STUDIES ON E.C.F. BLEACHING SEQUENCES OF PULPS FROM AN ENVIRONMENTAL POINT OF VIEW

A DISSERTATION

submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

PULP AND PAPER

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in Dissertation entitled **"STUDIES ON ECF BLEACHING SEQUENCES OF PULPS FROM AN ENVIRONMENTAL POINT OF VIEW"** in partial fulfillment of the requirement for the award of degree of **Master of Engineering** in the Department of Pulp and Paper of the University of Roorkee, is an authentic record of my own work carried out during the period August, 1997 to January, 1998 under the supervision of Dr.J.S.Upadhaya, Associate Professor, Department of Pulp and Paper, University of Roorkee, Saharanpur.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma from any other University.

SANDEEP TIWARI

This is certified that the above statement made by the candidate is correct to the best of my knowledge.

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I feel gratitude on the opportunity to submit this project report on, **"STUDIES ON E.C.F. BLEACHING SEQUENCES OF PULPS FROM AN ENVIRONMENTAL POINT OF VIEW"**. This process, I feel, would be an asset in opening of new vistas in reduction of pollution to the environment. As is known the pollution reduction is the cry of every country so our's in India. Even a smaller reduction in pollution would be eco-friendly process in line with the title.

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Saharanpur

(SANDEEP TIWARI)

ABSTRACT

India is a Agriculture based country that produces 20-25 million tonnes air dried bagasse every year. Each tonne of sugarcane yield 150-160 kg of air dreid bagasse. Bagasse is an important raw matrial resources for pulp and papermaking in India. It has all the requiste properties to replace the conventional raw material like bamboo and wood for economical manufacturing of high grade of paper.

Conventionally, bagasse is being cooked with soda to a reasonable Kappa No ranging between 20-24. The addition of a small fraction (0.1% on o.d. basis) of AQ has helped to reduce the Kappa Number of the pulp significantly. This pulping process is ecofriendly due to absence of sulphur.

The oxygen delignification is done before E.C.F. bleaching stages. The main theme of the study is production of bleached paper by using E.C.F. bleaching sequences and also to undertake environmental impact of this process.

SANDEEP TIWARI

CHAPTER - 1

CHAPTER - 1

INTRODUCTION

As is known the Paper Industry was dependent on hard wood and bamboo which were naturally coming from the forest. Heavy felling of the forest caused environmental depletion and thus, the Industry was compelled for consideration of other materials/by products of other industries as a result hand is fallen on bagasse, fibrous residue of sugarcane left after crushing and extraction process. This can become endless raw material provided some alternative source of heat is used by sugar mills leaving bagasse for paper industry and felling of forests may be avoided to a greater extent without affecting the environment. Apart from bagasse, rice straw and wheat straw are also available for use in pulp and paper industry.

Pulping and bleaching of bagasse is well established in pulp and paper industry but the processes where chlorine, sulphur are to be avoided so that there is no pollution to the environment which is prime concern of the present world.

To avoid depletion of environment "Soda Process" is used for bagasse pulping with small amount of AQ to increase yield and lower Kappa No. pulp gained after pulping. The oxygen delignification is done before E.C.F. bleaching stages. The main theme of the study is production of bleached paper by using E.C.F. bleaching sequences and also to undertake environmental impact of this process.

In conventional bleaching sequence like CEH will typically produces 6-9 kg chloro organics per tonne of bleached pulp prior to effluent treatment which is knows as adsorable organics halides (AOX) approximately 75 to 80% of the organically bound chlorine in bleached kraft mill effluents is in high molecular in weight, which is not easily identified.

In the early 1990's Due to environmental aspects, pressure have been given to develop bleaching sequences without use of chlorine for pulp bleaching by complete substitution of chlorine by chlorine dioxide called as Elemental chlorine free bleaching (E.C.F.) discovered by Sweden & developed rapidly due to decrease in pollution load, effluent load of bleaching also reduces. Further development led to bleaching process is total chlorine free bleaching (T.C.F.) that used neither chlorine nor chlorine dioxide that is done by Hydrogen peroxide, Ozone and oxygen technology. Oxygen delignification is used before bleaching stages to get low Kappa No. Pulp after oxygen delignification which decreases chemical demand for bleaching.

