

Studies on Bleaching of Wheat Straw Pulp

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ABSTRACT

This paper deals with the extensive investigation on bleaching of wheat straw pulp of different permanganate numbers (30.0 to 9.2). The bleaching studies were conducted by using HH, CHH and CEH bleaching sequences. All the pulps responded favourably to HH sequence also to achieve desired level of brightness. For chlorination, optimum chlorine dose percent is determined to be 1/3rd of the permanganate number of unbleached Pulp. The relation between permanganate number and total chlorine demand (T.C.D) to get a brightness around 7% is found as given below :

Total chlorine demand (HH)	=	K No. X 0.88
Total chlorine demand (CHH)	=	K.No. X 0.75
Total chlorine demand (CEH)	=	K.No X 0.57

The physical strength properties of both unbleached and bleached pulp increase with decrease in permanganate number. The pulps bleached with CEH sequence have given the highest strength properties followed by CHH and HH sequence.

Paper Industry is one of the largest consumer of forest wealth. With the depletion of forests and scarcity of the conventional raw material papermakers are looking towards other fibrous raw materials. The straw seems to be very promising raw material on account of its availability in sufficient quantity and its continuity of supply.

Wheat straw can be made available for pulp and papermaking to meet demand of raw material, to a certain extent, for paper industry. It becomes necessary to investigate various processing parameters for its efficient utilization in papermaking. A series of articles on wheat straw pulping are published in different technical journals. However, very little work has been reported on the bleaching of wheat straw pulp. In the present investigations extensive studies have been carried out on the bleaching of wheat straw pulps.

EXPERIMENTAL :

Wheat straw was collected from Koraput District of Orissa and taken for this study.

PROXIMATE CHEMICAL ANALYSIS :

The sample was powdered in laboratory grinder and taken for proximate chemical analysis. The analysis was carried out as per TAPPI standards. The results are recorded in Table-1.

TABLE - 1
PROXIMATE CHEMICAL ANALYSIS

PARTICULAS	%	RESULTS*
1. Ash		8.1
2. Cold water solubility		12.0
3. Hot water solubility		14.6
4. 1% NaOH solubility		38.5
5. Alcohol-Benzene solubility		6.6
6. Holocellulose		56.6
7. Pentosans		22.6
8. Lignin**		13.6

* Results expressed on O.D. rawmaterial basis

** Ash corrected

PULPING :

The straw samples were pulped in 15 lit. capacity, electrically heated rotary digester by varying the alkali charge from 8 to 16% NaOH. The pulps were washed, defibrated in valley beater and dewatered. Pulp yield and permanganate number, and residual alkali in black liquor were determined. The pulping conditions and results are recorded in Table-2.

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TABLE—2
PULPING DATA OF WHEAT STRAW

PARTICULARS	COOK-1	COOK-2	COOK-3	COOK-4	COOK-5
1. NaOH on O.D. rawmaterials, %	8.0	10.0	12.0	14.0	16.0
2. Bath ratio	1:4	1:4	1:4	1:4	1:4
3. Cooking schedule :					
50 to 150°C, hr.	1.0	1.0	1.0	1.0	1.0
at 150°C, hr.	2.0	2.0	2.0	2.0	2.0
4. Pulp yield, %	57.6	54.5	52.6	48.9	46.0
5. 40-ml KMnO ₄ number, No.	30.0	24.6	18.6	13.7	9.2
6. Kappa number, no.	68.4	50.1	35.5	26.9	20.7
7. pH of Black liquor,	9.8	10.3	10.5	10.7	11.2
8. Residual alkali, gpl	nil	1.6	3.2	4.0	4.5
9. Ash in pulp, %	9.9	3.0	2.6	1.9	1.3

BLEACHING :

Bleaching of pulps were done by using HH, CHH and CEH sequences under the following constant conditions :

Chlorination Extraction Hypo I & II			
Consistency, %	3.0	5.0	5.0
Temperature, °C	Ambient	50	40
Retention time, hr	0.5	1.0	2.0
(Chemicals were added on O.D. unbleached Pulp basis)			

The targeted brightness was kept $78 \pm 1\%$. HH sequence optimization was carried out by varying hypo charge in the first stage to get brightness around 72% and a fixed charge of hypo was given in second stage. The results are recorded in Table-3.

