/Oxygen pulp (Kappa No.12.8) was bleached under C/EP/H, C/EP/H/P and C/EP/H/D Sequences for higher pulp brightness around 85% PV. Bleaching conditions and results are tabulated in **Table-7.**

Effluent Characteristics

Effluent characteristics of each stage of three bleaching conditions were determined by standard procedures and results are reported in **Table-8.**

Table-1

Kraft pulping of Bamboo + Eucalyptus (70:30)

S.No.	Particulars	Kraft digestion of Bamboo + Eucalyptus (70:30) Cook No.1	Cook No.2	Cook No.3
1.	Active alkali, used as Na_2O%	17.0	18.0	18.0
2.	Sulphidity, %	15.7	15.7	15.7
3.	Bath Ratio	1:3:5	1:3:5	1:3:5
4.	Cooking Schedule (mts)			
	(i) Upto 135°C	120	120	120
	(ii) from 135-165°C	60	60	60
	(iii) At 165°C	60	60	90
5.	Total Cooking Cycle (hrs)	4.0	4.0	4.5
6.	Screened yield, % O.D.	44.1	43.0	42.4
7.	Rejects, % O.D.	1.1	0.5	0.3
8.	Kappa No.	32.3	29.5	25.2
9.	Black Liquor Analysis			
	(i) °TW at 60°C	20.0	23.0	24.0
	(ii) R.A.A., g/l, as Na_2O	17.1	18.6	17.8
	(iii) Inorganic, %	31.6	32.5	30.7
	(iv) Organic, %	68.2	67.5	69.3

Table-2

Oxygen/Alkali delignification of Bamboo + Eucalyptus (70:30) pulps

S.No.	Particulars	Bamboo + Eucalyptus (70:30) pulps Cook No.2	Cook No.3
1.	Kappa No. of pulp	29.5	25.0
2.	Initial Pulp brightness, % P.V.	20.5	20.5
3.	Alkali added, %	2.5	2.5
4.	Initial pH	11.7	11.6
5.	Mg SO_4 added, %	0.5	0.5
6.	End pH	10.1	10.3
7.	Final pulp brightness, % P.V.	30.1	35.0
8.	pulp Shrinkage, %	3.6	4.3
9.	Kappa No. of Oxygen bleached pulp	20.6	12.8
10.	**Effluent Analysis**		
	(i) pH	10.1	10.3
	(ii) BOD_5 mg/l	480	560
	(iii) COD, mg/l	2198	3040
	(iv) S. Solid, mg/l	182	112
	(v) Disolved solid, mg/l	3828	4080
	(vi) Total solids, mg/l	4010	4192
	(vii) Colour, Pt. Co Unit	2300	2740
	(viii) Chloride, mg/l	80	70

Constant Oxygen delignification conditions

Consistency %	Reaction time (mts)	Reaction temp °C	Oxygen pressure maintained Kg/Cm²
8.0	60.0	95.0	5.25-5.5

Table-3

Comparison of physical strength properties of higher Kappa No. and lower Kappa No. unbleached and Oxygen bleached pulps

S. No.	Particulars	Higher Kappa No. pulp		Lower Kappa No. pulp	
		Unbleached Pulp Kappa No.29.5	Oxygen bleached Pulp Kappa No.20.6	Unbleached Pulp Kappa No.25.0	Oxygen bleached Pulp 12.8
1.	Final Freeness °SR of beaten pulp	45.0	45.0	45.0	45.0
2.	Number of beating revolutions in P.F.I. mill	11,000	9,200	10,000	9,000
3.	Bulk, CC/Gram	1.43	1.4	1.41	1.36
4.	Breaking length, meters	5815	6666	6032	6951
5.	Burst factor	55.08	57.7	57.7	60.7
6.	Tear factor	115.5	105.5	110.1	101.4
7.	Double fold	1017	928	1022	957
8.	Tensile Index, N. m/g	57.01	65.35	59.13	68.15
9.	Burst Index, K.Pa. m^2/g	5.4	5.65	5.65	5.95
10	Tear Index, m $N.m^2/g$	11.32	10.34	10.79	9.94