SODA-AQ PULPING OF BAGASSE

Bagasse is obtained after the extraction juice from sugar cane each tonne of sugar cane yield 150 to 160 kg of air dried bagasse. It is estimated that 20 to 25 million tonnes air dried bagasse is produced every year in India. Due to shortage of fibrous raw materials in India, we have always paid particular attention to bagasse as a source of raw material for paper making.

Environmental control laws on Industrial emission, particularly the emission of sulphur compounds, together with the need of more effective utilization of raw materials have contributed to the intense work done in recent years for the development of cooking methods which will give similar pulp qualities and preferably higher yields than the kraft method without the addition of sulphur compounds. One such method might be the soda process. By adding additives mainly anthra quinone (AQ) which gives higher yield and improves quality of paper by eliminating air pollution also.

OXYGEN DELIGNIFICATION

Another way for reduction of the amount of chloro-organo compounds which has been successfully employed to wood based raw materials to delignify the pulp prior to bleaching is oxygen delignification. Magnesium compounds ($MgCO_3$ and $MgSO_4$) have been used along with oxygen to protect the pulp strength, oxygen delignification stage is now increasingly used as a favourable method of reducing the requirement of elemental chlorine during bleaching thereby decreasing the quantity of chloro organic compounds in the effluent and gaseous emission from the bleach plant. It has been indicated that strength properties of oxygen delignified pulps are not deteriorated as long as the degree of delignification does not exceed above 50%. Various factors which can have detrimental effect on pulp strength are transition metals, excess alkali charge, black liquor carry over and low reaction pressure. Therefore, it is quite important to select parameters during oxygen delignification which will yield the lower degradation at the target kappa number. Very little attempts have been made with agro residues such as straws, bagasse using above techniques, which are now major raw materials for Indian Pulp and Paper Industry.

BLEACHING OF BAGASSE

Bleaching sequences practiced by the integrated pulp and paper mills depend upon the market requirement of the quality of the paper. Till 80's most of the Mills in India were producing pulp in the brightness range 72-80 with marginal benefit derived from optical whitening agents, Low cost Chlorine has remained as principle bleaching agent, conventional CEH or CEHH sequence normally being followed.

During the 80's with the liberal import of high brightness pulp permitted by the Government, Indian market started getting high brightness paper which incidentally also fetched premium. This created a natural demand for high brightness paper in the market.

During early 90's integrated production of higher brightness pulp and paper started by few mills by partly substituting chlorine with chlorine dioxide with bleaching sequence CD EO HED. This however necessiated installing, chlorine dioxide generating plant, installing bleach washers, piping, pumps, storage towers of better material of construction.[1]

CLO_2 bleaching permitted bleaching of Bamboo and Hardwood Chemical Pulp to brightness of 85-87 ISO and there was immediate acceptance of the same in the Indian market. These high brightness paper also found export market in South Asia and Asia Pacific region.

CLO_2 bleaching also had other expected advantage of :

i. Lower equivalent chlorine consumption
ii. Very selective in destroying lignin without degradation of carbohydrates
iii. Preserving the pulp strength, giving higher brightness and less colour reversion
iv. Improved effluent properties i.e. colour toxicity and total chlorinated organic compounds.

Other progressive mills in India are in the process of adopting chlorine dioxide stage in their bleaching process.

CHLORINE DIOXIDE BLEACHING

Chlorine dioxide is an unusual compound, since ClO_2 has 19 valence electrons. Thus, it has an unpaired electron and is really a free radical. This probably accounts for its relative instability. It may explode at lower concentrations with less violence if heated, exposed to light, or subjected to an electric spark. It is stable in liquid form at its melting point ($-61^{0}C$) or in aqueous solution. It is highly toxic to almost all forms of life.

In acid solution complete reduction of chlorine dioxide provides five oxidation equivalents.

$$ClO_2 + e^- = ClO_2$$

$$ClO_2 + 3H^+ + 2e^- = HClO + H_2O$$

$$HClO + H^+ + 2e^- = Cl^- + H_2O$$

Under neutral and alkaline conditions chlorite is stable and must be acidified to be effective bleaching agent. The hypochlorous acid formed has a higher oxidation potential then chlorous acid and hence can oxidize the chlorous acid to chlorine dioxide according to the following reaction :-

$$HClO + 2HClO_2 = 2ClO_2 + H_2O + Cl^-$$

Hypochlorous acid and chlorine dioxide may also be formed from the disproportionation for chlorous acid according to following reaction :-

$$8HClO_2 = 6ClO_2 + HClO + HCl + H_2O$$

Sodium chlorite was used for this bleaching process. This solution was added to pulp and pH at the end was maintained less than 6.