In order to optimize the chlorine charge of CHH and CEH sequences, varying dose of chlorine was given and subsequently alkali extraction, was carried out. The permanganate numbers of alkali extracted pulps were determined. The optimum dose was subsequently determined by plotting a graph, between chlorine charge

and permanganate number of alkali extracted pulp and by intersecting the tangent of the resultant curves. The results are shown in fig. 2 and Tables 4-8)

With the optimum dose of chlorine, the chlorinated pulp was taken for optimization of 'HH' stages of CHH sequence and 'H' stage of CEH sequence. The optimization was done by varying the hypo dose to get desired level of brightness. (Table 4-8)

PHYSICAL STRENGTH PROPERTIES :

The unbleached and bleached pulps were beaten in laboratory valley beater to different freeness levels. Standard handsheets were prepared on British Handsheet making machine and tested after conditioning. The strength properties at 45° SR were taken out by interpolation of graph between freeness and strength properties and recorded in Table-9.

OBSERVATION AND DISCUSSION :

1. It can be observed from Table-1 that wheat straw taken for this study has slightly lower lignin and high low molecular weight carbohydrates as shown by pentosans (22.6%) and 1.0% NaOH solubility (38.5%). Ash is lower compared to rice straw.

TABLE-3

OPTIMISATION OF 'H-H' BLEACHING SEQUENCE

Particula s	C-1				C-2				C-3				C-4				C-5					
KMnO ₄ Number No.	30.0	30.0	30.0	30.0	24.6	24.6	24.6	24.6	18.6	18.6	18.6	18.6	13.7	13.7	13.7	13.7	9.2	9.2	9.2	9.2		
	1	2	3*	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4		
HYPO I STAGE																						
Cl ₂ added, %	18.0	20.0	22.0	24.0	16.0	18.0	20.0	22.0	24.0	8.0	10.0	12.0	14.0	8.0	9.0	10.0	11.0	11.0	3.0	4.0	5.0	6.0
Cl ₂ consumed, %	14.6	19.8	21.8	23.6	15.9	17.8	19.8	21.7	23.6	8.0	10.0	11.9	13.8	7.9	8.9	9.8	10.7	10.7	2.9	3.9	4.8	5.8
Final pH	5.3	5.6	5.7	5.7	5.9	5.8	5.8	5.8	5.8	6.3	6.2	5.9	5.8	6.3	6.4	6.3	6.2	6.2	7.6	7.5	7.3	7.1
HYPO II STAGE																						
Cl ₂ added, %	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cl ₂ consumed, %	2.7	2.4	2.3	2.3	2.7	2.7	2.7	2.7	2.7	2.8	2.5	2.3	2.3	0.7	0.7	0.6	0.6	0.6	1.0	0.9	0.8	0.8
Final pH	6.5	6.6	6.8	6.7	6.5	6.4	6.5	6.5	6.5	6.5	6.6	6.7	6.6	7.2	7.2	7.2	7.2	7.2	7.4	7.2	7.4	7.3
Brightness, %																						
(EL)	70.2	74.8	78.8	78.8	76.7	77.5	77.9	78.7	78.7	70.2	76.6	77.7	79.7	75.6	76.0	79.2	80.0	79.3	76.7	77.8	79.1	79.1
P.C. Number No.	—	—	22.4	—	—	—	18.6	—	—	—	—	16.4	—	—	—	14.1	—	—	—	—	12.0	—
Shrinkage, %	—	—	16.4	—	—	—	15.5	—	—	—	—	14.2	—	—	—	9.2	—	—	—	—	7.6	—

*Take as optimum

TABLE-4
OPTIMIZATION OF 'CEH AND 'CHH' SEQUENCE OF C-1 (K. No.-30.0)

PARTICULARS	1	2	3	4	5	6	7	8
CHLORINATION :								
Cl ₂ added, %	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
Cl ₂ consumed, %	6.0	7.0	8.0	9.0	10.0	10.9	11.9	12.8
Final pH	1.7	1.6	1.5	1.5	1.5	1.4	1.4	1.3
ALKALI EXTRACTION :								
NaOH added,	1.6	1.9	2.2	2.4	2.6	3.0	3.0	3.4
Final pH	9.2	9.1	9.2	9.2	9.3	9.4	9.2	9.3
KMnO ₄ number of alkali extracted pulp. no.	14.3	12.7	11.4	10.6	8.3	7.4	6.9	6.6

*10.0% Cl₂ is taken as optimum.