Table-4

Bleaching of higher and lower Kappa No. pulps under C/E/H and O/C/E/H bleaching Sequence

S. No.	Particulars	Higher Kappa No. pulp (29.5)		Lower Kappa No. pulp (25.2)	
		Unbleached Pulp	Oxygen bleached Pulp	Unbleached Pulp	Oxygen bleached Pulp
1.	**Chlorination Stage-**				
	(i) Chlorine applied, % / Chlorine consumed, %	6.0/5.6	4.5/4.2	5.0/4.4	2.5/2.3
	(ii) End pH	2.1	2.5	2.0	2.6
2.	**Caustic Extraction Stage-**				
	(i) Caustic applied, %	2.5	1.75	2.0	1.0
	(ii) End pH	11.0	11.3	10.9	11.0
3.	**Calcium Hypochlorite Stage-**				
	(i) Hypochlorite applied, % / Hypochlorite consumed %	3.50/3.45	2.5/1.72	3.00/2.65	2.0/1.41
	(ii) Buffer added %	1.0	0.7	1.0	0.6
	(iii) End pH	8.2	8.5	8.7	8.6
4.	**Final Results-**				
	(i) Total Chlorine applied, % / Total Chlorine consumed %	9.5/9.05	7.0/5.92	8.0/7.05	4.5/3.71
	(ii) Brightness of pulp % PV	79.0	80.5	80.0	80.5
	(iii) Viscosity (0.5%, CED), Cps	8.3	8.0	8.5	8.2
	(iv) Shrinkage of pulp %	11.8	13.5	10.4	11.5

Constant Bleaching Conditions

S.No.	Particulars	C	E	H
1.	Consistency, %	3.0	10.0	10.0
2.	Temperature, °C	room	60 ± 1	40 ± 1
3.	Time, mts	60	60	120

Strength Properties

Physical strength properties of the Oxygen pulp bleached under the three different bleaching sequences were determined by beating the pulps to 45 °SR freeness and preparing & testing of standard sheets as per Tappi Standards, Results are given in **Table-9.**

RESULTS & DISCUSSIONS

Bamboo + Eucalyptus (70:30) Screened chips was taken as per our mill conditions for digestion with 18% alkali as Na_2O to produce unbleached pulps of Kappa No. 29.5 and 25.2 Unbleached pulp yield was 43.0% and 42.4% respectively. Cooking conditions and results are given in Table-1.

Oxygen/Alkali delignification

To reduce chlorinated organics, oxygen/Alkali delignification of Bamboo + Eucalyptus (70:30) pulps of Kappa No. 29.5 and 25.2 was carried out which resulted decrease in Kappa No. 20.6 and 12.8 respectively. The gain in pulp brightness was 9.6 and 14.5 degrees respectively. Oxygen delignification conditions and results are reported in Table-2.

BOD_5 , COD, dissolved solids and colour of effluent are higher in lower Kappa No. Oxygen

Table-5

Effluent Characteristics of higher and lower Kappa No pulps bleached under C/E/H and O/C/E/H Sequence