This stage was used to replace both chlorination and hypochlorite stage in case of soda pulping.

ALKALINE EXTRACTION

The purpose of this step is to remove as much of the residual lignin as feasible without the pulp damage and yield loss which would occurs with more severe cooking. It is also desirable to remove as much lignin as possible in this and the succeeding hot caustic extraction stage to minimize expenditures for chlorine dioxide, hypochlorite or other more costly oxidizing chemicals.

In peroxide reinforced extraction chlorinated lignin derivatives are to be extracted out of the pulp by addition of Alkali. The Alkali charge was 1.5% as NaOH and 0.5% H_2O_2 (on O.D. basis). After given a certain retention time the pulp was washed.

ENVIRONMENTAL STUDY

Environmental control laws on industrial emission, particularly the emission of sulphur compounds, together with the need of more effective utilization of raw materials have contributed to the intense work done in recent years for the development of cooking methods which will give similar pulp qualities and preferably higher yields than sulphur compounds. One such method might be the old soda method, If only the yield and pulp quality could be improved. Many different additives have been used to improve the yield and quality of soda pulp. Among the additives, anthaquinone (AQ) has given quite encouraging results. It appears that AQ is still the most cost effective sulphur free accelerator for alkaline pulping, albeit of limited applications. The Soda-AQ process does offer a direct advantage of eliminating air pollution associated with kraft process.

In the case of bagasse, as for other annual plants, but unlike that of wood, the problem of mass transfer of delignifying agent (molecular oxygen) should be much less important, since the plant structure, penetration of the delignifying agent into the reactive zones of fibre wall. The loose and open structures and low lignin content of bagasse make it suitable to perform soda-oxygen and soda-oxygen-AQ (SOAQ) pulping.

As an alternative to the forest based raw materials to meet the increasing shortfall of furnish such as hardwood and bamboo the paper industry has been considering non-wood fibrous raw material as the chief source of fibres. The main fibrous raw materials available in India are bagasse, rice straw and wheat straw. The bagasse will continue to play key role even in future as potential raw material for paper Industry. That's why bagasse study is necessary to get full utilization with deep study of this raw material to produce market acceptable grade paper.

Another way for reduction of the amount of chloro-organo compounds which have been successfully employed to delignify the pulp prior to bleaching is oxygen delignification. Magnesium compounds ($MgSO_4$ and $MgCO_3$) have been used along with oxygen to protect the pulp strength. Oxygen delignification stage is now increasingly used as a favourable method of reducing the requirements of elemental chlorine during bleaching thereby decreasing the quantity of chloro-organics compounds in the effluent and gases emission from the bleach plant. Very little attempts have been made with agro residues such as bagasse, rice straw using this techniques, which are now major raw materials for Indian pulp and Paper Industry.

The paper submitted by Rajesh K.S.[2] highlights the usage of E.C.F. bleaching sequences that can easily be retrofitted in the existing bleaching system of kraft wood and bagasse to achieve 90% ISO brightness with decreases in the chlorinated organics [2].

As the primary objective of chlorine free bleaching is to achieve very high brightness without using chlorine. It was felt that the incoming kappa number of the unbleached pulp should be reduced before entering in E.C.F. or T.C.F. bleaching sequences by adopting R.D.H. M.C.C. and oxygen delignification techniques. Results shows that K.N. of bagasse can be reduced to 10 without loss in pulp strength and yield.

The oxygen delignified bagasse pulp was treated with 0.5% calcium hypochlorite followed by $O\text{-}H_{0.5}D_1$ and 86% ISO brightness achieved. For effective chlorine dioxide brightening the incoming K.N.of the pulp entering the ClO_2 stage should be less than two. Increasing the hypochlorite charge from 0.5 to 1% in the O-H-D sequence was sufficient to reach the target of 90% ISO. Since the response of bagasse pulp to E.C.F. bleaching was found to be good [2].

An envisaged, the chlorinated organics generated in the E.C.F. bleaching sequence are considerably reduced. About 70% reduction in A.O.X. has been observed. AOX was calculated by using.

A.O.X. kg/tonne = 0.1[C+0.2D+0.6H]

C,D and H represent chlorine, ClO_2 and hypochlorite respectively.

