RECYCLING POTENTIAL OF *SACCHARUM MUNJA* PULP

A DISSERTATION

Submitted in partial fulfillment of the requirement
for the award of the degree
of

MASTER OF TECHNOLOGY
IN
PULP AND PAPER
BY

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CANDIDATE DECLARATION

I hereby certify that the work which is being presented in this dissertation "RECYCLING POTENTIAL OF *SACCHARUM MUNJA* PULP" in partial fulfillment of the requirement for the award of degree of Master of Technology in Pulp and Paper, submitted at the department of paper technology, IIT Roorkee, is a authentic record of my own work, carried out during the period from June 2004 to June 2005, under supervision of Dr. S. P. Singh, Associate Professor and Dr. Vivek Kumar, Lecturer, Department of Paper Technology, IIT Roorkee, Saharanpur Campus, Saharanpur.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Date: 30-06-05

Place: Saharanpur

Candidate's signature

This is to certify that the above statement by the candidate is correct to best of our knowledge.

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ABSTRACT

Internationally, Wood is primary fibrous raw material for paper making. But, the supply of wood based raw material to the Indian paper industry is inadequate. The Indian paper industry is making continuous effort to alternative of woody raw materials. The nonwoods and wastepaper are widely used raw materials by small scale paper mills in India. The nonwood pulp fibers have high specific surface area and high fines contents that give better printing characteristics than those of softwood pulps. Nonwoods have also benefits of low cost and easy availability of raw material when compared with wood.

In a resent study (1) recycling potential of bagasse and wheat straw pulps have been evaluated. It was observed that on recycling of the wheat straw pulps the loss in tensile strength was quite low in comparison to the loss in bagasse and wood pulps. The recycling behavior of bagasse pulp was quite similar to that of wood pulps.

'Sarkanda', *Saccharum munja* is another important nonwood raw material used by Indian paper mill. Mills using bagasse and wheat straw as raw material also use sarkanda to maintain the raw material supply in off seasons of bagasse and wheat straw. In the present study, we have attempted to evaluate the recycling potential of sarkanda, and compared wheat straw and softwood pulps.

The *Saccharum munja* was procured from M/S Shri Badri Kedar paper mill Ltd. Najibabad (U.P.) and was pulped in the laboratory batch digester. The raw material was screened on a 20-mesh screen and then washed with water to remove very fine material and other non cellulosic impurities. The effect of alkali dose during soda pulping of sarkanda was evaluated. It was found that a 12% alkali dose (as NaOH) is sufficient to pulp a bleachable pulp at 165°C for 45min. Each pulping experiment was

repeated for two times. For final pulping two batches were pulped separately (1500g o.d. raw material) and bleached separately using CEHH bleaching sequence.

One sample of wheat straw pulp was procured from M/S Shreyans Industries Ltd., Mandi Ahmedgarh (Pb) and another pulp sample of wheat straw was prepared in the laboratory, from wheat straw procured from near by village area. Both mill made and laboratory prepare wheat straw unbleached pulps were bleached in the laboratory using CEHH sequence.

The bleached softwood pulp pads were procured from M/S Shreyans Industries Ltd., Mandi Ahmedgarh (Pb) to compare the recycling behavior of sarkanda pulp.

NOTATION

SR	Sarkanda Pulp
SR1, SR2	Two batches of sarkanda pulps were pulped, SR1 represents first batch and SR2 represents second batch
SR 1/2 (0/1/2)	Virgin Refined/Once Recycled/Second Recycled sarkanda pulp of first or second batches
SR 1/2(0/2)R48/P48R200/R200	Screened sarkanda pulp of 48 mesh/ Between 48 and 200 mesh/ 200 mesh, of virgin refined/ Second recycled sarkanda pulp of first or second batches
WS	Wheat Straw pulp
WSMM/LM	Wheat Straw pulp in mill made or laboratory made
WSMM/LM (0/1/2)	Virgin refined/ once recycled/ twice recycled wheat Straw pulp of mill made or laboratory made
SW	Soft wood pulp
SW1/2	Soft wood pulp of first or second experiment
SW1/2 (0/1/2)	Virgin refined/ once Recycled/twice recycled softwood pulp of first or second experiment

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Introduction

INTRODUCTION

1.1 GENERAL

The global paper industry is sincerely concerned in finding suitable replacement of wood fibers within a papermaking medium. The rapid growth in paper production has rendered the forests incapable of sustaining the supply of wood. Nonwoods and agricultural residues have proved to be economically viable sources of fiber supply.

Nonwood raw materials account for 5-7% of the worldwide production of paper. There are two main reasons for increase in use of non woods in Indian paper industry.

1. Environmentalist strongly supports the use of nonwoods along with agro-residues as a way to preserve natural forests.
2. Due to high increase in paper demand there is currently shortage of wood fiber, non-wood fibers and agro-residues can be either used as an extender for wood fiber or as reinforcing aid for recycled pulps.

Sarkanda is potential Nonwood used for papermaking in India. 'Sarkanda', *Saccharum munja* is a species of *Gramineae* family. The mills using bagasse and wheat straw as raw material also use sarkanda to maintain the raw material supply in off seasons of bagasse and wheat straw. In the present study, attempts were made to evaluate the recycling potential of sarkanda and its recycling behavior was compared with recycling behavior of wheat straw and softwood pulps. Some mills which use Sarkanda are:

1. Abhishek Industries Ltd., Hosiyarpur (Pb)
2. Bindal Duplex Ltd., Muzaffarnagar (U.P.)
3. Mohit Paper Mills Ltd. Bijnor (U.P.)
4. Rana Paper Ltd., Muzaffarnagar (U.P.)
5. Ruchira Paper Ltd., Sirmaur (H.P.)
6. Satia Paper Mills Ltd., Rupana, Distt. Faridkot (Pb)

7. Shree Bhawani Paper Mills Ltd., Allahabad (U.P.)
8. Shri Badri Kedar Paper Mill Ltd., Najiabad (U.P.)

1.2 OBJECTIVE

There is a need to increase the knowledge that how non-wood fibers will be influenced by recycling. In the present study, the recycling behavior of Sarkanda pulp has been evaluated and the results are compared with wheat straw fiber and a long fibered softwood pulp. On recycling, softwood pulps show high loss in tensile strength, whereas wheat straw pulps show comparatively lower loss in tensile strength.

The objectives of present work may be summarized as:

1. To assess the effect of changes that occurs in fiber during recycling of Sarkanda, wheat straw and softwood pulps.
2. To compare the properties changed on recycling of pulps of Sarkanda, wheat straw and softwood pulps.

1.3 METHODOLOGY

Preparation and procurement of Pulps

1. Sarkanda pulp was prepared in the laboratory using different alkali dose and cooking temperature, we found that 12% NaOH charge and 160°C cooking temperature was the best conditions for obtain bleachable grade pulp. Two batches of pulp prepared using these conditions. The pulps were bleached using CEHH sequence. The chlorine dose was determined by bleaching several samples.
2. Single specie unbleached pulp of wheat straw (WS-MM) was procured from M/S Shreyans Industries Ltd., Mandi Ahmedgarh (Pb). The pulp was bleached in laboratory using CEHH for a target brightness of 80% ISO.

3. Wheat straw (WS-LM) pulp was also prepared in the laboratory using 15% NaOH charge at 165°C cooking temperature. Pulp was bleached using CEHH sequence after optimizing the total chlorine charge for a target brightness of 80% ISO.

4. Imported bleached softwood pulp (SW) was procured from M/S Shreyans Industries Ltd., Mandi Ahmedgarh (Pb).

5. The handsheets were prepared from unrefined pulps and refined pulps and evaluated for various properties.

Recycling of pulps

1. Recycling was limited to drying and rewetting of pulps and the sheets between the cycles were made on a laboratory sheet-making machine. Initially the pulps were beaten in the valley beater to freeness level to 350 ml to 200 ml CSF.

2. From a portion of the pulp, standard handsheets were prepared for the evaluation of various properties of the pulp. To speed up the experimental work, thick pads (550 g/m^2) were prepared on the same sheet-making machine from the remaining portion of the pulp. The pads were wet pressed (700 kN/m^2) and dried on a heated cylinder at 50 °C. The handsheets and the pads were dried in contact with gloss plates. The backwater was re-circulated during the making of sheets and pads.

3. For subsequent cycles the pads were reslushed in the laboratory disintegrator at 1.2% consistency and remade into handsheets and pads without beating in between. All the pulps (SR, WS-MM, WS-LM, and SW) were recycled for two times.

4. The virgin refined and two times recycled Sarkanda pulps were fractioned in a Bauer-McNett classifier at 48 and 200-mesh screens. The two fractions (R48 and P48R200) were made in to handsheets for evaluation of the various properties of these fractions. The pulps were also screened separately on only 200-mesh screen. The R200 fraction was made in to handsheets for evaluation of various properties of this fraction.

5. The entire recycling experiment was repeated on second sample of sarkanda pulp to check reproducibility.

1.4 LIMITATIONS

In the present study, all the recycling experiments, from pulp making to sheet making have been conducted in laboratory. The mill conditions differ from the laboratory conditions at almost each step. Further, the recycled sheets in these experiments were not subjected to those operations to which actual paper goes through during printing, converting, and end-use. These conditions may influence the recycling behavior of the paper.

Chapter

TWO

Literature review

Paper made of recycled pulp has properties different from paper made of virgin pulp. The most significant effect is on the strength properties. The other important properties influenced by recycling are printability, coefficient of friction, and water absorbency. Loss of strength properties or changes in the other properties of the paper made from the recycled pulp is widely studied by various investigators. In this review we have tried to update some of the recent findings.

2.1 Fiber Dimensions

Drying-rewetting cycles on pulps do not produce any noticeable change in fiber length even after four or six cycles (2,3,4,5,6,7,8). This is true for both chemical and mechanical pulps. Drying-rewetting cycles cause a slight decrease in fiber perimeter possibly due to fiber wall shrinkage (4,6). The effect of recycling on fiber coarseness, weight per unit length of fiber (mg/100m), is also negligible (4,5,7,9).

2.2 Pulp Freeness

Several authors have reported that drying-rewetting cycles increase the freeness of chemical pulps (10,11,12), as well as mechanical pulps (13,14,8). The effect of recycling on pulp freeness appears to depend on the initial freeness of the pulp. Law et al. (14) observed that on recycling the freeness decreased for low initial freeness pulps and increased for high initial freeness pulps. They observed further that when the pulp was fractionated into long fibers and fines, the freeness of long-fiber fraction increased and of fine fraction decreased with recycling.

2.3 Apparent Density, Air Resistance and Scattering Coefficient

The apparent sheet density of low-yield chemical pulps is found to decrease on recycling (10,15,16,3,5). For high-yield mechanical pulps, the sheet density increases on recycling (3,17,14,8). The sheet density is related with the fiber-fiber bonding. Apparently, the pulp that produces strong interfiber bonds in its virgin state looses its bonding ability on recycling, and gives a low-density sheet. Pulps exhibit decrease in air resistance on recycling as they show a decrease in apparent density. In recycling experiments, the scattering coefficient is measured to estimate the relative bonded area. Pulps the scattering coefficient increases indicating a decrease in bonding properties and thus, loss in tensile strength (3,4,9,18).

2.4 Strength

Recycling has a major effect on strength properties of pulp. On recycling of chemical pulps the tensile strength decreases significantly, whereas for mechanical pulps, the change in tensile strength is less. The loss in tensile strength of chemical pulp has been reported between 20% and 70% depending upon the type of raw material, conditions of pulping and bleaching, and the recycling procedures adopted. The main reason for the loss in tensile strength of recycled fibers is reduced fiber-fiber bonding. For mechanical pulps, however, the recycling increases the fiber flexibility and fiber bonding. Recycling affects the burst strength in a similar way as it affects the tensile strength. The effect of recycling on tear strength of pulp is not as well defined as to tensile strength However, in most cases the tear strength on recycling increases for chemical pulps and decreases for mechanical pulps. Tear strength of a paper sheet is a complex function of fiber properties and the degree of sheet consolidation (19,20). Among all the factors, the fiber length has the greatest influence on the tear strength. The longer the fiber the greater is the tear index. However, the degree of dependence of tear on fiber length is influenced largely by fiber bonding. For a well-bonded sheet of paper the dependence of tearing resistance on fiber length decreases and the role of fiber strength becomes predominant (19). This implies that the tear strength should increase with the decrease in fiber bonding if the fiber length is held constant.