S. No.	Particulars	Higher Kappa No. pulp(29.5) Unbld. Pulp	Oxygen bld. Pulp	Percent reduction	Lower Kappa No. pulp(25.2) Unbleached Pulp	Oxygen bld. Pulp	Percent reduction
1.	**Effluent Characteristics in Chlorination Stage-**						
	(i) pH	1.9	2.5	-	2.0	2.6	-
	(ii) BOD_5 , mg/l	120	45	62.5	110	35	68.2
	(iii) COD, mg/l	649	476	26.7	631	359	43.1
	(iv) S. Solids, mg/l	418	268	35.9	144	70	51.4
	(v) Dissolved Solid mg/l	3444	1774	48.5	2964	1738	41.4
	(vi) Chloride, mg/l	2300	1040	54.8	1900	660	65.3
	(vii) Colour, Pt. Co Unit	1.77	55	68.9	32	13	59.4
2.	**Effluent Characteristics in Alkali Extraction Stage-**						
	(i) pH	11.0	11.3	-	10.9	11.0	-
	(ii) BOD_5 , mg/l	500	380	24.0	460	260	43.5
	(iii) COD, mg/l	3418	1759	48.5	2419	1172	51.6
	(iv) S. Solids, mg/l	370	366	1.1	274	266	3.0
	(v) Dissolved Solid mg/l	5424	3758	30.7	4786	2228	53.4
	(vi) Chloride, mg/l	790	490	38.0	700	330	52.9
	(vii) Colour, Pt. Co Unit	8900	6800	23.6	6800	3100	54.4
3.	**Effluent Characteristics in Hypochlorite Stage-**						
	(i) pH	8.2	8.5	-	8.7	8.6	-
	(ii) BOD_5 , mg/l	220	110	50.0	180	100	44.4
	(iii) COD, mg/l	1446	466	67.8	1069	406	62.0
	(iv) S. Solids, mg/l	494	488	1.2	324	200	38.3
	(v) Dissolved Solid mg/l	12088	9000	25.5	10248	7078	30.9
	(vi) Chloride, mg/l	5400	3720	31.1	4300	2830	34.2
	(vii) Colour, Pt. Co Unit	320	Nil	-	Nil	Nil	-

Table-6

Physical Strength Properties of Higher and Lower Kappa No. Pulps bleached under C/E/H and O/C/E/H Sequences

S. No.	Particulars	Higher Kappa No. pulp (29.5) C/E/H Sequence bld. pulp	Higher Kappa No. pulp (29.5) O/C/E/H Sequence bleached pulp	Lower Kappa No. pulp (25.2) C/E/H Sequence bld. pulp	Lower Kappa No. pulp (25.2) O/C/E/H Sequence bleached pulp
1.	Final Freeness °SR of beaten pulp	45.0	45.0	45.0	45.0
2.	Number of Beating revolutions in P.F.I. mill	10,000	8,000	9,000	7,800
3.	Bulk, CC/Gram	1.35	1.30	1.32	1.27
4.	Breaking length, meters	5720	5311	5860	5476
5.	Burst factor	55.8	50.4	54.9	52.5
6.	Tear factor	90.5	80.9	85.8	84.9
7.	Double fold	1220	890	1090	1030
8.	Tensile Index, N. m/g	56.08	52.07	57.45	53.68
9.	Burst Index, K.Pa. m^2/g	5.47	4.94	5.38	5.15
10.	Tear Index, m $N.m^2/g$	8.87	7.93	8.41	8.32

bleached pulp as compared to higher Kappa No. Oxygen bleached pulp. The Waste effluent from oxygen stage can be recirculated at the brown stock washers and thus organic matter dissolved in Alkali/Oxygen stage goes into the mill recovery. Hence effluent generated at this stage has not been accounted for generating pollution load.

Comparison of Strength Properties of Oxygen/Alkali and unbleached pulps

Unbleached Bamboo + Eucalyptus (70:30) pulps of higher and lower Kappa No. and their Oxygen/ Alkali treated pulps were beaten to 45 °SR freeness in a P.F.I. mill and evaluated for physical strength properties (Table-3). Physical strength properties of Oxygen/Alkali treated pulps are superior to their corresponding higher & lower Kappa No. pulps. The bulk and Tear factor of Oxygen/Alkali pulp has reduced. Further Oxygen/Alkali treated pulp of lower Kappa No. has physical strength properties superior to Oxygen/Alkali pulp of higher Kappa No.