Based on above, the following points emerges out:

1. It is possible to bleach bagasse and hardwood pulps to 90% ISO using ECF sequences, without using ozone.
2. The bleaching response of bagasse is excellent towards ECF bleaching.
3. The sequences discussed for high brightness, are considerably short.
4. Oxygen delignification is a preferred necessary step in hardwood ECF sequence to make it feasible.
5. The ECF bleaching yields a pulp of better strength and viscosity than the chlorine containing sequences.
6. Considerable reduction in AOX generation is observed thereby taking the TCDD and TCDF to below detectable levels as indicated in Fig. 1 & 2.
7. The sequences discussed are easily retrofittable in existing bleach plant for hardwood and bagasse without major modifications.

One experimental paper have been submitted by Tendulkar S.R.[3] for the bleaching of bagasse in which unbleached bagasse chemical pulp was collected from one of the paper mill from south Indian for this study. The permagnate number of the pulp was 8.8 and its brightness was 41.5% ISO. The unbleached pulp after disintegration in the laboratory was squeezed on

200 mesh. The squeezed pulp after determining the consistency divided into two parts [3].

(a) The first part was subject for CEH bleaching sequence.

(b) Second part was subjected for PHP bleaching.

Both are followed by general bleaching conditions as shown :

Stage	Consistency in (%age)	Temperature °C	Retention time (min)
C	2	ambient	45
E	10	60	60
H	10	ambient	120
P	10	80	120
H	10	ambient	120
P	10	80	120

It is observed that when pulp is bleached to almost 80% ISO in a typical experiment by CEH bleaching sequence, its brightness after accelerated ageing goes down to 71.4 %ISO showing reversion in brightness by almost 8.5% ISO units. The same pulp when bleached by PHP sequence the brightness level achieved was 78% ISO with 1% and 0.5% H_2O_2 at first and final stage of bleaching respectively. The brightness after reversion is 72.9% ISO (that is 1.5 unit higher then CEH).

Viscosity values for PHP bleached pulp are always on higher side. The improvement in viscosity values indicate that degradation of cellulose in PHP bleaching sequence is less as compared to CEH bleaching of bagasse chemical pulp [3].

Mechanical strength of PHP bleached pulp was stronger in all respect as compared to CEH bleached pulp. There was 9% and 7% improvement in breaking length and burst factor respectively. The tear factor has shown remarkable improvement. This is almost 26% higher in PHP bleached pulp that CEH bleached pulp. This improvement in mechanical strength may be due to elimination of chlorine totally and reducing hypochlorite partially.

Bleaching shrinkage during large scale PHP and CEH laboratory bleaching experiments were 3.6% and 6.6% respectively. This lower bleaching shrinkage in PHP bleaching could be a combination of improved cellulosic fibres and preservation of modified colourless products of lignin during PHP bleaching.

During this PHP bleaching sequence, almost 50-60% chlorine in the form of elemental chlorine was eliminated. Chlorinated organic were not tested either qualitatively or quantitatively during this study. How ever, that the proportionate reduction in chlorinated organics would be almost by 50% during PHP sequence as compared to CEH bleaching sequence. Thus, PHP bleaching would be definitely environmentally friendly as compared to CEH bleaching of bagasse chemical pulp. Earlier it was reported that the reduction in colour of extraction wash liquor of CEpH bleached pulp. Similarly here also it was observed that colour of wash liquor at P stages was lighter as compared to extraction wash liquor of CEH bleached pulp.

Bagasse Chemical Pulp can be bleached by usage of Peroxide- Hypochloric - Peroxide (PHP) bleaching sequence[3] to acceptable level of brightness.

The brightness stability of PHP bleached pulp is always on higher side as compared to pulp bleaching with CEH bleaching sequence.

It is possible to reduce 50-60% of total chlorine necessary for bleaching during PHP bleaching sequence and thus possible to reduce discharge of organically bound chlorine in effluent/pulp and paper.

The mechanical properties of PHP bleached bagasse chemical pulp are better than CEH bleached bagasse chemical pulp.

Total chlorine free [4] (TCF) bleaching involving oxygen, peroxide and hemicellulolytic enzyme xylanase produced a pulp of 80+ISO brightness with bagasse kraft pulp and hardwood kraft pulp. The various bleaching sequence and their implications with respect to achieving the target brightness have been considered. The quality of TCF pulp was comparable to that of conventional pulps. Chelation, acid wash and lignin activation treatments considerably improved the bleachability of bagasse and hardwood pulps.