The loss of strength of pulp on recycling has been attributed to several factors. Some of these factors are: change in chemical composition of the fiber, the loss in fiber strength, the degradation of cellulose, and the loss in fiber bonding due to Hornification. The changes in chemical composition and fiber strength are of relatively small magnitude. Significant losses in the tensile strength observed during recycling cannot be due to the minor loss in fiber strength. Loss in relative bonded area and bond strength between fibers due to stiffening and Hornification of fibers seem to be the main factors responsible for loss in strength properties on recycling of pulps.

2.7 Hornification

The largest changes in properties of paper made from recycled pulp are observed due to repeated wetting-drying cycles. The structural changes that take place in the cell wall of fiber from a drying -and- rewetting cycle are commonly referred to as Hornification. The term was used by Jayme (21) for the first time in 1944. Hornification is associated with the loss of swelling of the fiber wall, and a stiffening of the fibers that reduces their ability to form inter-fiber bonds. Hornification, especially for low yield chemical pulps, is an irreversible process. Several researchers have found that the extent of swelling for recycled fibers would not be achieved as that of virgin fiber even after prolonged soaking of the pulp (22,23). Cell wall of fiber consists of several lamellae of cellulose fibrils. During drying, as the water leaves lamellae, high surface tension forces draw them closer together forcing the lamellae adhere to one another. The situation is not entirely reversed on rewetting, resulting reduction in fiber swelling. This is very pronounced in chemical pulps and reduces the fiber flexibility (24). Two methods are commonly employed for measurement of ability of fiber to swell; water retention value (WRV) and fiber saturation point (FSP). Jayme (21) developed the method for determination of WRV. In this method, a wet pulp sample is subject to a centrifugal force for a specified time, after which it is weighed, dried and reweighed and its water content determined (23,25). The water retention value (WRV) is obtained by expressing the water content as a percentage of the dry weight of pulp. WRV is the most popular method because of its ease, simplicity and rapidity. WRV and the tensile strength of recycled fibers have been shown to be linearly related.

During drying, due to high and uniform surface tension forces, the microfibrils are re-organized in a better alignment of carbohydrate chains resulting in an intensively bonded fiber structure (24,26,27,28). This phenomenon was named "crack healing" (28). During drying of the fiber, if parts of the adjacent surfaces of cellulose and hemicelluloses coming together match sufficiently well in composition and orientation they could form crystallite zones and consequently restrict swelling on rewetting (29).

Chapter
THREE

Experiments and results

EXPERIMENTS AND RESULTS

3.1 Raw Materials and Pulps Used for the Study

The Sarkanda was procured from M/S Shri Badri Kedar paper mill Ltd. Najibabad (U.P.) and wheat straw was procured from nearby village area during the harvesting season. The raw materials were screened on 20 mesh screen and washed with water to remove dust and extraneous dirt. The proximate analysis of Sarkanda and wheat straw raw materials used for pulping are as given in table 1.

A single specie wheat straw unbleached pulp and imported softwood bleached pulp were procured from M/S Shreyans Industries Ltd., Mandi, Ahmedgarh (Pb).

Table: 1- Proximate Analysis of Sarkanda and wheat straw used for pulping

	Sarkanda	Wheat Straw
Hot Water Solubility (%)	12.32	9.5
Cold Water Solubility (%)	8.95	14.7
1% NaOH Solubility (%)	32.5	40.1
Ash (%)	10.43	8.23
Alcohol Benzene Solubility (%)	4.78	3.45
Holocellulose (extractive free) (%)	74.4	72.94
Alpha Cellulose (extractive free) (%)	38.9	41.6
Lignin (extractive free) (%)	22.3	21.6
Pentosen	-	19.7

3.2 Pulping of Sarkanda and Wheat straw

The sarkanda was cooked at different alkali charges and maximum temperatures to evaluate there effects on pulp yield, kappa number, and also the strength properties for producing a bleachable variety. Other pulping conditions that are kept constant in all pulping trials were; bath ratio - 1:5 and time at temperature - 45 minutes. The different conditions and results are shown on table 2.

Table: 2- Samples Pulping of Sarkanda Raw Material

Temp °C	Alkali %	Digester	Raw Material, g (o.d.)	Cooked Weight g (o.d.)	Accept Weight g (o.d.)	Reject Weight g (o.d.)	Unscrnd yield %	Scrnd Yield %	Kappa No.	CSF ml.
160	9	Rotary	125	55.04	49.9	5.13	44.03	39.92	27.2	-
160	10	Rotary	125	59.71	54.9	4.8	47.8	43.92	26.7	-
160	12	Rotary	125	53.98	50.5	3.49	43.19	40.39	20.2	-
170	9	Rotary	125	57.21	54.08	3.13	45.77	43.26	27.39	-
170	10	Rotary	125	54.8	52.68	2.14	43.86	42.14	22.9	-
170	12	Rotary	125	53.8	51.94	1.88	43.05	41.55	20.97	-
160	10	Glycol	250	106.4	100.2	6.2	42.57	40.1	28.2	-
160	11	Glycol	250	108.2	103.4	4.8	43.28	41.4	23.4	-
160	12	Glycol	250	98.99	34.6	4.4	39.6	37.84	20.7	-
160	12	Rotary	125	55.03	53.45	1.58	44.02	42.76	-	390
160	13	Rotary	125	54.08	52.59	1.49	43.26	42.07	-	390
160	14	Rotary	125	55.68	54.95	0.73	44.55	43.96	-	390
160	15	Rotary	125	52.46	51.03	1.43	41.97	40.82	-	400

From the pulp samples cooked with 9, 10, 12% alkali charge at 160 and 170 °C, standard handsheets were prepared for evaluation of various strength properties for comparison (table 3).

Table: 3- Properties of Unbleached Sarkanda samples Pulp

Alkali charge %	Temperature °C	Screened Yield, %	Tensile Index Nm/g	Burst Index mNm^2/g	Tear Index KPa-m^2/g
9	160	39.92	49.69	2.38	5.04
10	160	43.92	52.83	2.47	3.89
12*	**160**	**40.39**	**54.84**	**2.06**	**4.66**
9	170	43.26	45.62	1.51	3.51
10	170	42.14	54.2	2.1	4.27
12	170	41.55	51.8	2.14	4.52

Note: * Selected for final pulping

The final pulping of sarkanda was done at 12% alkali charge and 160 °C maximum temperature, as per the results shown in table 4. Wheat straw was cooked in the same laboratory batch digester with 15% alkali charge, 1:5 bath ratio and 165 ° C maximum temperatures for 30 min, based on the previous laboratory results. The results of pulping of sarkanda and wheat straw are given in table 4.

Table: 4- Final Pulping of sarkanda and wheat straw Pulps

Pulp	Raw Material g (o.d.)	Cooked Weight g (o.d.)	Accept Weight g (o.d.)	Reject Weight g (o.d.)	Unscreened yield %	Screened Yield %	Kappa No.
SR_1	1500	614.34	577.72	36.629	40.96	38.51	19.34
SR_2	1500	561.45	492.5	68.95	37.43	32.8	
WS-LM_1	1500	640.17	592.65	47.52	42.68	39.51	20
WS-LM2	1500	701.67	628.8	72.87	46.78	41.92	19.4

3.3 Bleaching of Sarkanda and Wheat Straw Pulp

The sarkanda and wheat straw pulp samples were bleach at different chlorine charge by CEHH sequence in order to achieve minimum chlorine charge for 80 plus brightness. The bleaching conditions are given in table 5. Bleaching results at different chlorine charge are given in table 6. The final belching of sarkanda was done at 6% chlorine charge and wheat straw was bleached at 7.5% chlorine charge, based on the previous laboratory results (table 7).

Table: 5- Conditions used for Bleaching

Stage	Consistency %	Temperature °C	Time min	pH	End pH	% of total Chlorine Charge	Alkali Charge %
C	3	25	45	2	3	70	-
E	10	60	60	>9.5	9	-	*C_{Cl2}/2+0.3
H	10	35	180	>9.5	9	20	To adjust pH
H	10	35	180	>9.5	9	10	To adjust pH

Note: * C_{Cl2}- Chlorine charge in C stage

Table: 6- Trial Bleaching Results

% Chlorine Charge	% Shrinkage of SR1	Brightness % ISO	
		SR_1	WS-MM
5	11.7	78	-
6	14.2	80.2	75.6
7	16	80.5	78.1

Table: 7- Final Bleaching of sarkanda and wheat straw pulps.

Pulp	Chlorine Charge, %	Shrinkage, %	Brightness, % ISO
SR_1	6	12.86	81.7
SR_2	6	12.35	80.6
WS-MM	7.5	18.8	82
WS-LM	7.5	12.5	81.5

3.4 Properties of Unrefined Pulps

The bleached sarkanda pulps, wheat straw pulps and imported softwood pulp were evaluated for different properties before beating, as given in table 8.

Table: 8- Properties of unrefined Pulps

Properties		SR_1	SR_2	WS-MM	WS-LM	SW1
CSF, ml		430	470	410	390	690
WRV, %		165.5	158.9	200	234	125
Drain. Time, sec		7.66	7.4	-	-	-
% Bauer Mc-Nett Classification	R28	17.29	16.8	7.67	-	85.57
	R48	23.04	19.8	25.64	-	6.85
	R100	23.59	30.8	23.81	-	2.99
	R200	16.07	17.7	25.27	-	1.27
	P200	19.94	14.9	17.61	-	3.35
Apparent Density, kg/m^3		510.1	661.2	648.1	957.5	447
Tensile Index, Nm/g		55.14	54.78	44.5	76.21	38.3
Tear Index, mNm^2/g		4.00	4.04	4.6	3.83	17.8
Burst Index., $kpam^2/g$		2.39	3.28	3.0	4.5	2.3
Scattering Coefficient, m^2/g		45.42	39.1	35.5	-	26.89
No. of double folds		-	7.0	-	21.0	-
Absorption coefficient		0.78	0.47	-	-	-

3.5 Initial Beating of pulps

All pulps were initially beaten in Valley Beater. Table 9 shows the response of beating for different pulps.

3.6 Recycling of pulps

The recycling was done as shown in Figure 1. Recycling was limited to drying and rewetting of pulps and the sheets between the cycles were made on a laboratory sheet-making machine. The initial freeness of the pulps used for recycling study was kept in the range of 350 to 200 ml CSF. Chemical pulps were beaten in a valley beater to achieve the desired freeness. From a portion of the pulp, handsheets of 60 g/m^2 were prepared according to the standard method SCAN M5: 76 for the evaluation of various properties of the pulp. To speed up the experimental work, thick pads (550 g/m^2) were prepared on the same sheet-making machine from the remaining portion of the pulp. The pads were wet pressed (700 kN/m^2) and dried on a heated cylinder at 50 °C. The handsheets and the pads were dried in contact with gloss plates. The backwater was re-circulated during the making of sheets and pads. For subsequent cycles the pads were reslushed in the laboratory disintegrator at 1.2% consistency and remade into handsheets and pads without beating in between. The entire recycling experiment was also repeated for second sample of sarkanda pulp and softwood pulp to check the reproducibility of the recycling results.