Comparative bleaching studies of unbleached and Alkali/Oxygen treated pulps under C/E/H Sequence

Comparison of bleaching of higher Kappa No. unbleached pulp and Oxygen/Alkali pulp shows that there was around 35% less chlorine consumption when oxygen/Alkali pulp was bleached under C/E/H Sequence as compared to unbleached pulp bleaching under C/E/H Sequence (Table-4). Pulp Shrinkage was higher in O/C/E/H bleaching Sequence for 79-80% PV brightness in respect to C/ E/H bleaching sequence.

Similarly bleach consumption for lower Kappa No. Oxygen/Alkali pulp was around 45% less compared to lower Kappa No. unbleached pulp bleaching under C/E/H Sequence to attain 79-80% pulp brightness (Table-4). Pulp shrinkage in O/C/E/H Sequence was higher than C/E/H bleaching Sequence.

Comparative effluent characteristics from Lower & Higher Kappa No. pulps bleached under C/E/H Sequence

A perusal of Table-5 shows with reduction in Kappa No. of either unbleached pulp or oxygen/Alkali pulp followed by C/E/H bleaching sequence leads to reduction in effluent parameters like BOD_5, COD, dissolved solids, suspended solids, chloride and colour. The reduction percentage of the above parameters, is much higher in Oxygen/Alkali pulp (lower Kappa No.) than Oxygen/Alkali pulp (higher Kappa No.) when bleached under C/E/H Sequence as compared to corresponding unbleached pulp bleached under C/E/H Sequence.

A perusal of **figure-1** shows pollution load Kg/ ton of pulp of the parameters BOD_5 ,COD, Chlorine,

Table-7

Bleaching of lower Kappa No. (12.85) Oxygen bleached pulp under C/EP/H, C/EP/H/P and C/EP/H/D sequences

S.No.	Particulars	Oxygen pulp bleached under C/EP/H sequence	Oxygen pulp bleached under C/EP/H/P sequence	Oxygen pulp bleached under C/EP/H/D sequence
1.	**Chlorination Stage-**			
	(i) Chlorine applied, % / Chlorine consumed, %	2.5/2.29	2.5/2.29	2.5/2.29
	(ii) End pH	2.8	2.8	2.8
2.	**Caustic Extraction Stage-**			
	(i) Caustic applied, %	1.0	1.0	1.0
	(ii) H_2O_2 added, %	0.3	0.3	0.3
	(ii) End pH	9.0	9.0	9.0
3.	**Calcium Hypochlorite Stage-**			
	(i) Hypochlorite applied, % / Hypochlorite consumed %	1.5/0.93	1.0/0.79	1.0/0.79
	(ii) Buffer added %	0.60	0.53	0.53
	(iii) End pH	8.8	9.0	9.0
4.	**Hydrogen Peroxide Stage-**			
	(i) H_2O_2 applied, %/H_2O_2 consumed %	-	0.3/0.28	-
	(ii) Buffer added, %	-	0.5	-
	(iii) End pH	-	9.0	-
5.	**Chlorine dioxide Stage-**			
	(i) ClO_2 added, % as available chlorine ClO_2 consumed % as available chlorine	-	-	0.79/0.74
	(ii) Buffer added %	-	-	0.1
	(iii) End pH	-	-	6.5
6.	**Final Results-**			
	(i) Total Chlorine applied, % / Total Chlorine consumed %	4.0/3.22	3.5/3.08	4.29/3.82
	(ii) Brightness of pulp % PV	83.5	84.0	84.5
	(iii) Viscosity of pulp (0.5%, CED), Cps	8.0	8.5	9.4
	(iv) Pulp shrinkage, %	14.3	15.2	13.5

Constant Bleaching Conditions

Particulars	C	EP	H	P	D
Consistency, %	3.0	10.0	10.0	10.0	10.0
Temperature, °C	room	60.0	40.0	60.0	70.0

Table-8

Effluent Characteristics of lower Kappa No. (12.8) Oxygen pulp bleached under C/EP/H, C/EP/H/P and C/EP/H/D Sequences