The oxygen delignification (O) and peroxide reinforced oxygen delignification (EOP) were performed in electrically operated programmable rotating stainless steel vessel with 500 gms (o.d.) pulp. Molecular oxygen gas was injected from an oxygen cylinder through a specially made adopter to the desired experimental pressure. To enhance the mixing, a stainless steel shredder was placed inside the digester. Throughout the oxygen delignification surplus O_2 pressure was maintained. Prior to the oxygen delignification the pulp was manually mixed with sodium hydroxide and magnesium carbonate as the viscosity protector. After the oxygen treatment the pulp was washed and thickened in the hydro extraction.

Following recommendations have been suggested for the bleaching of bagasse pulp.[4]

1. TCF bleaching of bagasse pulps and hardwood pulps has completely ruled out chlorinated organics.
2. The chemical pretreatment with acid peroxide and chelation improved the pulp bleahability significantly.
3. Without alkaline oxygen delignification it is impossible to perform TCF bleaching economically.
4. In TCF bleaching the kappa number of the unbleached pulp seems to be chief determining factor for reaching high brightness.
5. Bagasse pulps are more readily bleachable than hardwood pulps without major process modifications.
6. By combining oxygen and peroxide it is possible to reach the target brightness of 80+ISO.
7. The bleaching chemical cost for bagasse sequences are far less than that of hardwood sequences.
8. The bleaching chemical cost of hardwood sequences can be considerably reduced by the effective usage of xylanase enzymes.
9. The bleaching cost of the TCF sequences are higher than

that of the conventional bleaching methods.

Above literature study indicates that bleached paper can be produced with desirable properties with the using of bagasse as a raw material. The process using to produce pulp from bagasse by Soda-AQ process is eco-friendly due to sulphur free process. After that oxygen delignification is done prior to ECF/TCF bleaching sequences. That decreases chemical demand in bleaching and pollution load in different stages.

The above experimental work on ECF bleaching of bagasse pulp indicates that +90% ISO brightness can be achieved and opening of new vistas in reduction of pollution to the environment. Due to shortage of fibrous raw material in India, we have always paid particular attention to bagasse as a source of raw material for paper making.

1.1. The objective of Present Studies :-

Environmental regulations on industrial emission, particularly the emission of sulfur compounds, together with the need of more effective utilisation of raw materials have contributed to the intense work done in recent years for the development of cooking methods which will give similar pulp qualities and preferably higher yields than the kraft method without the addition of sulfur compounds.

To avoid depletion of environment "Soda Process" is used for bagasse pulping with small amount of AQ to increase yield and lower Kappa No. pulp gained after pulping. The oxygen delignification is done before E.C.F. bleaching stages. The main theme of the study is production of bleached paper by using E.C.F. bleaching sequences and also to undertake environmental impact of this process.

In this experimental work bagasse is taken as a raw material and pulping is done by Soda-AQ process to get higher yield with low Kappa number pulp. Before entering in bleaching stages oxygen delignification of the bagasse pulp is done by adding small amount of $MgSO_4$ to protect strength of the pulp by following oxygen delignification, it decreases Kappa No. and decreases chemical demand for bleaching also decreases pollution load. The pulp is followed by DCE/EP D_1D_2 bleaching sequence by adding chlorine and chlorine dioxide in different ratio.

CHAPTER -2

EXPERIMENTAL METHODOLOGY

2.1. Raw Material and Its Preparation

The whole bagasse was procured from M/s. Sarsawa Sugar Mill Ltd., Sarsawa, Saharanpur. The whole bagasse was processed through vertical moist depither followed by wet depithing in laboratory model Bagasse wet depthing plant. The physical composition of the whole fresh bagasse and stored bagasse were determined as per TAPPI-UM3. These results have been reported in Table - 1.

The air dry depithed bagasse was disintegrated in the laboratory "WEVERK DISINTEGRATOR". The portion of bagasse meal passing through 40 mesh shieve but retained on 80 mesh was utilized for proximate chemical analysis. The proximate chemical analysis was carried out as per TAPPI Standard procedure. The chemical composition of depithed bagasse is reported in Table - 2.

2.2 Soda-AQ Pulping of Bagasse

The depithed bagasse was cooked in electrically heated rotory digestor of 0.02 m^3 capacity having four bombs of 1 litre capacity, furnishing sufficient pulp for evaluation to determine the optimum pulping conditions during the course of pulping, a number of experiments conducted at different conditions by varying the different process variables such as alkali charge, temperature, time, bath ratio and AQ dose etc.