TABLE-4 (CONTD)
OPTIMISATION OF 'HH' STAGE OF 'CHH' SEQUENCE

PARTICULARS	1	2	3*	4	5
HYPO I STAGE					
Cl ₂ added, %	4.0	5.0	6.0	7.0	8.0
Cl ₂ consumed, %	4.0	5.0	6.0	7.0	8.0
Final pH	3.4	3.6	3.7	3.8	3.9
HYPO II STAGE					
Cl ₂ added, %	3.0	3.0	3.0	3.0	3.0
Cl ₂ consumed, %	3.0	2.9	2.9	2.9	2.9
Final pH	5.8	5.8	5.9	6.3	6.4
Brightness (Elrepho) %	74.5	76.0	78.2	80.6	80.7
P. C. Number, No.	—	—	8.4	—	—
Shrinkage %	—	—	18.8	—	—

OPTIMIZATION OF 'H' STAGE OF 'CEH' SEQUENCE

PARTICULARS	1	2	3	4*	5
HYPO STAGE					
Cl ₂ added, %	3.0	4.0	5.0	6.0	8.0
Cl ₂ consumed, %	3.0	4.0	5.0	5.9	7.9
Final pH	6.3	6.6	7.2	6.8	6.6
Brightness (Elrepho) %	69.4	70.8	76.7	78.5	79.8
P. C. Number no.	—	—	—	7.0	—
Shrinkage %	—	—	—	22.8	—

*Taken as optimum

TABLE-5
OPTIMISATION OF "CEH" AND "CHH" SEQUENCES OF C-2 (KMnO₄ No. 24.6)

PARTICULARS	1	2	3	4	5*	6	7	8
CHLORINATION								
Cl ₂ added, %	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
Cl ₂ consumed, %	4.0	5.0	6.0	7.0	8.0	8.9	9.9	10.9
Final pH	2.2	2.1	1.9	1.8	1.8	1.8	1.7	1.6
ALKALI EXTRACTION								
NaOH added, %	1.6	1.6	1.6	1.9	2.2	2.4	2.6	3.0
Final pH,	8.7	8.5	8.5	9.0	9.3	9.3	9.5	9.7
KMnO ₄ Number (AE pulp), no	11.8	8.9	8.4	8.0	5.4	5.0	3.8	3.6

*Taken as optimum

TABLE-5 (contd).
OPTIMISATION OF 'HH' STAGES OF CHH SEQUENCE

PARTICULARS	1	2	3*	4	5
HYPO I STAGE					
Cl ₂ added, %	4.0	5.0	6.0	7.0	8.0
Cl ₂ consumed, %	4.0	5.0	5.9	6.9	7.9
Final pH	3.2	3.3	3.5	3.6	3.6
HYPO II STAGE :					
Cl ₂ added, %	3.0	3.0	3.0	3.0	3.0
Cl ₂ consumed, %	2.9	3.0	3.8	3.6	3.6
Final pH	5.2	5.6	5.8	6.1	6.0
Brightness (Elrepho), %	73.8	76.5	78.1	80.5	81.0
P.C. number, no.	—	—	12.7	—	—
Shrinkage, %	—	—	14.4	—	—

OPTIMISATION OF 'H₁' STAGE OF 'CEH' SEQUENCE

PARTICULARS	1	2*	3	4	5
HYPO STAGE					
Cl ₂ added, %	5.0	6.0	7.0	8.0	9.0
Cl ₂ consumed, %	4.7	5.7	6.7	7.6	8.6
Final pH	6.0	6.1	6.2	6.3	6.5
Brightness (Elrepho), %	75.0	77.9	78.4	79.0	79.6
P. C. number, no.	—	9.6	—	—	—
Shrinkage, %	—	18.6	—	—	—

*Taken as optimum

TABLE-6
OPTIMISATION OF 'CEH' AND 'CHH' SEQUENCES OF C-3 (KMnO₄ NO. 18.6)

PARTICULARS	1	2	3*	4	5	6
CHLORINATION						
Cl ₂ added, %	5.0	6.0	7.0	8.0	9.0	10.0
Cl ₂ consumed, %	5.0	6.0	6.9	7.6	8.3	9.2
Final pH	1.9	1.8	1.7	1.6	1.6	1.6
ALKALI EXTRACTION						
NaOH added, %	1.9	1.0	2.0	2.0	2.2	2.2
Final pH	9.3	9.0	9.1	9.0	9.1	9.2
KMnO ₄ Number (AE Pulp) no.	7.9	6.8	5.6	5.5	5.6	5.0