S.No.	Particulars	C/EP/H sequence	C/EP/H/P sequence	C/EP/H/D sequence
1.	**Chlorination Stage-**			
	(i) pH	2.8	2.8	2.8
	(ii) BOD_5 , mg/l	70	70	70
	(iii) COD, mg/l	385	385	385
	(iv) S. Solids, mg/l	134	134	134
	(v) Dissolved Solids, mg/l	1846	1846	1846
	(vi) Chloride, mg/l	770	770	770
	(vii) Colour, Pt. Co, unit	15	15	15
2.	**Alkali-Peroxide Stage-**			
	(i) pH	10.0	10.0	10.0
	(ii) BOD_5 , mg/l	240	240	240
	(iii) COD, mg/l	1628	1628	1628
	(iv) S. Solids, mg/l	414	414	414
	(v) Dissolved Solids, mg/l	2906	2906	2906
	(vi) Chloride, mg/l	370	370	370
	(vii) Colour, Pt. Co, unit	1280	1280	1280
3.	**Hypo Chlorite Stage-**			
	(i) pH	10.2	9.5	9.5
	(ii) BOD_5 , mg/l	100	90	90
	(iii) COD, mg/l	442	427	427
	(iv) S. Solids, mg/l	270	155	155
	(v) Dissolved Solids, mg/l	5284	3223	3223
	(vi) Chloride, mg/l	1970	1240	1240
	(vii) Colour, Pt. Co, unit	Nil	Nil	Nil
4.	**Hydrogen Peroxide Stage-**			
	(i) pH	-	10.0	-
	(ii) BOD_5 , mg/l	-	120	-
	(iii) COD, mg/l	-	582	-
	(iv) S. Solids, mg/l	-	246	-
	(v) Dissolved Solids, mg/l	-	1536	-
	(vi) Chloride, mg/l	-	30	-
	(vii)Colour, Pt. Co, unit	-	Nil	-
5.	**Chlorine dioxide Stage-**			
	(i) pH	-	-	6.0
	(ii) BOD_5 , mg/l	-	-	30
	(iii) COD, mg/l	-	-	171
	(iv) S. Solids, mg/l	-	-	126
	(v) Dissolved Solids, mg/l	-	-	1142
	(vi) Chloride, mg/l	-	-	210
	(vii)Colour, Pt. Co, unit	-	-	Nil

Table-9

Physical Strength Properties of Bamboo + Eucalyptus (70:30) bleached pulp under O/C/EP/H, O/C/EP/H/P and O/C/EP/H/D Sequences

S.	Particulars	O/C/EP/H Sequence Bamboo+Eucalyptus (70:30) Bleached Pulp	O/C/EP/H/P Sequence Bamboo+Eucalyptus (70:30) Bleached Pulp	O/C/EP/H/D Sequence Bamboo + Eucalyptus (70:30) Bleached Pulp
1.	Pulp beaten to °SR	45.0	45.0	45.0
2.	Number of P.F.I. mill Beating revolution	7500	8500	9000
3.	Bulk, cc/gram	1.27	1.26	1.26
4.	Breaking length, meters	6060	6395	6661
5.	Burst Factor	58.43	60.10	64.40
6.	Tear Factor	82.5	75.72	79.14
7.	Double Fold	570	508	626
8.	Tensile Index N.m/g	59.41	62.70	65.30
9.	Burst Index, K.Pa. m^2/g	5.73	5.89	6.31
10.	Tear Index, Nm^2/g	8.09	7.42	7.75

Colour & AOX could be brought down by 50% incorporating Alkali/Oxygen stage prior to bleaching of lower Kappa No. pulp under C/E/H Sequence. AOX, Kg/Ton of pulp has been calculated theoritically by the formula.

AOX Kg/Ton of pulp = 0.1(C+0.2D+0.6H). ToCl 2Kg/Ton of pulp could be easily met by oxidation process either by Activated sludge process or use of surface aerators at the effluent treatment plant.