Table: 9- The response of pulps to beating

Time, min	CSF of pulp, ml					
	SR1	SR2	WS-MM	WS-LM	SW1	SW2
Initial	430	470	410	390	690	-
3	-	-	320	350	-	-
5	370	390	-	210	-	-
8	315	335	-	-	-	-
10	275	295	-	-	-	-
11	-	270	-	-	-	-
15	-	-	-	-	650	-
30	-	-	-	-	580	-
40	-	-	-	-	530	-
50	-	-	-	-	430	480
55	-	-	-	-	385	360
59	-	-	-	-	330	320

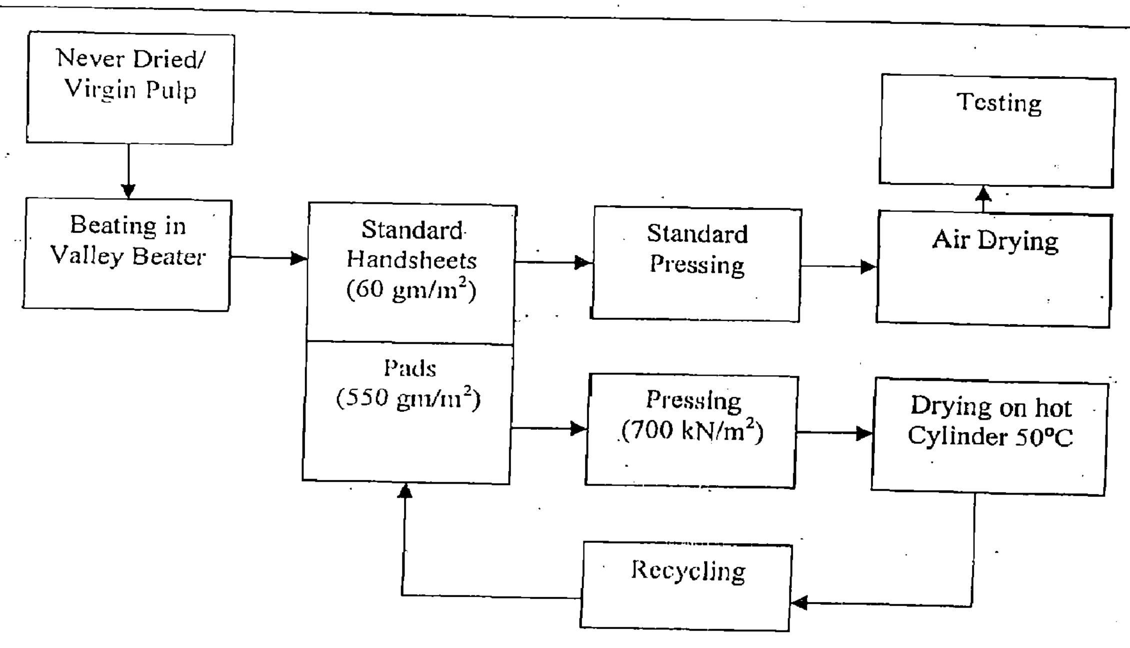


Figure: 1- Schematic representation of repeated Paper making Process

3.7 Bauer-McNett Fractionation of virgin refined and recycled sarkanda pulps

The fractionation experiments were conducted on Bauer-McNett classifier as shown in figure 2. Virgin refined sarkanda pulp and recycled sarkanda pulp (pads) after two recycles were fractionated in Bauer-McNett Classifier into three fractions. The first

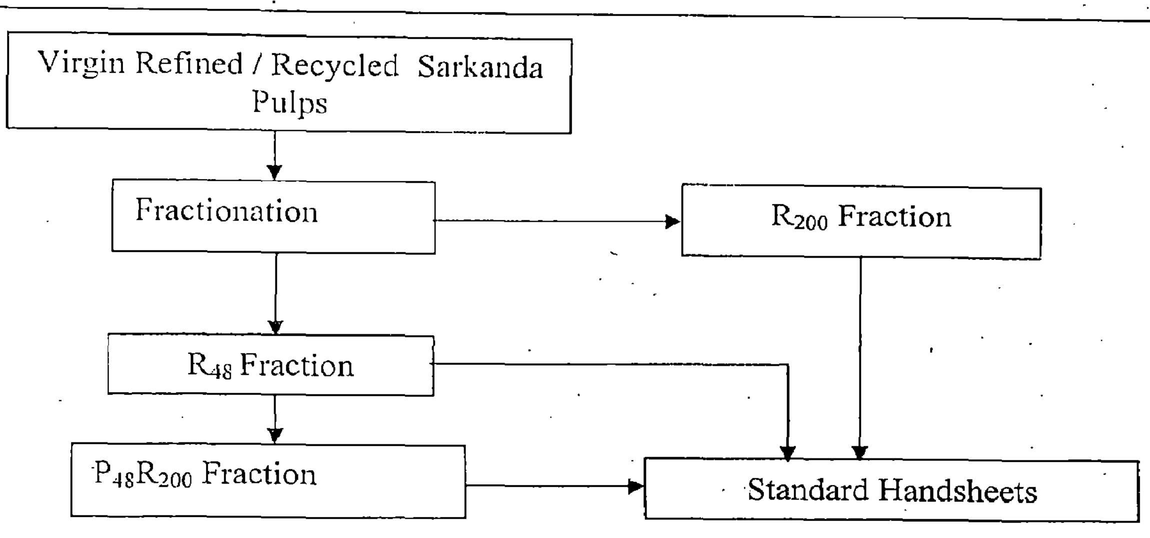


Figure: 2- Schematic representation of fractionation experiments

fraction was the retained on 48 mesh sized screen i.e. coarser fibers, the second fraction was passed from 48 mesh sized screen and retained on 200 mesh sized screen i.e. finer fraction and for the third fraction the pulp was separately fractionated on 200 mesh screen i.e. pulp with out very fine pulp particles. The standard handsheets were made from the different fractions of pulps for evaluation of various properties.

3.8 RESULTS

The handsheets made at the different cycles from different pulps are tested for various properties. The results are average values of ten experimental values. Tables 10 and 11 give the recycling result of first and second samples of sarkanda pulp.

Table: 10- Effect of recycling on Properties of first sample of sarkanda pulp.

Recycle number		Recycling			Properties of different Fractions							
		0	I	II	0	II	0	II	0	II
					R48	R48	P48R200	P48R200	*R200	*R200
CSF, ml		275	300	320	-	-	-	-	-	-
Drain. Time, sec		18.66	15.33	12.33	6.33	7	8	11	7	7
WRV, %		187.72	144.94	139.37	139.78	117.26	171.13	134.48	153.37	122.36
Bauer-McNett Classification	R28	12.2	12.8	13.2	-	-	-	-	-	-
	R48	20.5	20.8	19.3	-	-	-	-	-	-
	R100	26.1	27.4	25.5	-	-	-	-	-	-
	R200	16.1	16.1	16.9	-	-	-	-	-	-
	P200	25.1	22.9	25.1	-	-	-	-	-	-
App. Density kg/m^3		592.35	566.75	535.63	475.52	518.82	613.62	552.54	530.43	499.93
Tensile Index, Nm/g		73.57 (2.81)	52.98 (6.43)	42.94 (7.01)	39.33 (13.19)	34.79 (7.04)	57.77 (7.54)	33.45 (18.04)	52.89 (5.37)	30.89 (9.9)
Tear Index, mNm^2/g		3.07 (10.13)	3.67 (9.3)	3.73 (9.05)	6.54 (2.56)	5.98 (4.84)	2.56 (0.0)	2.06 (114.42)	4.88 (7.38)	4.47 (5.97)
Burst Index, kPa m^2/g		4.07 (8.04)	2.27 (9.24)	1.62 (6.81)	1.98 (14.4)	0.94	2.18 (13.4)	0.96 (45.83)	2.49 (9.6)	0.84 (21.9)
Scatt. Coeff., m^2/g		29.27	43.24	46.3	34.61	42.12	37.92	48.87	36.53	41.76
Abs. Coeff., m^2/g		0.58	0.71	0.74	0.52	0.48	0.67	0.71	0.54	0.6

Note: * R200 – fiber fraction separately retained on 200-mesh screen.

Table: 11- Effect of recycling on Properties of second sample of srakanda pulp.

		Recycling			Properties of different Fractions			
Recycle number		0	I	II	0	II	0	II
					P48R200	P48R200	*R200	*R200
CSF, ml		270	290	280	-	-	-	-
Drain. Time, sec		13.2	11	11.3	10	10.1	7.3	7
WRV, %		179.06	141.96	129.13	192.71	151.05	159.59	129.19
Bauer-McNett Classification	R28	13.2	15.2	16.8		-		-
	R48	20.2	20.9	19.8		-		-
	R100	30.9	28.8	30.8		-		-
	R200	18.1	16.5	17.7		-		-
	P200	17.6	18.6	14.9		-		-
App. Density kg/m^3		746.86	657.48	643.67	755.61	639.12	717.3	578.11
Tensile Index, Nm/g		65.07 (13.4)	49.49 (10.8)	43.68 (11.75)	59.04 (1.04)	35.81 (6.33)	65.43 (5.59)	38.86 (4.15)
Tear Index, mNm^2/g		3.32 (12.37)	3.58 (6.3)	3.92 (3.96)	1.67 (12.83)	1.72 (9.8)	3.67 (4.8)	12.05 (148.9)
Burst Index, $kPam^2/g$		4.423 (7.48)	2.56 (9.6)	2.34 (11.8)	2.49 (8.88)	1.17 (12.08)	3.86 (4.11)	1.68 (5.74)
Scatt. Coeff., m^2/g		33.13	42.19	45.73	31.61	43.61	27.09	42.01
No. of double folds		10	7	6	5	15	2	7
Abs. Coeff.		0.45	0.51	0.53	0.46	0.49	0.4	0.39

Note: * R200 – fiber fraction separately retained on 200-mesh screen.

The recycling results for wheat straw and softwood pulps are given in table 12.

Table: 12- Properties of handsheets from wheat straw and soft wood pulps

	WS-MM			WS-LM		SW1			SW2	
Recycle No.	0	1	2	0	1	0	1	2	0	1
CSF, ml	320	-	-	210	215	330	-	-	320	390
WRV, %	209	168	154	250.8	-	197	151	135	176.7	138.5
Apparent Density kg/m^3	690	636.7	630.2	821.1	704.6	639.1	568.5	583	651.5	590.7
Tensile Index, Nm/g	51.4	42.1	41.3	82.0 (9.6)	76.5 (4.1)	80.2	59.5	56.3	85.1 (7.7)	62.4 (8.4)
Tear Index, mN m^2/g	4.3	4.2	5.1	3.82 (6.24)	5.92 (3.7)	12.5	16.4	14.87	11.12 (3.4)	13.55 (5.6)
Burst Index, kPa m^2/g	3.6	2.3	2.7	5.42 (11.1)	4.59 (5.3)	12.5	16.4	14.87	7.18 (8.5)	4.82 (13.7)
Scatt.Coeff., m^2/g	33.12	38.4	38.1	-	-	17.84	24.9	23.6	-	-
No. of double folds	12.0	14.0	17.0	33.0 (0.2)	51.0 (0.2)	398.0	309.0	194.0	165.0 (0.2)	158.0 (0.1)

Chapter
FOUR

Discussion

4.1 Properties of Sarkanda pulp

The bleached sarkanda pulps were prepared at same pulping and bleaching conditions. The two pulps at unrefined state have nearly identical drainage characteristics, as given in table 8 (pp-13). The pulps have same differences in fiber fractions retained at 48 and 100-mesh screens (table 8). The tensile and tear index of the unrefined sarkanda pulps are also identical (Figure 3 & 4), indicating that the produced pulps are of similar quality.

After 10 min beating in valley beater the pulps were brought to freeness level of about 270ml CSF. A comparison of the tensile, tear and burst index of two batches of sarkanda pulps and their fractions are shown in figures 3 – 5. Further, the strength values of the sarkanda pulp are not very different from the wheat straw pulp (table 8, 10-12). Except that, the number of double folds of the sarkanda pulp is very low, the value lies between 1 to 10 for both the sarkanda pulps.

Figure 3: Tensile index of whole pulp and different fraction of virgin sarkanda pulps.

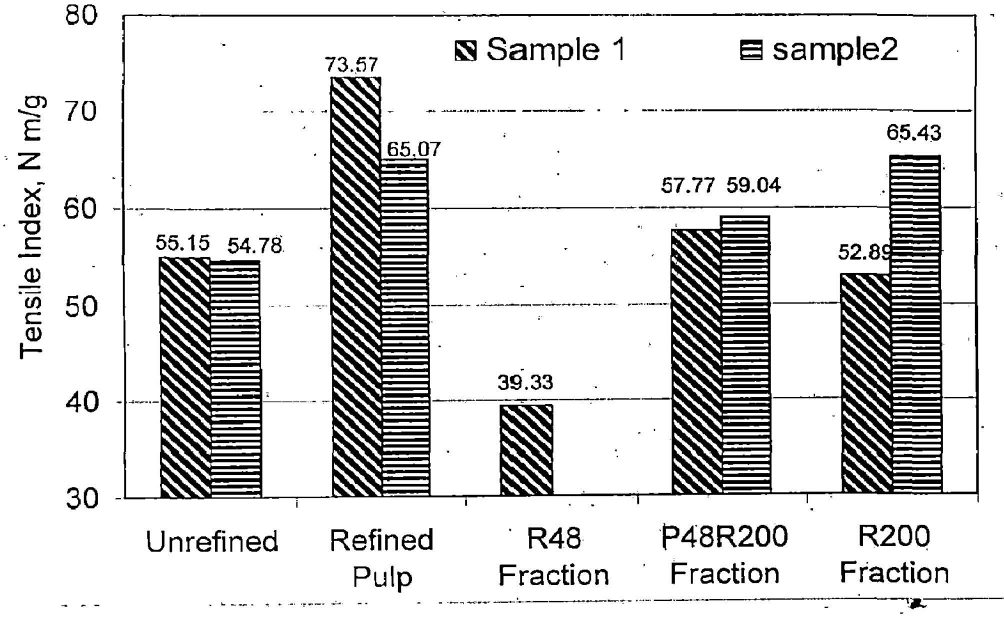


Figure 4: Tear index of whole pulp and different fraction of virgin sarkanda pulps.