OPTIMISATION OF 'HH' STAGE OF CHH SEQUENCE

PARTICULARS	1	2	3*	4	5	6
HYPO I. STAGE						
Cl ₂ added, %	3.0	4.0	5.0	6.0	2.0	8.0
Cl ₂ consumed %	3.0	4.0	4.8	5.9	6.8	7.6
Final pH	3.4	3.5	3.7	4.0	4.2	4.5
HYPO II STAGE						
Cl ₂ added, %	2.0	2.0	2.0	2.0	2.0	2.0
Cl ₂ consumed %	1.9	1.8	1.6	1.5	1.4	1.3
Final pH	5.3	5.9	6.3	6.5	6.6	6.3
Brightness (Elrepho) %	72.6	26.6	78.6	80.9	81.7	82.0
P. C. Number no.	—	—	10.5	—	—	—
Shrinkage, %	—	—	20.0	—	—	—

OPTIMIZATION OF 'H' STAGE OF 'CEH' SEQUENCE

HYPO STAGE						
Cl ₂ added, %	3.0	4.0	5.0	6.0	7.0	8.0
Cl ₂ consumed, %	2.9	3.7	4.4	5.1	6.7	8.4
Final pH	6.6	6.7	6.5	6.6	6.3	6.4
Brightness Elrepho), %	74.6	77.7	78.5	79.6	80.0	80.4
P. C. Number, No.	—	9.6	—	—	—	—
Shrinkage, %	—	16.0	—	—	—	—

*taken as optimum

TABLE-7
OPTIMISATION OF 'CEH' AND 'CHH' SEQUENCES OF C-4 (KMnO₄ No. 13.7)

PARTICULARS	1	2	3	4	5
CHLORINATION					
Cl ₂ added, %	3.0	4.0	5.0	6.0	7.0
Cl ₂ consumed, %	3.0	4.0	4.8	5.8	6.6
Final pH	2.3	2.0	1.9	1.8	1.7
ALKALI EXTRACTION					
NaOH added %	1.2	1.2	1.4	1.6	1.9
Final pH	9.1	8.6	8.9	8.8	9.1
KMnO ₄ Number no.	8.1	7.0	4.0	3.8	2.0

*NB 4.5 % Cl₂ is taken as optimum

OPTIMISATION OF 'HH' STAGES OF 'CHH' SEQUENCE

PARTICULARS	1	2	3	4	5
HYPO I STAGE					
Cl ₂ added, %	4.0	5.0	6.0	7.0	8.0
Cl ₂ consumed, %	3.9	4.8	5.7	6.4	7.3
Final pH	4.6	4.8	5.0	5.3	5.3
HYPO II STAGE					
Cl ₂ added, %	1.0	1.0	1.0	1.0	1.0
Cl ₂ consumed, %	0.5	0.8	0.7	0.7	0.7
Final pH	5.7	6.2	6.3	6.4	6.5
Brightness (Elrepho), %	76.7	78.8	79.1	80.5	80.9
P.C. Number No.	—	12.0	—	—	—
Shrinkage, %	—	8.3	—	—	—

OPTIMISATION OF 'H' STAGE OF 'CEH' SEQUENCE

PARTICULARS	1	2	3	4	5
HYPO STAGE					
Cl ₂ added, %	1.0	2.0	3.0	4.0	5.0
Cl ₂ consumed, %	3.9	4.8	5.7	6.4	7.3
Final pH	6.9	6.9	7.2	7.1	7.1
Brightness (Elrepho), %	63.7	74.9	78.5	78.7	80.1
P. C. Number, No.	—	—	8.0	—	—
Shrinkage, %	—	—	10.2	—	—

* Taken as Optimum

TABLE—8
OPTIMIZATION OF 'CEH' AND 'CHH' SEQUENCES OF
C-5 (KMnO₄ No. 9.2)

PARTICULARS	1	2	3	4	5	6
CHLORINATION						
Cl ₂ added, %	1.9	2.0	3.0	4.0	5.0	6.0
Cl ₂ consumed, %	1.0	2.0	3.0	3.9	4.8	5.8
Final pH	3.9	2.6	2.2	2.0	1.9	1.9
ALKALI EXTRACTION						
NaOH added, %	1.0	1.0	1.2	1.2	1.3	1.4
Final pH	10.1	9.5	9.0	9.3	8.9	9.2
KMnO ₄ , Number no. (AE pulp)	8.0	6.1	4.7	3.6	3.1	2.6