Comparative physical strength properties of C/E/H and O/C/E/H Sequence bleached pulps

Physical Strength properties of lower Kappa No. pulps (unbleached & Alkali/Oxygen pulp) bleached under C/E/H Sequence are better in strength properties as compared to the counterpart higher Kappa No. bleached pulps (Table-6) because of lower consumption of Chlorine in hypochlorite stage.

Bleaching of lower Kappa No. (12.85) Oxygen pulp under various bleaching Sequences to retain higher strength properties and higher brightness

Lower Kappa No. (12.85) Alkali/Oxygen pulp (Table-2) was selected for bleaching under various sequences as this pulp has reduced pollution parameters and retained higher strength properties under C/E/H bleaching sequence compared to higher Kappa No. (20.6) Alkali/Oxygen Pulp.

In order to retain higher strength properties at 84-85% PV, brightness hydrogen peroxide and chlorinedioxide were used in the bleaching sequences C/EP/H, C/EP/H/P, C/EP/H/D. The bleaching conditions and results reported in Table-7 shows higher brightness & higher viscosity of pulp were achieved under C/EP/H/D Sequence followed by C/EP/H/P and C/EP/H Sequences. The pulp shrinkage to attain 84-85% was higher as compared to C/E/H bleaching Sequence of lower Kappa No. pulp to achieve 79-80% brightness (Table-4). Pulp shrinkage was minimum under C/EP/H/D bleaching sequences as compared to other bleaching sequences.

Effluent Characteristics from pulps bleached to higher brightness

Effluent characteristics pH, BOD_5 , COD, S. Solids, Dissolved solid, Chloride and Colour at every stage of bleaching under C/EP/H, C/EP/H/P and C/EP/H/D Sequences reported in Table-8 shows COD and suspended solids were higher in EP stage. but colour was reduced by about 60% as compared to E-Stage of C/E/H Sequence (Table-5). COD, Suspended Solids, Dissolved Solids and Chloride were reduced in hypochlorite stage of C/EP/H/P and C/EP/H/D Sequences, comparing to the results of C/EP/H Sequence. The reduction in parameters is due to lower dosage of hypochlorite applied in both the Sequences, as compared to C/EP/H Sequence.