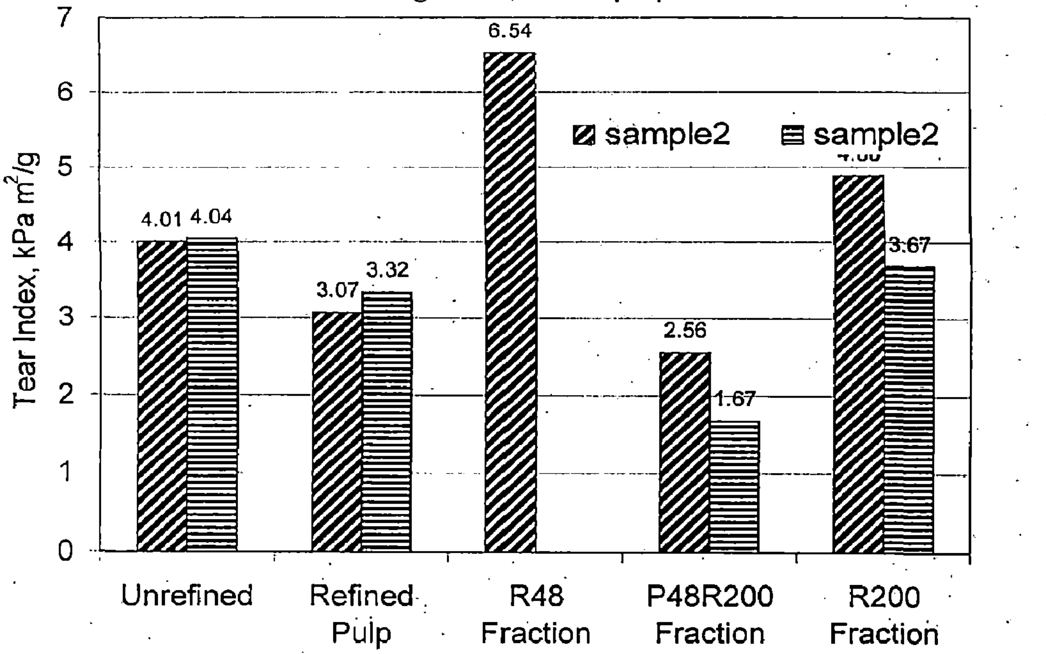
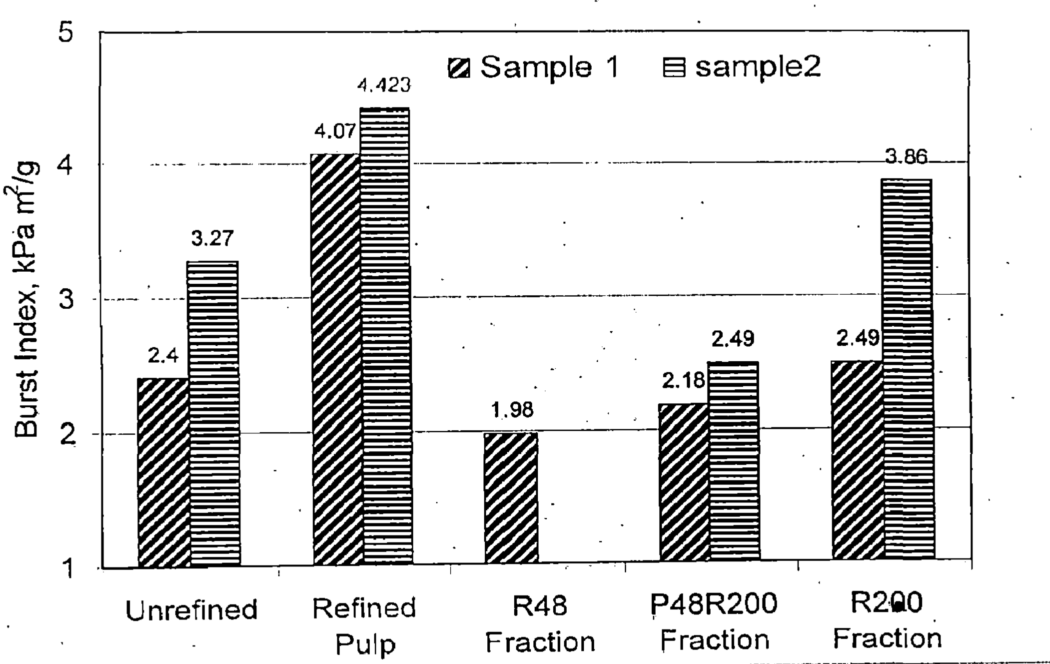


Figure 5: Burst index of whole pulp and different fraction of virgin sarkanda pulps.



The R48 fraction (fraction retained on 48-mesh screen) of sarkanda pulp has lower tensile and burst index than the whole pulp ((Figure 3 and 5). The P48R200 fraction (fraction passing 48-mesh screen and retained on 200-mesh screen) shows higher tensile index than R48 fraction, indicating its higher bonding potential.

R200 fraction, (separately retained on 200-mesh screen) has lower tensile and burst index than the whole pulp. This suggests that the fines (P200) that are lost during the fractionation process also contribute to the strength properties of the sarkanda pulp.

Figure 4 shows that on refining of sarkanda pulps tear index decreases. The R48 fraction shows high tearing resistance probably due to higher average fiber length.

Figure 6 shows the drainage time of sarkanda pulps and its fractions. The unrefined pulps show identical values. The R48 fraction and P48R200 fraction takes less time to drain than the whole pulp.

The separately retained R200 fractions of two batches of sarkanda pulps have almost identical drainage time. The drainage time of R200 fraction is nearly half of the drainage time of whole pulp. This suggests that the P200 fraction in sarkanda pulp is responsible for increasing the pulp drainage time. The Bauer-McNett classification results of two pulps shows that the SR1 pulp has higher proportion of R200 that the SR2 pulp.

Figure 7 shows the water retention value (WRV) of sarkanda pulps and their fractions. The R48 fraction has low WRV than whole pulp and finer fraction (P48R200). R200 fraction also has low WRV than the whole pulp.

Figure 6: WRV of whole pulp and different fraction of virgin sarkanda pulps.

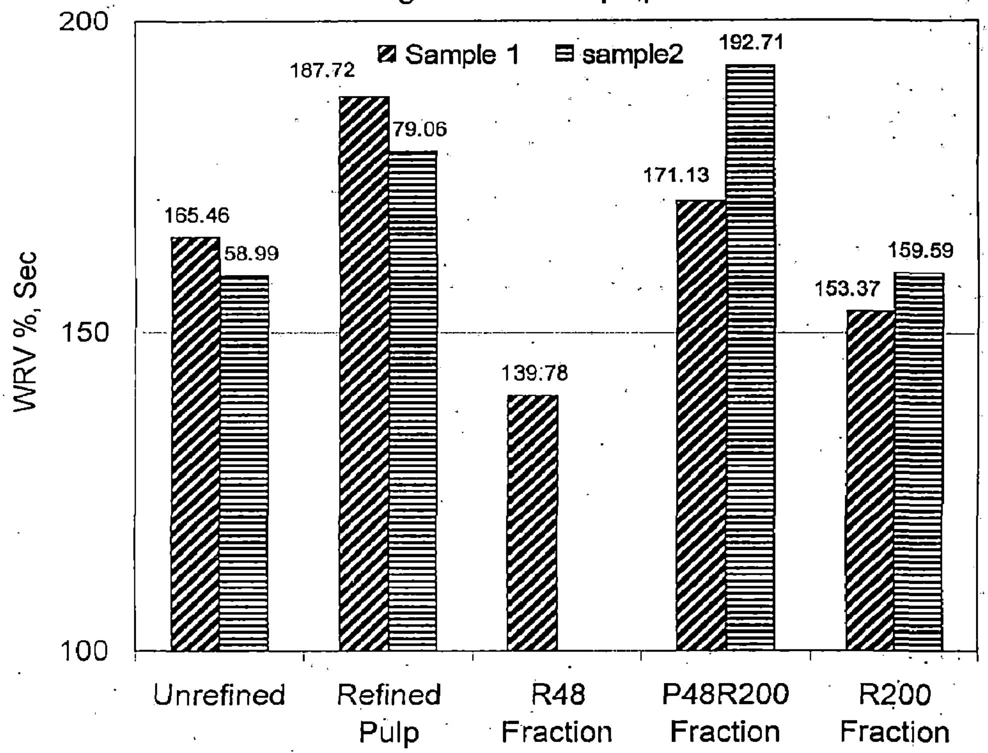
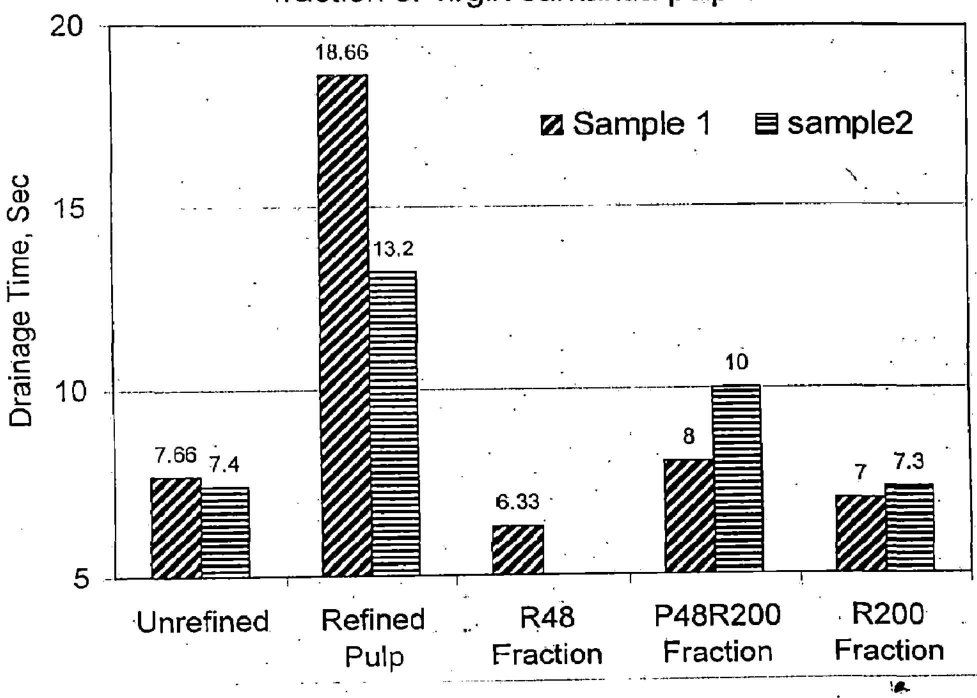


Figure 7: Drainage Time of whole pulp and different fraction of virgin sarkanda pulps.



4.2 Recycling Potential of Sarkanda Pulps

Figures 8 and 9 show the effect of recycling of sarkanda pulps on freeness (CSF) and drainage time. Both freeness and drainage time show that the pulps are becoming freer on recycling. Earlier workers have found no definite relationship between freeness and recycling (2,3,10,12,16). The loss of fines and initial freeness level of pulp in the previous cycle is responsible for rise in pulp freeness (1).

Fiber swelling measured in terms of water retention value (WRV) decreases in a similar manner for two samples of sarkanda pulps, as shown in figure 10. There is about 27% loss in WRV after three cycles. On recycling, loss in WRV is a measure of Hornification of the pulp fibers. It indicates to stiffening of the fibers that reduces their ability to form inter-fiber bonds (Chapter- 2, pp-7).

The Bauer-McNett classification results of the two pulp samples of sarkanda pulp indicate that the fiber classification of the pulps Is not affected by the process of recycling (table 9 and 10, pp 17-18). It has to be remembered that no mechanical treatment was given to the pulps except disintegration, between the cycles. Recycling has no major impact on the fiber length of sarkanda pulps.

Recycling causes loss in tensile and burst strength of sarkanda pulps in a manner similar to softwood and bagasse pulps (1) (figure 11 and 12). The tensile index for first sample of sarkanda pulp drops by about 22 points and for second sample it drops by about 30 points after three cycles. Figure 13 shows that tear index increases on recycling of sarkanda pulps. The rise in tear index and loss in tensile index is attributed to loss in bonding between the fibers (chapter- 2, pp-6).

Figure 14 shows that the scattering coefficient of the sarkanda pulps increases with recycling. The rise in scattering coefficient on recycling of pulps again indicates to loss in fiber-fiber bonding. This loss in fiber-fiber bonding is also seen in the results of apparent density, apparent density; decreases on recycling of sarkanda pulps (table- 10 and 11, pp- 17-18).