OPTIMIZATION OF 'HH' STAGES OF 'CHH' SEQUENCE

PARTICULARS	1	2*	3	4
HYPO I STAGE				
Cl ₂ added, %	1.0	2.0	3.0	4.0
Cl ₂ consumed, %	1.0	1.9	2.9	3.3
Final pH	5.0	5.3	5.5	6.6
HYPO II STAGE				
Cl ₂ added, %	1.0	1.0	1.0	1.0
Cl ₂ consumed, %	0.9	0.8	0.7	0.7
Brightness (Elrepho) %	76.7	79.0	82.1	84.2
P.C. Number no.	—	11.2	—	—
Shrinkage %	—	8.1	—	—

OPTIMISATION OF 'H' STAGE OF 'CEH' SEQUENCE

PARTICULARS	1	2	3	4
HYPO STAGE				
Cl ₂ added, %	1.0	2.0	3.0	4.0
Cl ₂ consumed, %	0.9	1.6	2.5	3.4
Final pH	7.2	7.5	7.5	7.8
Brightness (Elrepho), %	74.9	79.5	82.2	82.6
P.C. Number no.	—	8.4	—	—
Shrinkage, %	—	7.2	—	—

*Taken as Optimum

TABLE—9
PHYSICAL STRENGTH PROPERTIES OF BLEACHED PULP AT 45° SR

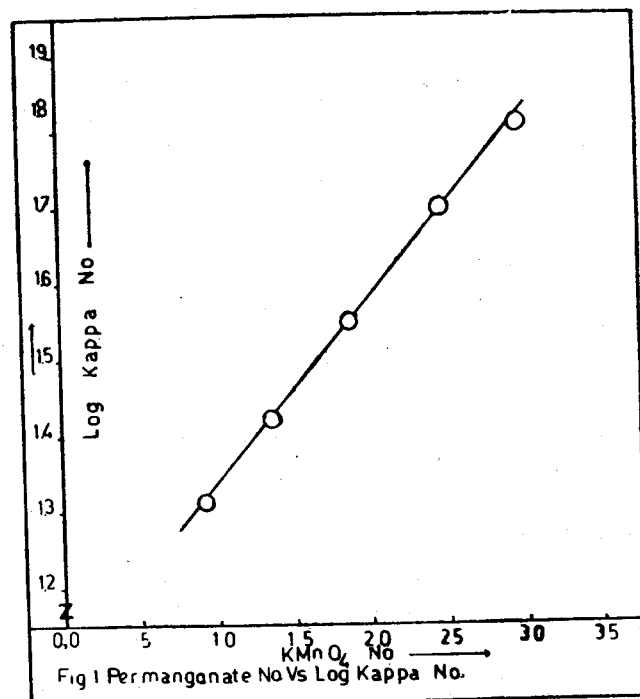
PARTICULARS	COOK I	COOK II	COOK III	COOK IV	COOK V
H-H SEQUENCE					
Burst Factor	25.9	29.5	34.8	37.0	37.6
Tear Factor	24.0	29.0	36.7	38.0	35.8
Breaking Length (M)	4950	5240	5630	5970	6180
Double Folds, no.	7	30	87	80	92
CHH SEQUENCE					
Burst Factor	30.0	34.8	38.8	39.6	39.1
Tear Factor	27.5	37.0	42.9	45.6	45.3
Breaking Length, (M)	5400	5650	5940	6134	6212
Double folds, no.	12	43	102	182	212
CEH SEQUENCE					
Burst Factor	34.0	36.8	37.7	40.8	42.8
Tear Factor	28.0	33.8	38.7	39.5	40.0
Breaking length, (M)	5750	5951	6256	6393	6481
Double folds, no.	4	31	77	187	324

2. The relationship between permanganate number and kappa number for wheat straw pulps is also determined (fig 1) and the same is in accordance with following relation.

$$\text{Log Kappa number} = 1.085 + 0.025 (\text{K No.})$$

- Pulping of wheat straw with 8 to 16% NaOH at the fixed conditions has given pulps which need slight defibration in valley beater. The pulps yield and permanganate number decrease with increase in chemical charge. Ash in unbleached pulp decreases with increase in alkali charge which may be due to the formation of sodium silicate (Table-2)
- All the pulps responded favourably to 'HH' bleaching sequence also and attained the desired level of brightness i.e. $78 \pm 1\%$ (Table-3). But the consumption of hypochlorite and shrinkage are higher in case of pulp of high permanganate number. Post colour number decreases from high permanganate number pulp to low permanganate number.
- The optimization of chlorine charge is being done by varying the chlorine charge and determining the permanganate number of alkali extracted pulps.