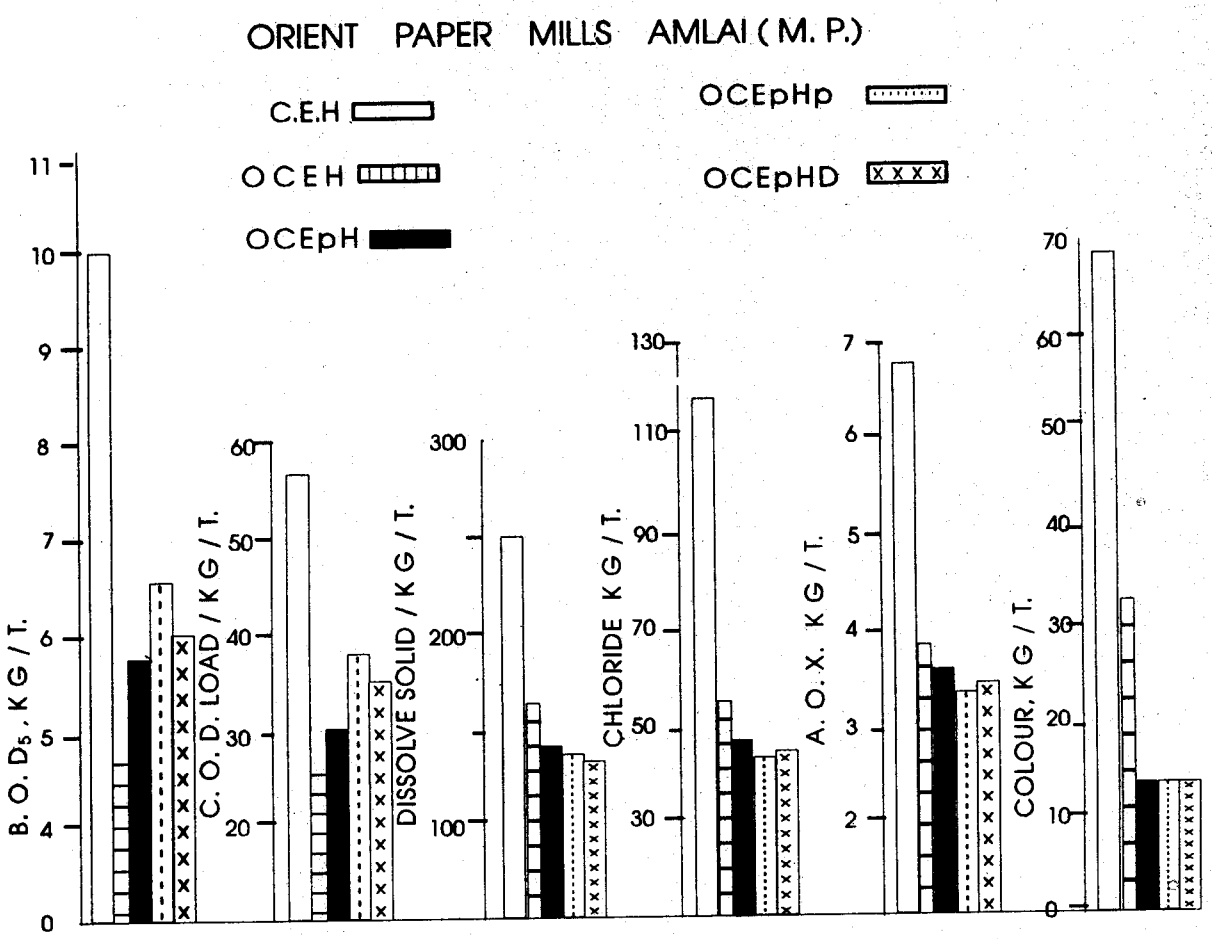

Fig.1- Effluent Load, Kg/T. of B.O.D$_5$, C.O.D., Dissolve Solids, Chloride, A.O.X. And Colour From Pulps Bleached Under Different Bleaching Sequences.

Dissolved Solids, Chloride, Colour and AOX Kg/Ton under O/C/EP/H, O/C/EP/H/P and O/C/EP/H/D Sequences, were lower as compared to O/C/E/H sequence (Fig.1) but BOD$_5$ and COD were little on higher side.

Physical Strength Properties of higher brightness pulps

Physical Strength properties reported in Table-9 shows bleached pulp of O/C/EP/H/D Sequence has excellent physical strength properties followed by O/C/EP/H/P and O/C/EP/H sequences. Chlorinedioxide and hydrogen peroxide in these bleaching Sequences has helped in getting higher tensile & Burst Index as compared to O/C/E/H Sequence where these two chemicals have not been used **(Fig.2).**

CONCLUSION

Lower Kappa No. (25.2) unbleached Bamboo + Eucalyptus (70:30) pulp is more suitable for Oxygen/Alkali delignification than higher Kappa No. (29.5) unbleached pulp for reducing pollution load and in getting higher physical strength properties to achieve 79-80% PV pulp brightness under C/E/H bleaching Sequence.