At the end of the cooking operation the digestor pressure was reduced by gas relief untill the temp reach to 100^{0}C. The charge was then blown from the digestor. The pulp was washed on laboratory inclined flat washer. The pulp was further screen through a laboratory vibratory flat "WEVERK SCREEN" having 0.15 mm slits and the screened pulp was futher washed, pressed and crumbled.

All the conditions for Soda AQ pulping is given in Table 3 A and results achieve after pulping is given in Table 3 B.

2.3 Oxygen delignification

The Soda-AQ pulps were oxygen delignified in the 0.02 m^3 laboratory digestor fitted with lids incorporating values to introduce oxygen into the vesel. Pulp samples (100 gm O.D. basis) were mixed with Magnesium sulphate (0.1% on O.D.basis), Sodium hydroxide (2% on Pulp basis) and water to give pulp concentration of 10%. The mixture was placed in the digester which were pressurised with oxygen 5 kg/cm^2 to the initial pressure of the digestor at 50^{0}C) and heated till 110-115^{0}C is achieved. Then maintained at this temp. for 45 minutes. While time to temp was 30 min and the results obtained after oxygen delignification with conditions is reported in Table - 4A and 4B.

2.4. Bleaching of Pulps

The initial chlorine, chlorine dioxide/chlorine and chlorine dioxide were done in plastic bottles as per the conditions mentioned in Table - 5. In chlorine dioxide/chlorine bleaching the chlorine dioxide and chlorine was maintained at different ratio. (ClO_2/Cl_2 : 100/0, 75/25, 50/50, 25/75, 0/100) respectively of the total chlorine charge to the first stage and PH is maintained between 1.5 to 2.0.

The E-sate bleaching was done at 10% consistency in a plastic bags. The conditinos are maintained as given in Table - 5. The plastic bags were placed in water bath tub attached with heating rods to boil water and temp controler is adjusted at $60^{0}C$ and maintained for 60 min.

The E_p stage was done at 10% consistency of pulp in a laboratory rotory type digestor and the conditions were maintained as given in Table - 5.

The D_1 bleaching state with chlorine dioxide is done in plastic bags by adding 2.6% ClO_2 on available chlorine basis and maintained at the given conditinos as given in Table - 5.

The D_2 final stage of bleaching is als done in plastic bags by adding 1.3% (on available chlorine basis) chlorine dioxide and maintained at the given conditions as given in Table - 5.

The pulp was washed thoroughly with fresh water on a buckner funnel under suction pressure after each stage of bleaching and was continued till the clean water starts collected into funnel

CHAPTER -3

RESULTS & DISCUSSION

The one of the objective of the present study is to develop an environmentally compatctable bleaching sequences in order to achieve the brightness of pulps at the pre-requiste level with good strength properties with reduced environmental problems. In view of this, the bagasse pulp was bleached by employing the bleaching sequences as mentioned in table - 6.

On compairing the optical properties of pulps bleached by various sequences mentioned in Table - 6, indicated that the brightness level achieved by common bleaching sequence is only 75%. The brightness level was improved to a level of 82% with a bleaching sequence $OCED_1D_2$. The enhanced brightness of 90 was obtained in a modified bleaching sequence having chlorine free pre oxygen delignification sequence $ODED_1D_2$. The brightness was further enhanced to a level of 92% by introducing the peroxide stage in the previous bleaching sequence that is $ODEPD_1D_2$. Further bleaching studies were conducted with sequentional chlorination by replacing chlorine with chlorinedioxide in different proportion. In sequentional chlorination comparatively higher brightness to a level of 90% was obtained with a bleaching sequence $OD_{75\%}/C_{25\%}EPD_1D_2$.

The above results indicated that the bagasse pulp showed a good response towards sequentional chlorination and / or elemental chlorine free bleaching sequences having low environmental pollution load as indicated in Table - 7.