The same method has been adopted for all the pulps in this study. (Table 4-8). The optimum chlorine charges for pulp of 30, 24.6, 18.6, 13.7 and



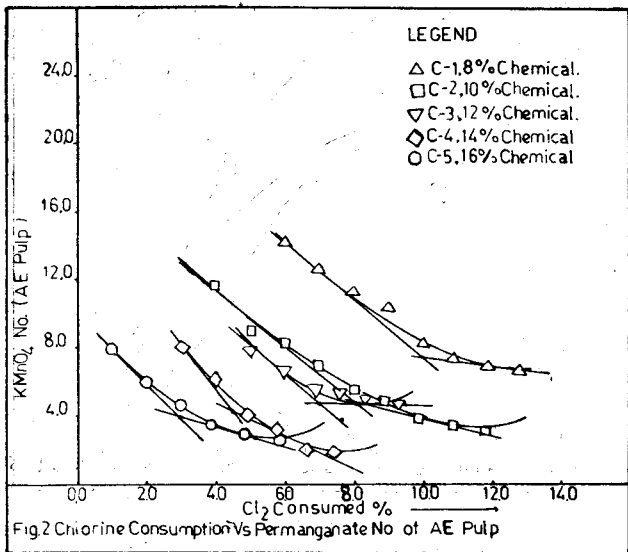


Fig 2 Chlorine Consumption Vs Permanganate No of AE Pulp

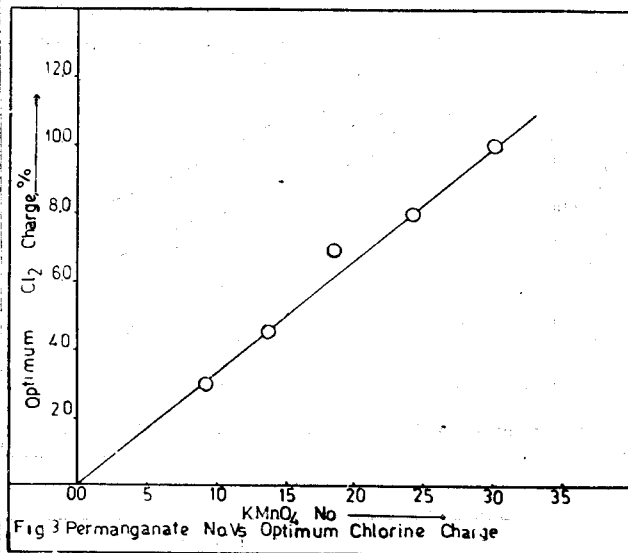


Fig 3 Permanganate No Vs Optimum Chlorine Charge

9.2 are obtained as 10.0, 8.0, 7.0, 4.5 and 3.0% respectively. It is observed that optimum chlorine charge percent for wheat straw pulps is 1/3rd of its permanganate number.

- Optimization of hypostage of CEH and CHH sequence was done by varying hypocharge, on to the chlorinated/extracted and chlorinated pulps to get desired level of brightness. The hypo consumption decreases from C-1 to C-5 (Table 4-8) in both the sequences. The pH in the first hypostage of CHH is very low (except in C-4 & C-5) because of excess formation of acidic compounds during chlorination.

The post colour number decreases with decrease in permanganate number of unbleached pulp.

The shrinkage, during bleaching, of the pulp is in order of HH > CHH > CEH and with in one sequence of bleaching shrinkage decreases from high permanganate number to low permanganate number pulp.

- In order to get a relation between total chlorine demand (TOD) and permanganate number graphs were plotted between permanganate number and TCD for different bleaching sequences. It is observed that there is a linear relationship between the two parameters as shown in Fig. 4.