To achieve higher pulp brightness (84-85%PV) the bleaching sequence in order of preference are O/

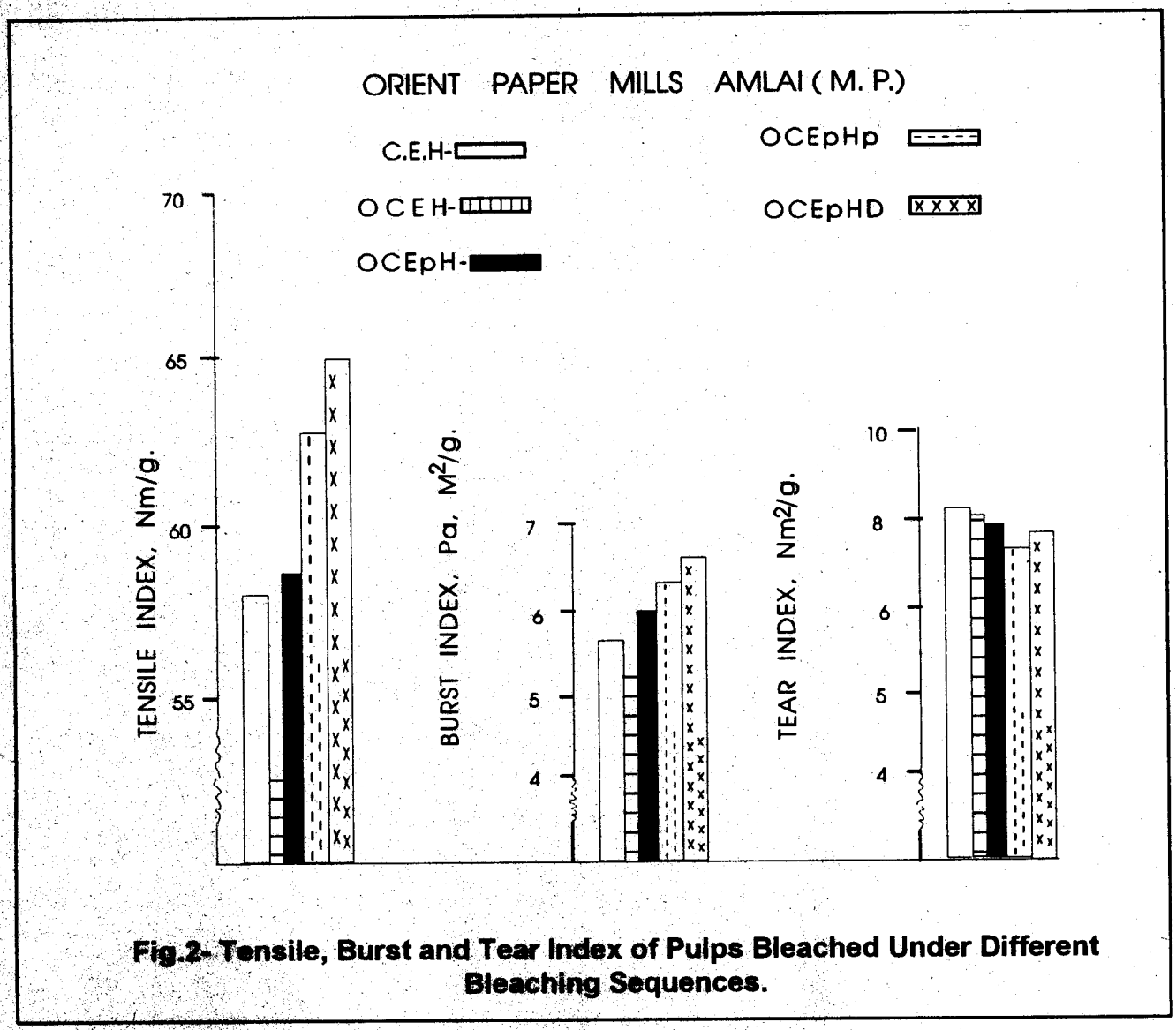

Fig.2- Tensile, Burst and Tear Index of Pulps Bleached Under Different Bleaching Sequences.

C/EP/H/D, O/C/EP/H/P and O/C/EP/H for getting higher pulp viscosity and higher physical strength properties. Pollution load is reduced under these bleaching sequences as compared to C/E/H bleaching Sequence. ToCl limit of 2 Kg/Ton of pulp is expected to be met after effluent treatment having either A.S.P. or surface arration system (Oxidation pond).

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