Figure 8: Change in Freeness on recycling of sarkanda pulps.

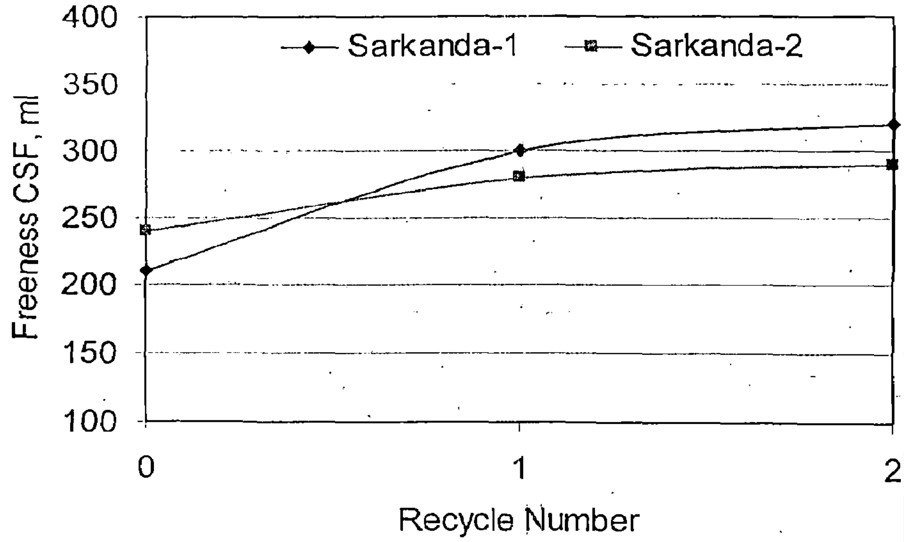


Figure 9: Change in drainage time on recycling of sarkanda pulps.

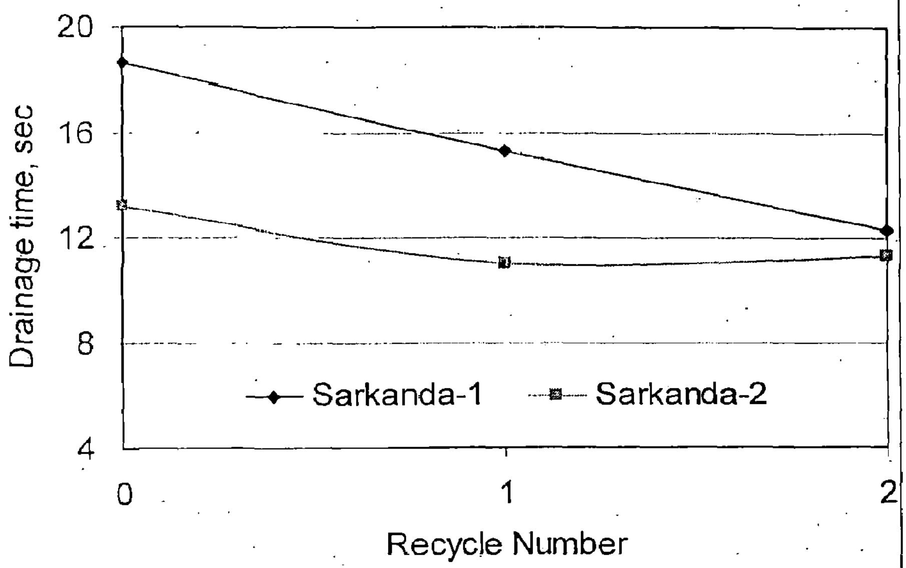


Figure 10: Change in water retention value (WRV) on recycling of sarkanda pulps.

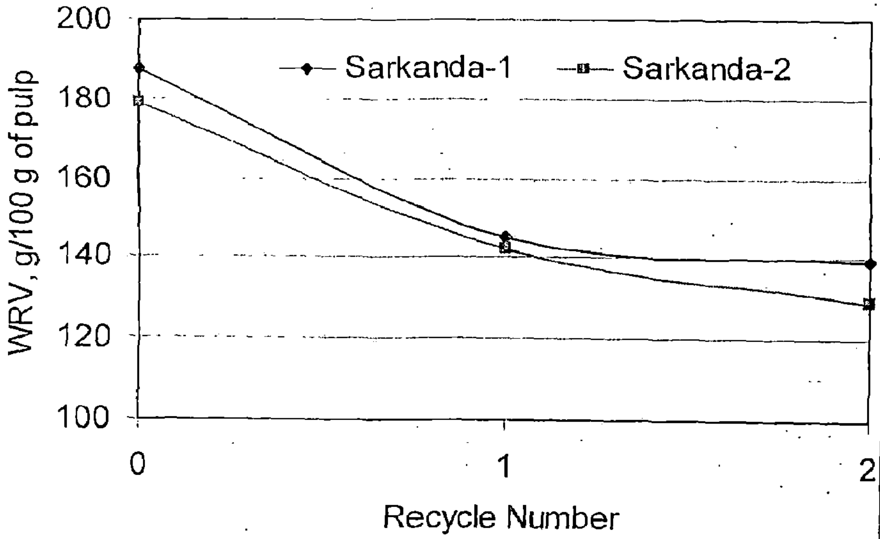


Figure 11: Change in Tensile index on recycling of sarkanda pulps.

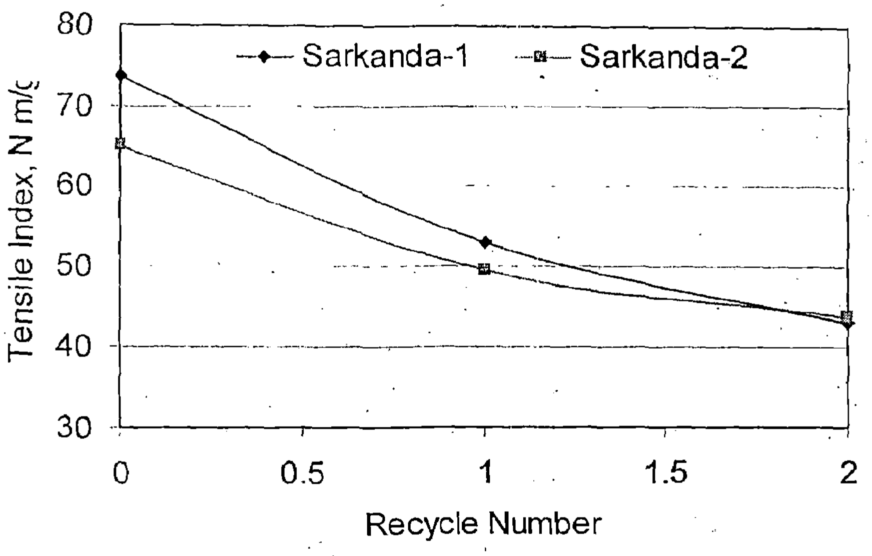


Figure 12: Change in Burst index on recycling of sarkanda pulps.

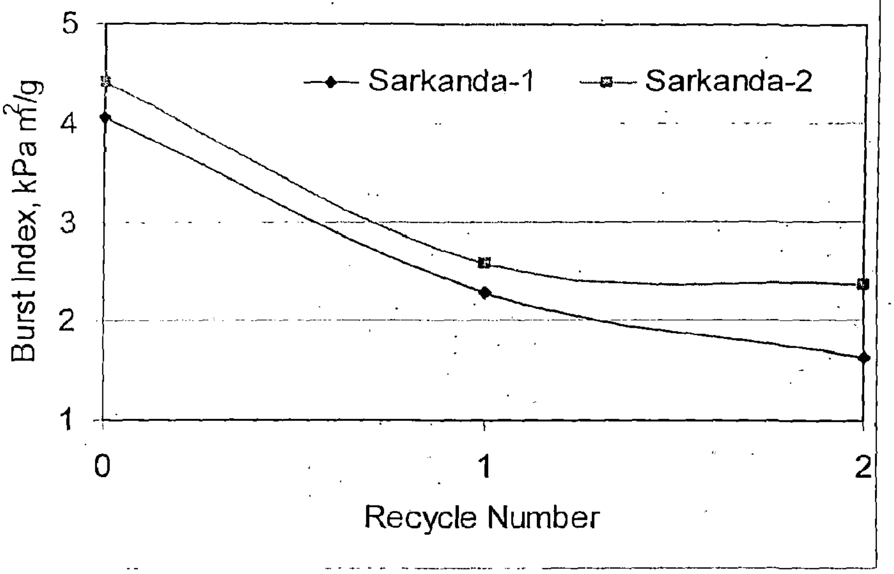


Figure 13: Change in Tear index on recycling of sarkanda pulps.

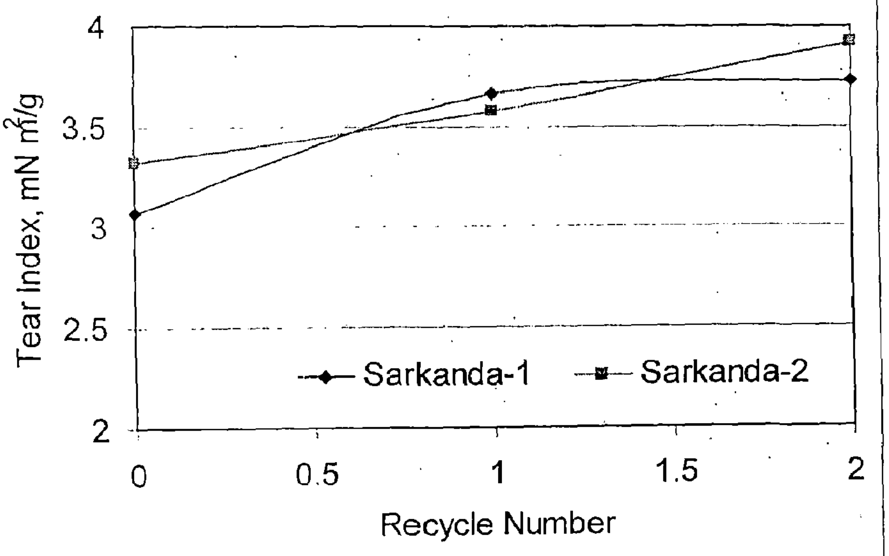
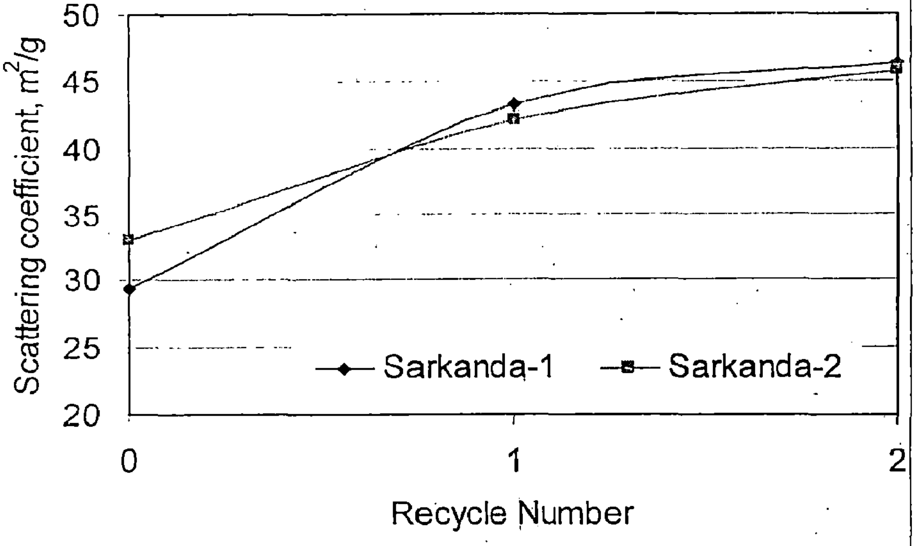


Figure 14: Change in Scattering coefficient on recycling of sarkanda pulps.



4.3 Comparison of recycling potential of pulps

The pulps freeness increases with recycling of sarkanda and softwood pulps (figure 15). Earlier workers have also observed increase in freeness on recycling of softwood pulps (Chapter- 2, pp-5). The freeness remains unchanged on recycling for wheat straw pulps. This may be due to the that fact the fines of wheat straw pulp are not to a great extent on recycling (1,30). The loss in fiber swelling, measured as water retention value (WRV), is found similar for all pulps, as shown in figure 16.