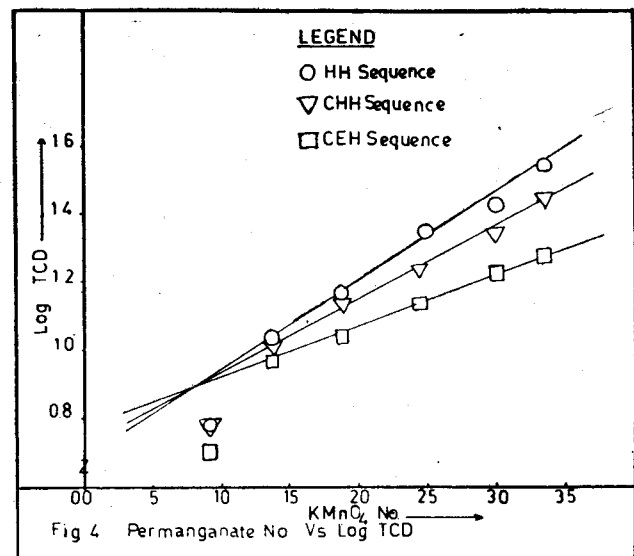


Fig 4 Permanganate No Vs Log TCD

Initially at higher permanganate number the difference between total chlorine demand for HH, CHH and CEH sequence is wide, but reduces gradually with decreasing unbleached pulp permanganate number (C₁ to C₅). However at very low permanganate number the correlation is disturbed and TCD for all the three sequences are more or less same. If we exclude C-5 in order to derive a workable relationship between permanganate number and TCD, on computation following relationship is obtained :

$$\begin{aligned}
 \text{T.C.D. (HH sequence)} &= \text{K.No.} \times 0.88 \\
 \text{T.C.D. (CHH sequence)} &= \text{K.No.} \times 0.75 \\
 \text{T.C.D. (CEH sequence)} &= \text{K.No.} \times 0.57
 \end{aligned}$$

9. All the strength properties of unbleached pulps increase with decrease of the permanganate number from C_1-C_5 (Fig. 5). This may be due to gradual decrease in lignin content in the pulp which ultimately improves the bonding. Similar trend is observed in bleached pulps strength properties. Out of three bleaching sequences bleached pulps obtained with a CEH sequence have the highest strength properties while 'HH' bleached pulps have the lowest (Fig. 6,7,8 & 9).