CHAPTER -4

SUMMARY AND CONCLUSION

Since the major objective of the present studies was to bleach the bagasse pulp with an elemental chlorine free bleaching sequence with low environmental pollution load. Therefore the bagasse was pulp by Soda process using 0.1% AQ to reduce the Kappa No. upto 25 to 30% without affecting the quality of the pulp. Soda delignified bagasse pulp were further delignified with oxygen under alkaline condition to further reduce the Kappa No. upto the extent of 50%. As a result of utilizing 0.1% AQ followed by oxygen delignification, there is a substantial reduction in Kappa No. of the pulp in order to reduce the demand of the bleaching chemical in bleaching seqences to reduce the environmental pollution load. The bagasse pulp responded very well towards sequential chlorination and elemental chlorine free bleaching sequences. The presence of a magnesium comound prevents cellulose degradation. In the absence of it there was a drop in the brightness of the pulp due to cellulose degradation. The pulp produced by E.C.F. bleaching sequences showed better strength than the pulp bleaching with chlorine and oxygen. The cellulose is directly exposed to chlorine and oxygen which weaken it however the use of ClO_2 protect the carbohydrades due to its higher selectivity of attaaching the lignin first.

The environmental pollution load of the bleaching process is related to the type and amount of chemicals used for bleaching. However, the amount of delignifying chemicals is related with the degree of delignification. Oxygen pre bleach Soda-AQ pulp produced the least environmental pollution load when bleached in the later stages with $DE_pD_1D_2$ sequence.

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ANNEXURE

TABLE - 1

Physical Composition of Fresh and Stored Bagasse

S.No	Particulars	Fresh Bagasse	Stored Bagasse
1.	Moisture in %	25	12
2.	Fibres in %	63	70.5
3.	Pith, etc. in %	28.5	23.5
4.	Water solubles in %	8.5	6.0

TABLE - 2

S.No	Particulars	Values
1.	Solubility in hot water in %	8
2.	Solubility in alcohol benzene in %	7
3.	Solubility in 1% NaOH	28
4.	Pentozones	26
5.	α-Cellulose	41
6.	Lignin	18
7.	Ash	2
8.	Silica	1.5

TABLE - 3 A

Process Conditions for Soda-AQ Pulping

S.No	Particulars	Values
1.	Alkali Charge in % as NaOH	16
2.	AQ-dose on OD-basis in %	0.1
3.	Bath ratio	1:5
4.	Time to temp. in min.	30-45
5.	Time at temp. in min	60
6.	Final Temp. in min	165^{0}C

TABLE - 3 B

Results of Soda-AQ Pulping

S.No	Particulars	Values
1.	Yield in %	55
2.	Kappa No.	22
3.	Brightness in % ISO	41
4.	C.O.D. in gm/litre	160

TABLE - 4 A

Conditions of Oxygen Delignification

S.No	Conditions	Values
1.	O_2 Pressure in kg/cm^2	5
2.	Consistency in %	10
3.	Alkali dose in % as NaOH	2
4.	Magnesium sulphate in % on OD basis	0.1
5.	Temp. in ^oC	110-115
6.	Time in min.	45

TABLE - 4 B

Results of Oxygen Delignification

S.No	Parameters	Values
1.	Kappa No.	10
2.	Yield in %	50
3.	C.O.D. in gm/litre	140
4.	Brightness in % ISO	55

TABLE - 5

BLEACHING CONDITIONS

Stage	Consistency in %	Temperature °C	Retention Time in (min.)	pH Range
C	3-4	ambient	45	1.5-2.0
E	10	60-70	60	10-12
H	10	40-45	120	~10
[1]O	10	100	45	-
DC	10	70	90	4.0-4.5
[2]E/Ep	10	110-115	30	-
[3]D_1	10	70	180-240	4.0-4.5
[4]D_2	10	70	180-240	4.0-4.5

1 - Alkali 2% as NaOH, $MgSO_4$-0.1% on O.D. Basis, O_2 pressure - 5kg/cm^2

2 - NaOH - 1.5% in Ep Stage, 0.5% H_2O_2 on O.D.Basis (in E/Ep both)

3 - D_1 - 2.6% chemical available chlorine

4 - D_2 - 1.3% chemical on available chlorine

TABLE - 6

RESULTS

Seque- -nces	Bright- -ness % ISO	Opacity in %	Folding Endurance in Log_{10}	Tear Index in m-Nm^2/gm	Burst index in kPa m^2/gm	Tensile index in Nm/gm
CEH	75	78	1.65	2.05	3.2	41.3
$OCED_1D_2$	82	80	1.85	2.2	2.8	40.1
$OCEPD_1D_2$	88	78	1.86	2.1	2.7	40.5
$ODED_1D_2$	90	86	1.9	2.0	2.3	41
$ODEPD_1D_2$	92	85	1.7	2.15	2.35	42
OD/CED_1D_2 75%-25%	89	84	1.68	2.12	2.45	40.5
$OD/CEPD_1D_2$ 75%-25%	90	82	1.65	2.06	2.5	41
OD/CED_1D_2 50%-50%	88	78	1.62	2.05	2.6	39.6
$OD/CEPD_1D_2$ 50%-50%	89	77	1.6	2.1	2.65	40
OD/CED_1D_2 25%-75%	87	76	1.58	2.15	2.7	39.8
$OD/CEPD_1D_2$ 25%-75%	88	75	1.5	2.10	2.75	40.5