The changes in tensile and burst index on recycling of pulps are shown in figures 17 and 18. The sarkanda and softwood pulps show high loss in these strength values than wheat straw pulps. The tensile index drops by around 30 points after three cycles for sarkanda pulps, whereas for wheat straw pulps this drop is less than 10 points. The wheat straw pulps have higher recycling potential than do the softwood and sarkanda pulps.

The high recycling potential of wheat straw pulp is attributed to the high bonding potential of finer fraction which does no loose their bonding ability even on recycling (1). The high gamma cellulose content in wheat straw pulps is also one of the reasons of high recycling potential of wheat straw pulps (1). It is also to be noted that drop in WRVs of the sarkanda, softwood and wheat straw pulps are in similar proportions but drop in tensile index is greatly varied.

Tear strength to increase with recycling of pulps (Figure 19). Softwood pulps with higher tear strength show high increase than wheat straw and sarkanda pulps.

The scattering coefficient of the pulps increases with recycling. Similarly, the apparent density decreases of all pulps with recycling. This indicates that on recycling of pulps there is a loss in fiber-fiber bonding.

Figure: 15 Change in freeness on recycling of pulps

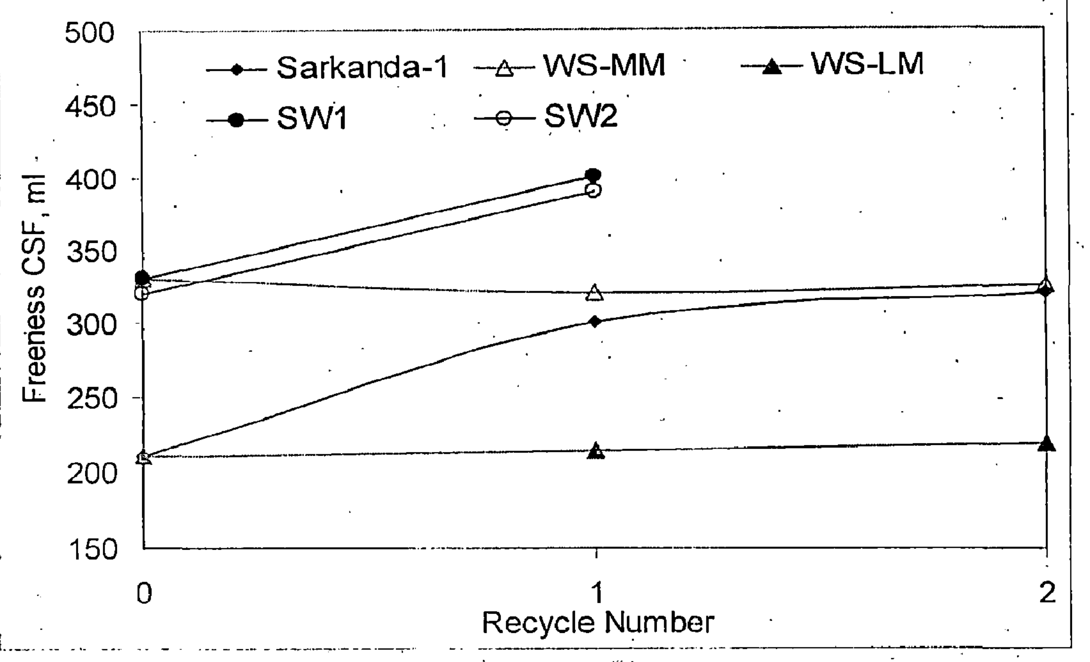


Figure: 16 Change in Water Retention value (WRV) on recycling of pulps

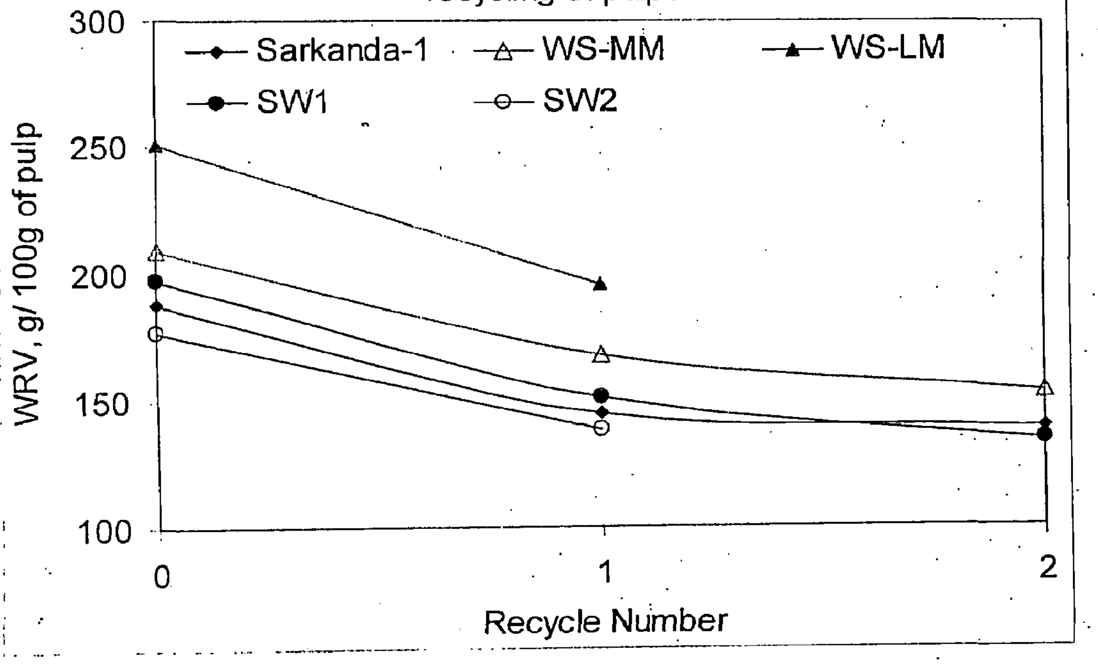


Figure: 17 Change in tensile index on recycling of pulps

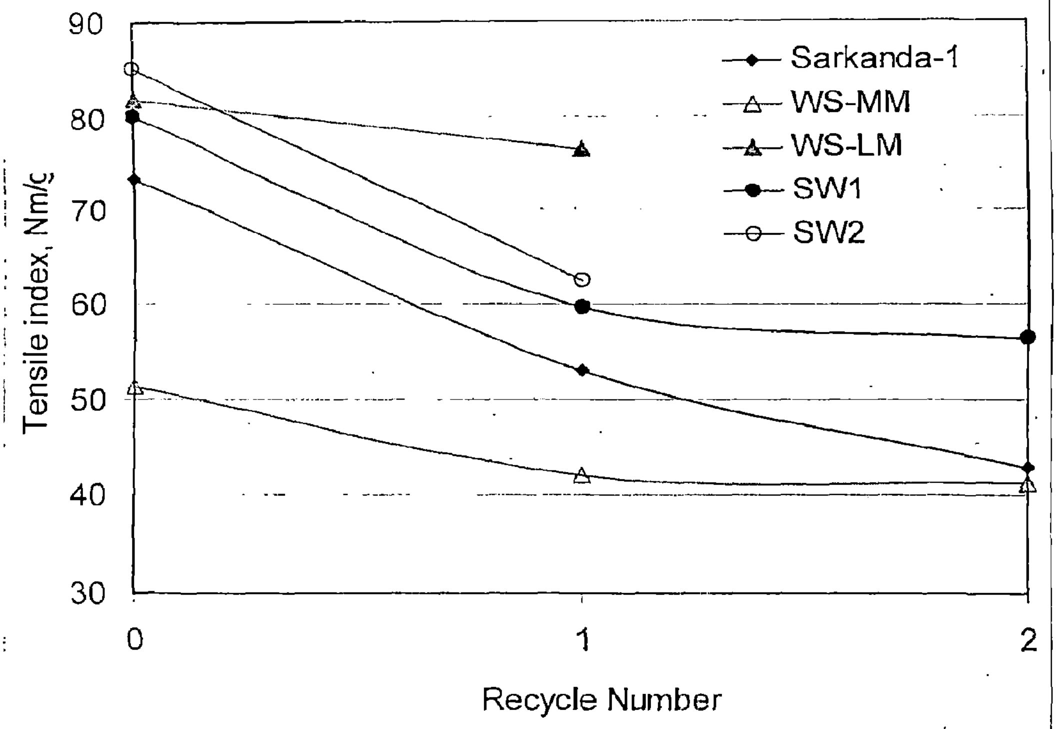


Figure: 18 Change in Burst index on recycling of pulps

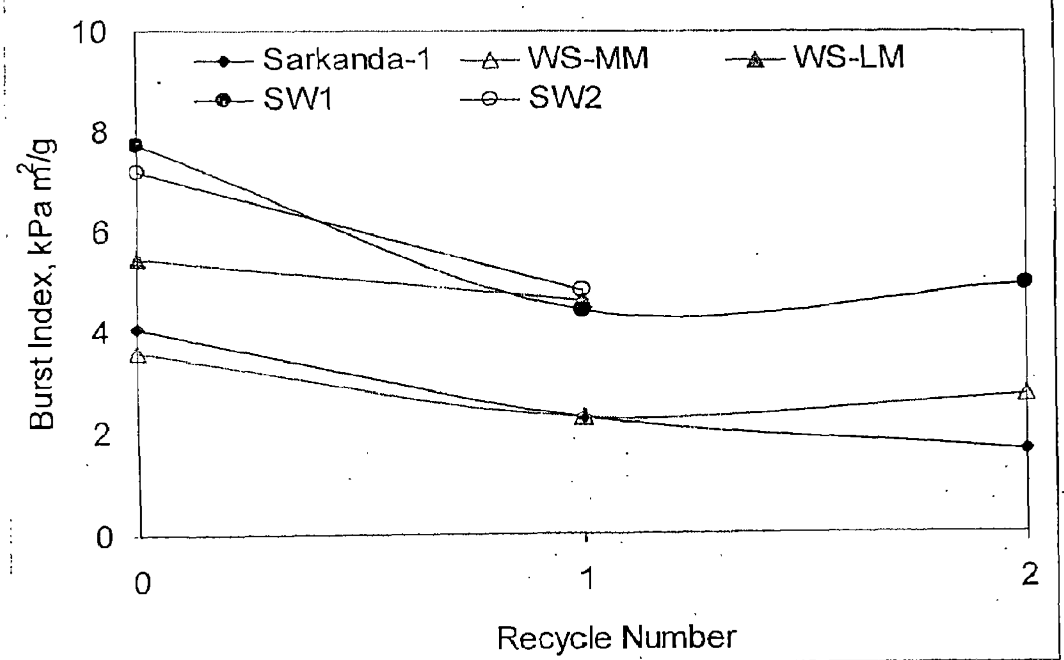
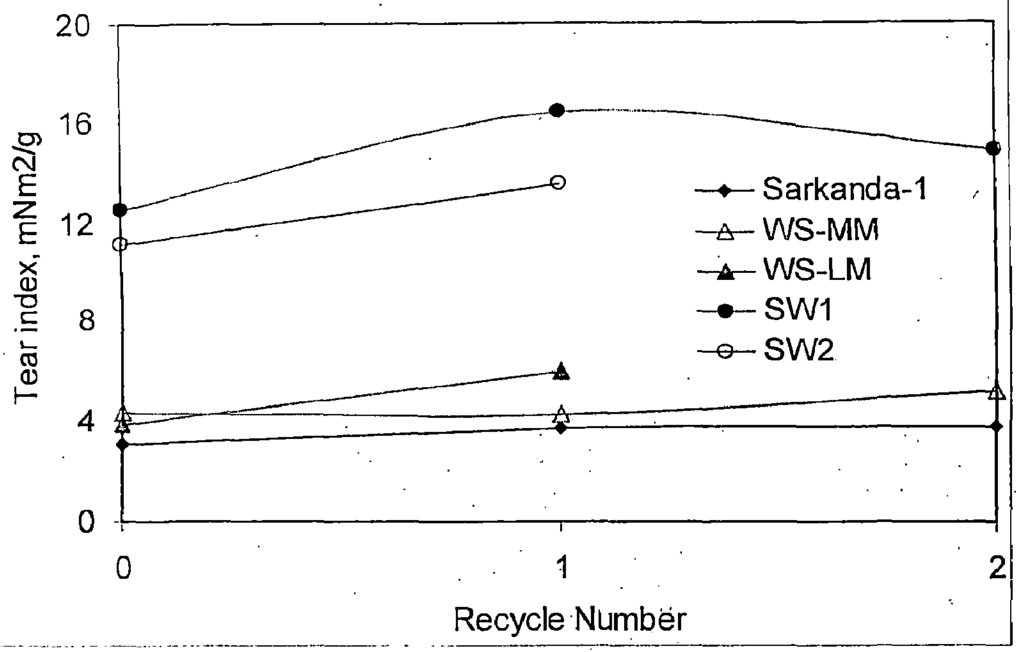


Figure: 19 Change in Tear index on recycling of pulps



4.4 Recycling behaviour of different fractions of sarkanda pulp

Figures 20 and 21 show the effect of recycling on drainage time of two samples of sarkanda pulps and their different fiber fractions. As discussed earlier the drainage time decreases on recycling of whole pulps of sarkanda. Whereas, the change in drainage time of its fractions is marginal on recycling. This again indicates that P200 fraction of sarkanda pulps is responsible for high drainage time.