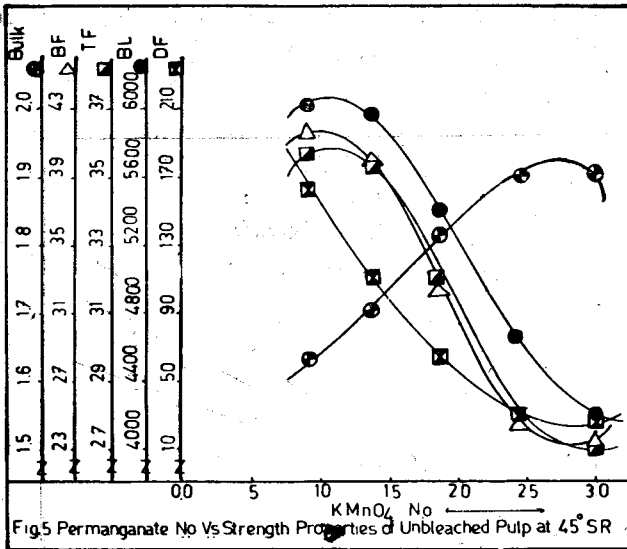


Fig.5 Permanganate No Vs Strength Properties of Unbleached Pulp at 45° SR

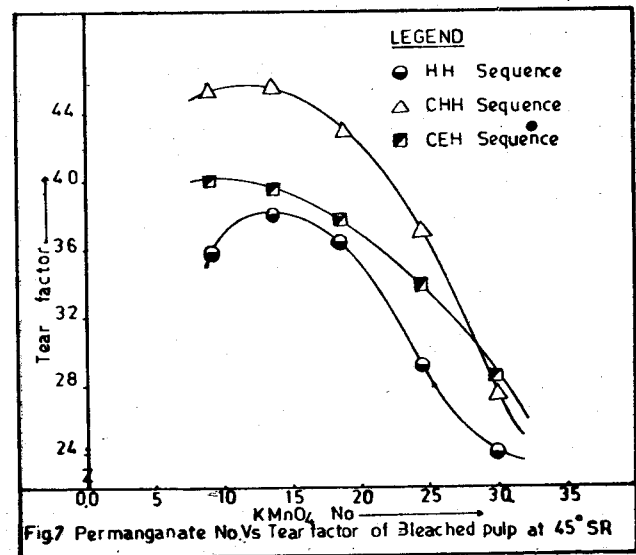


Fig.7 Permanganate No Vs Tear factor of Bleached pulp at 45° SR

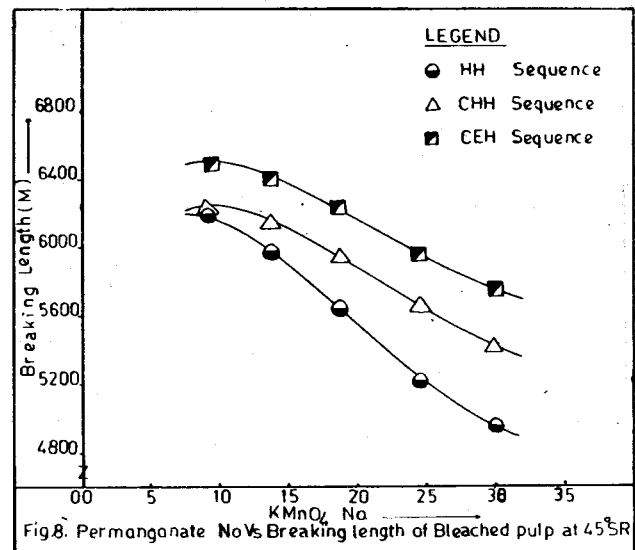


Fig.8. Permanganate No Vs Breaking length of Bleached pulp at 45° SR

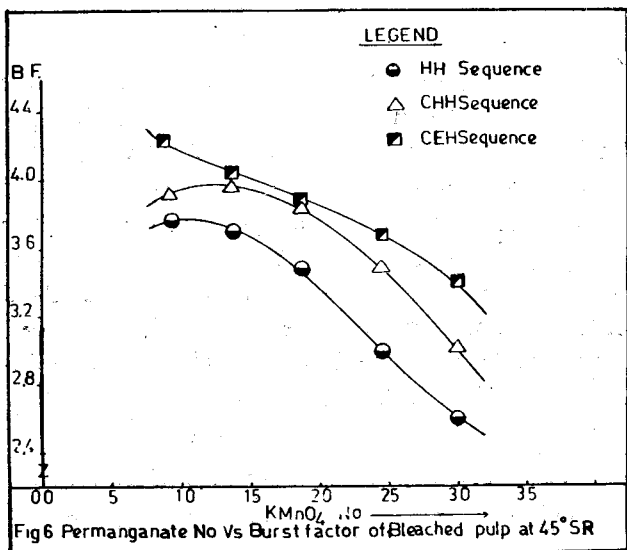


Fig.6 Permanganate No Vs Burst factor of Bleached pulp at 45° SR

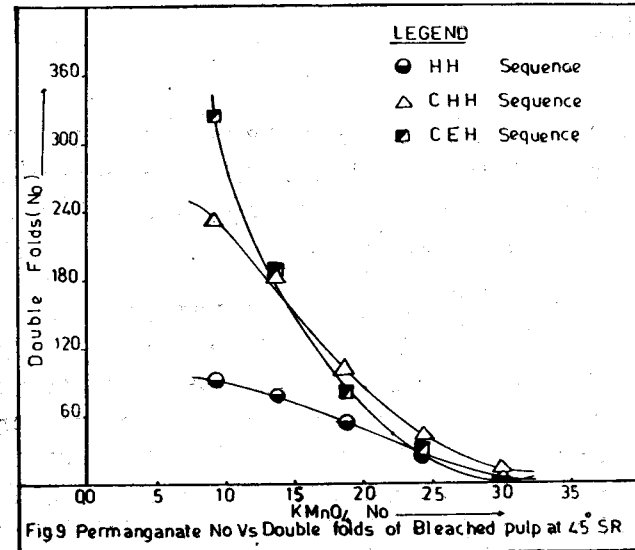


Fig.9 Permanganate No Vs Double folds of Bleached pulp at 45° SR

CONCLUSION :

The present study reveals that wheat straw pulps of varied permanganate number can be bleached to desired level of brightness by following HH, CHH and CEH sequences. However, total chlorine requirement and pulp degradation during bleaching vary from sequence to sequence, which ultimately reflects on the physical strength properties. The pulp bleached with CEH sequence requires lowest chlorine dose and gives

highest strength properties which follows by CHH and HH sequence respectively.

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