TABLE - 7

Results of Chemical Oxygen Demand

Bleaching Sequences	Chemical Oxygen Demand
CEH	85 kg/tonne
$ODEPD_1D_2$	630 mg/lit.
$ODED_1D_2$	700 mg/lit.
$OCED_1D_2$	950 mg/lit.
$OCEPD_1D_2$	900 mg/lit.

Fig. 1 Chlorinated organics for various bleaching sequences for bagasse

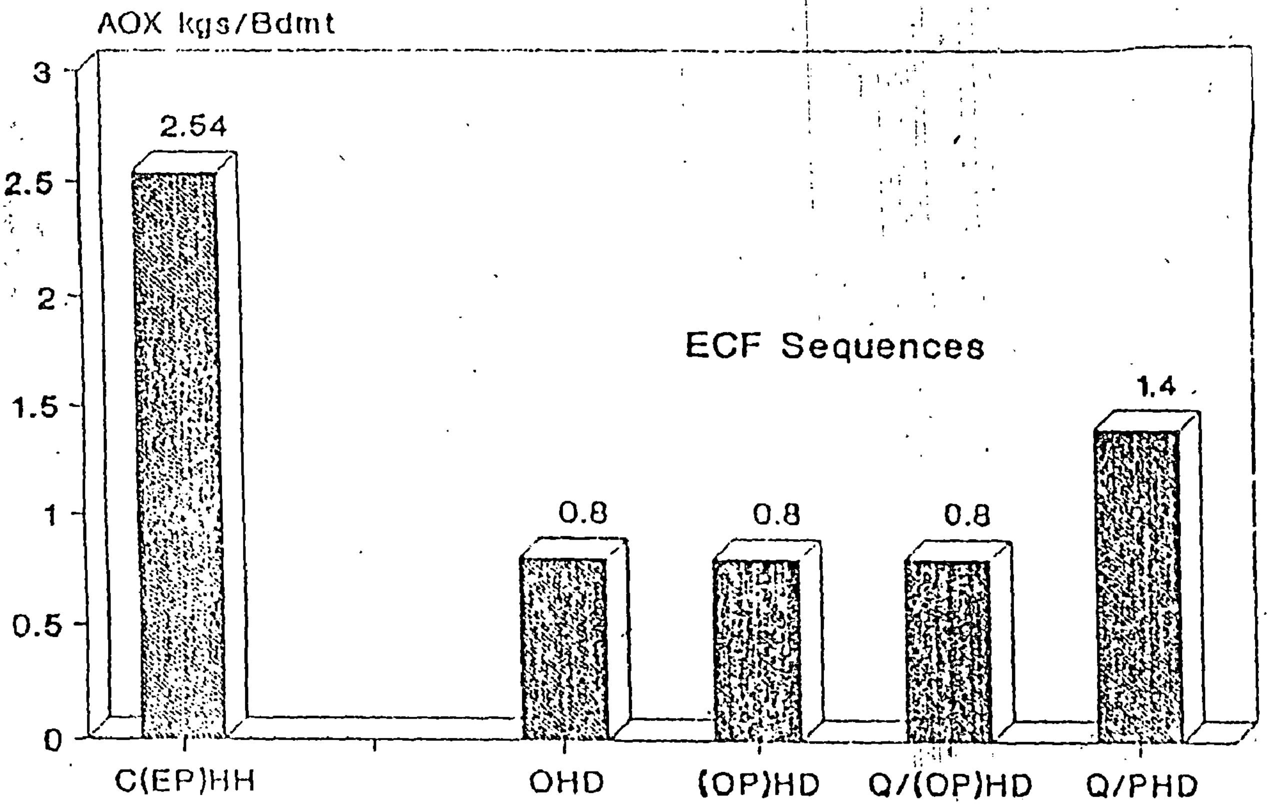

Fig 2. Chlorinated organics for various bleaching sequences for hardwood