The R48 and P48R200 and separately retained R200 fraction show similar trend for change in WRV as for whole pulp, as shown in figures 22 and 23.

The loss in tensile index on recycling of R48 fraction is quite loss than for P48R200 fraction and separately retained R200 fraction of sarkanda pulp (figures 24 and 25). This indicates that the loss in tensile index of sarkanda pulp is mainly due to loss of bonding ability of fiber fraction that may pass 48-mesh screen. The reasoning may apply to the observed the loss in burst index, as shown in figures 26 and 27.

Figures 28 and 29 show the effect of recycling on tear index of two samples of sarkanda pulps and of their different fiber fractions. The change in tear index for sarkanda pulps and its fractions is small. Only the R200 fraction of second sample of sarkanda pulp shows high increase in tear index for some unknown reason.

Figure20 Effect of recycling on drainage time of different fiber fractions of first sample of sarkanda pulp.

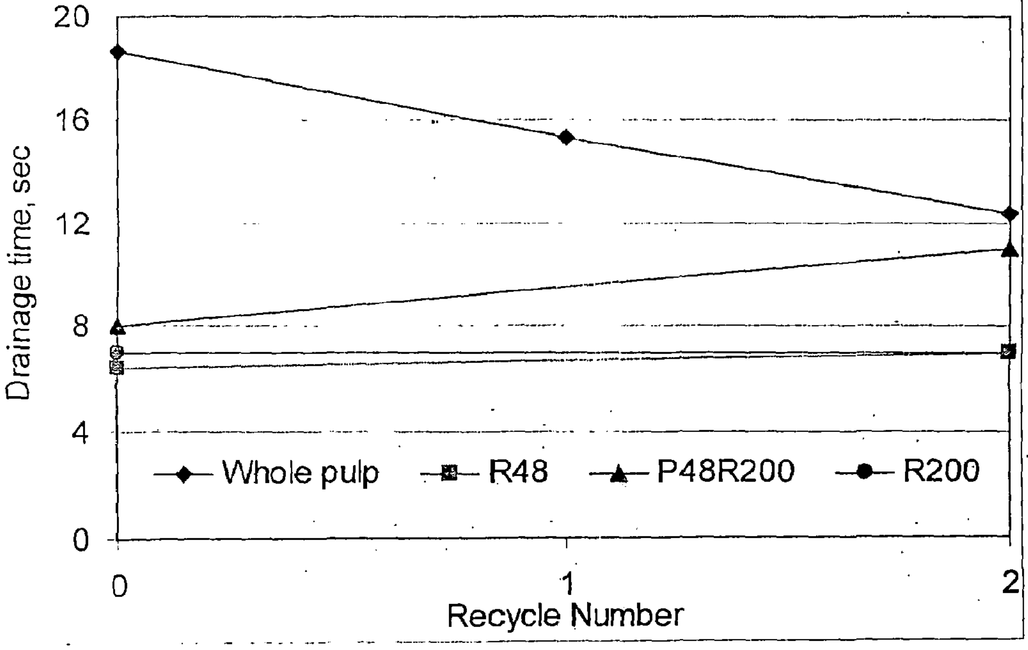


Figure 21 Effect of recycling on drainage time of different fiber fractions of second sample of sarkanda pulp.

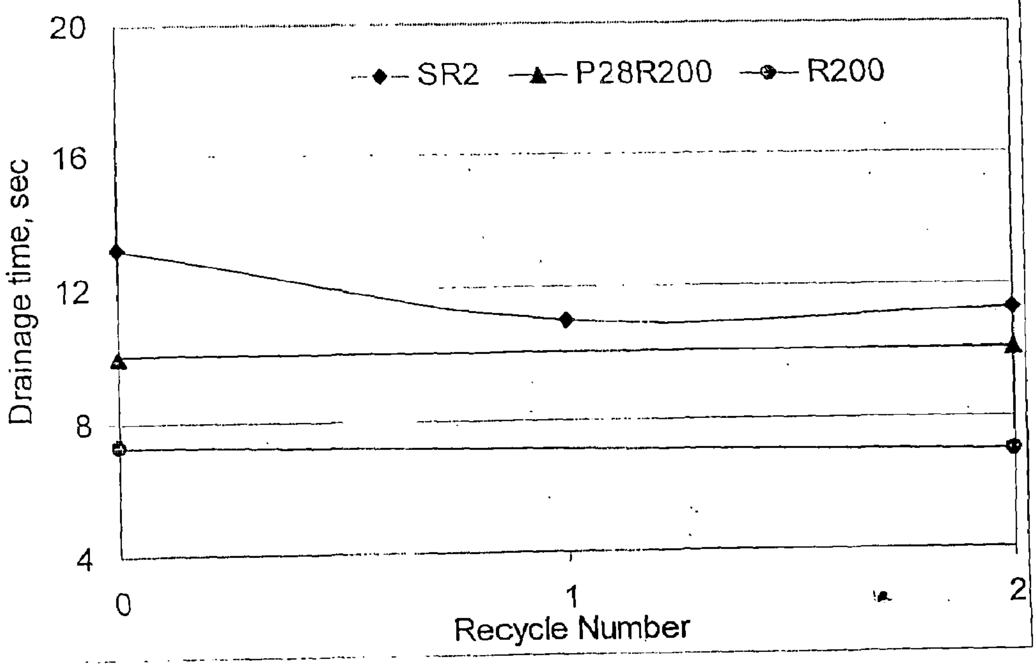


Figure 22 Effect of recycling on water retention value of different fiber fractions of first sample of sarkanda pulp.

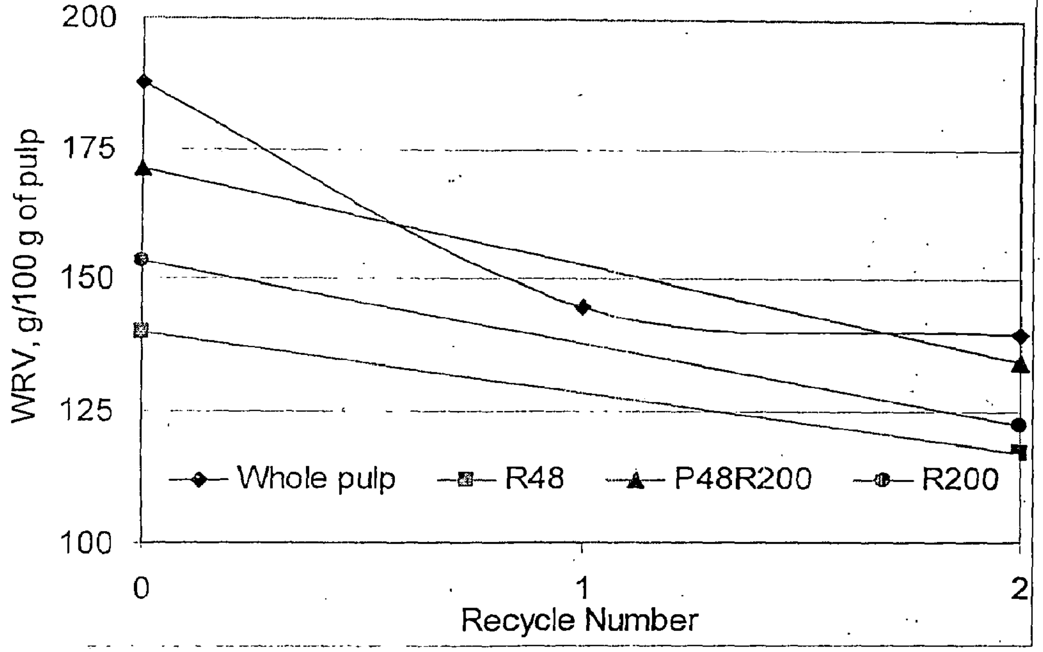


Figure 23 Effect of recycling on water retention value of different fiber fractions of second sample of sarkanda pulp.

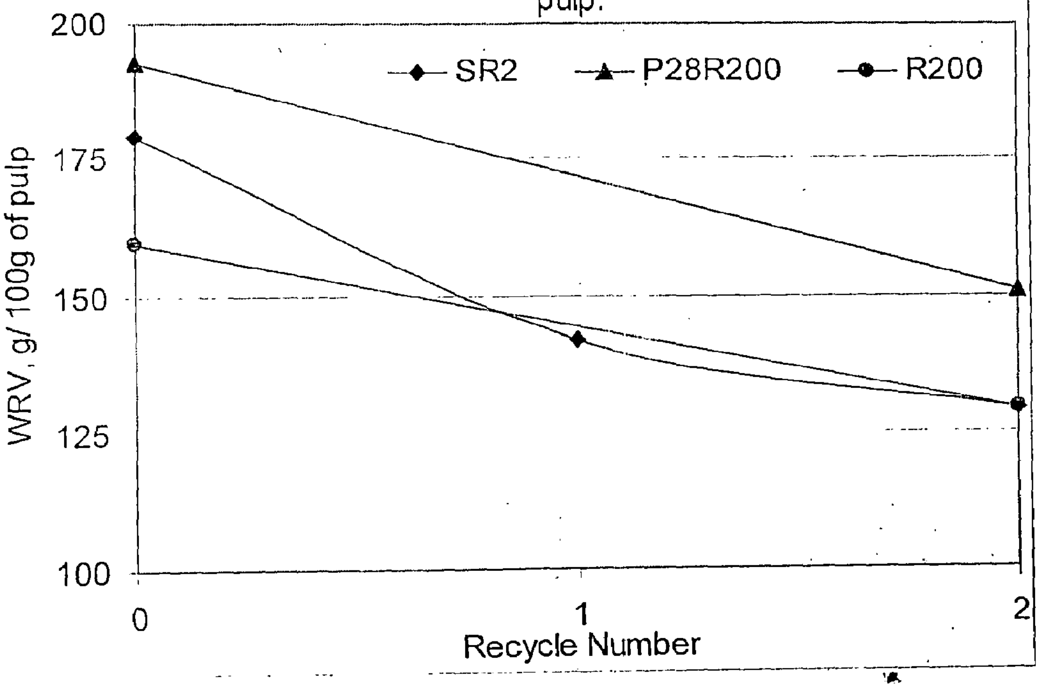


Figure 24 Effect of recycling on tensile index of different fiber fractions of first sample of sarkanda pulp.

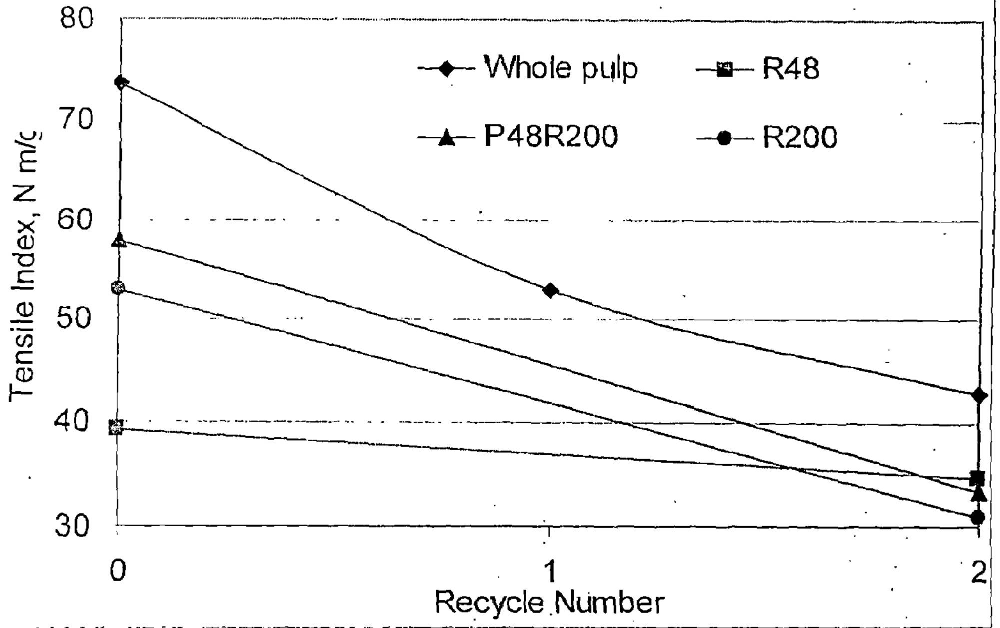


Figure 25 Effect of recycling on tensile index of different fiber fractions of second sample of sarkanda pulp.

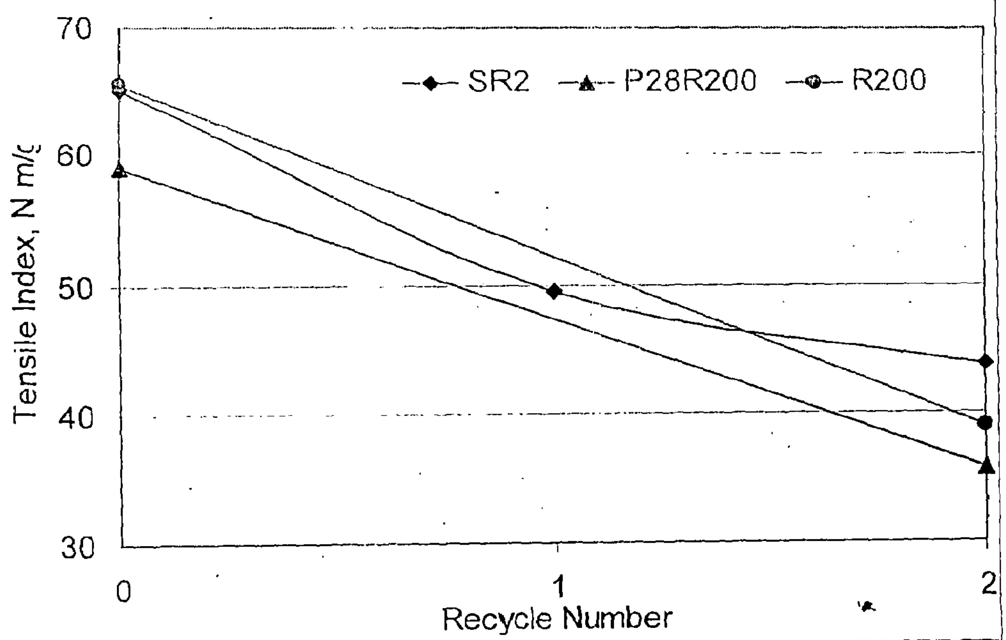


Figure 26 Effect of recycling on burst index of different fiber fractions of first sample of sarkanda pulp.

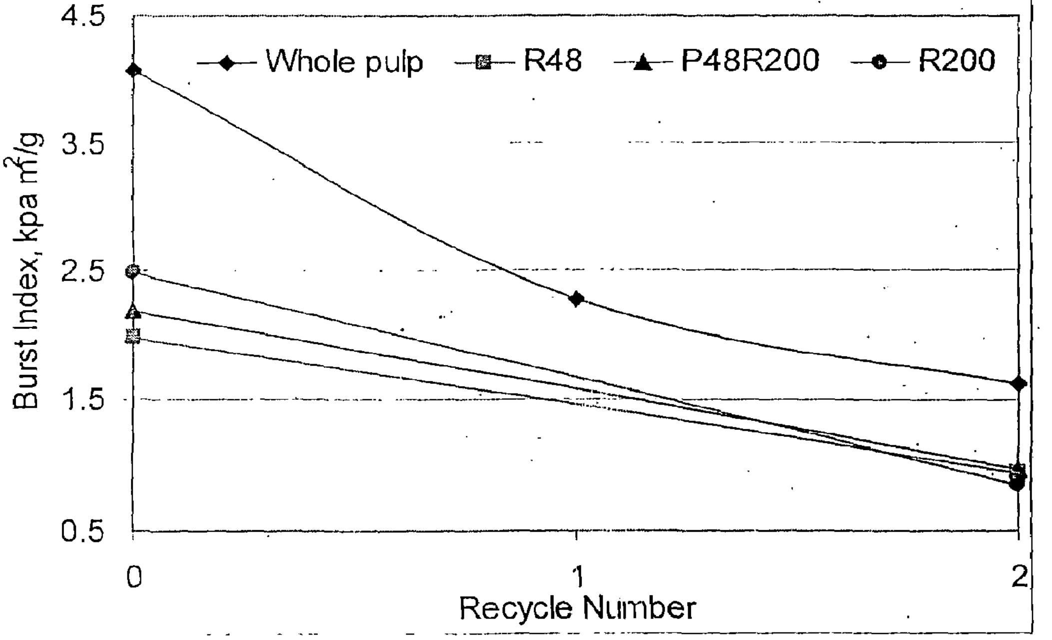


Figure 27 Effect of recycling on burst index of different fiber fractions of second sample of sarkanda pulp.

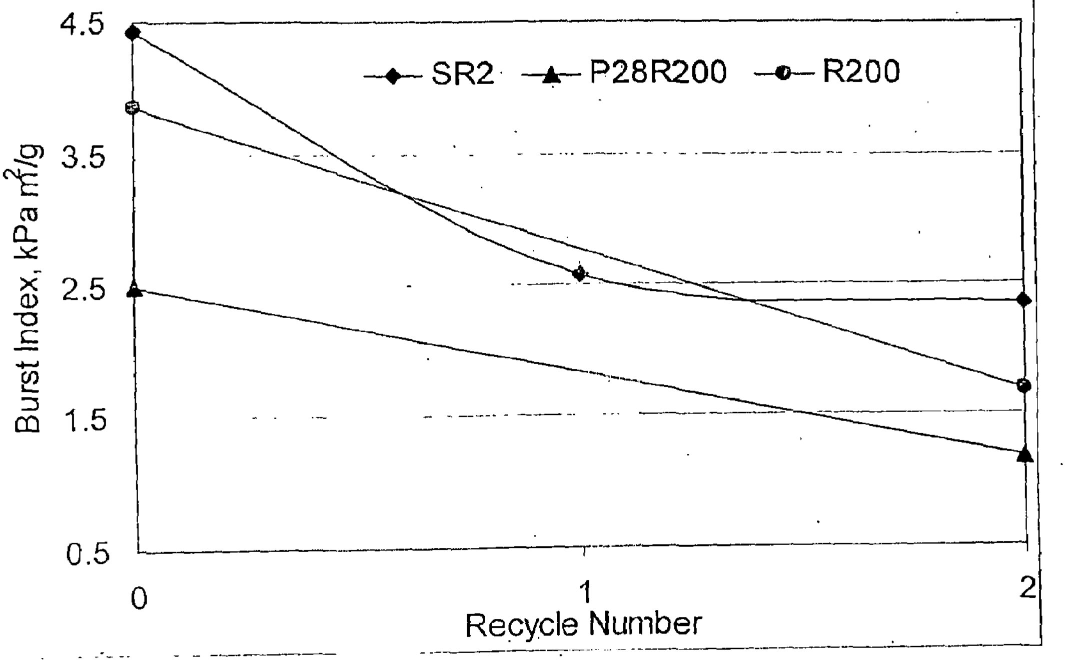


Figure 28 Effect of recycling on tear index of different fiber fractions of first sample of sarkanda pulp.

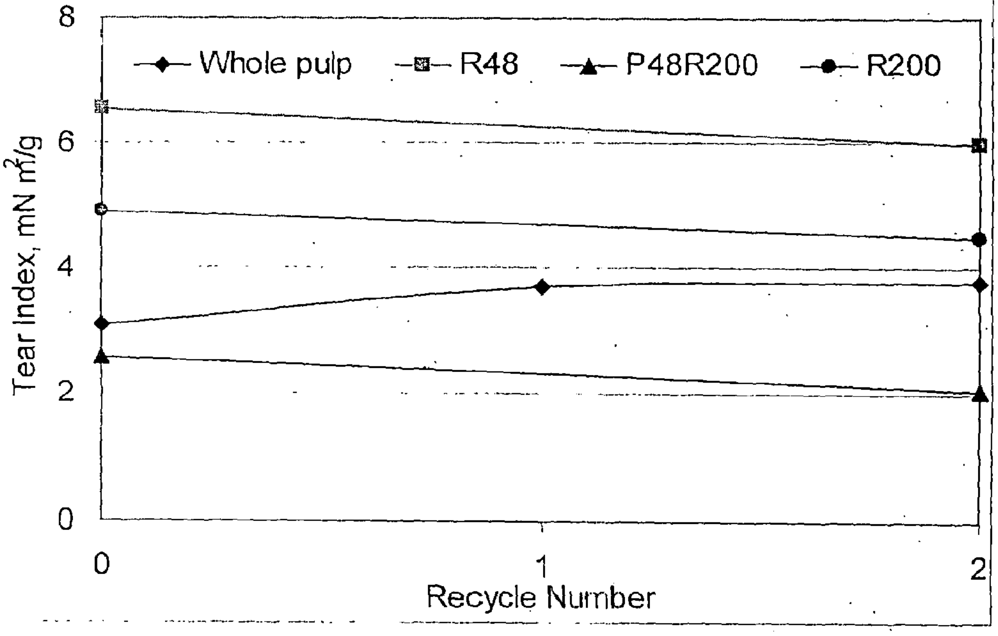
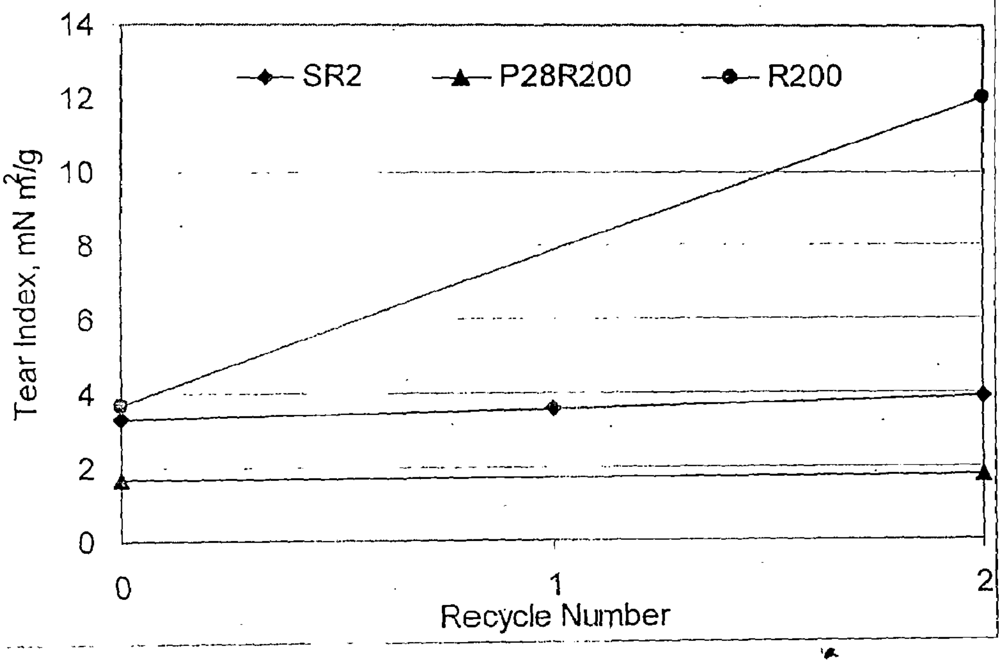


Figure 29 Effect of recycling on tear index of different fiber fractions of second sample of sarkanda pulp.



Chapter
FIVE

Conclusion

CONCLUSIONS

1. The sarkanda pulps are similar in initial strength levels to the wheat straw pulps except that the number of double folds of the sarkanda pulp is very low. The value lies between 1 to 10 for both the sarkanda pulps studied.

2. The R48 fraction (fraction retained on 48-mesh screen) of sarkanda pulp has lower tensile and burst index than the P48R200 fraction (fraction passing 48-mesh screen and retained on 200-mesh screen) and whole pulp. This indicates to high bonding potential of P48R200 fraction of sarkanda pulp. The fines (P200) that are lost during the fractionation process seem to contribute to strength properties of the sarkanda pulp also.

3. The P200 fraction in sarkanda pulp is responsible for high pulp drainage time.

4. The Bauer-McNett classification results of the two pulp samples of sarkanda pulp indicate that the fiber classification of the pulps is not affected by the process of recycling. Recycling has no major impact on the fiber length of sarkanda pulps.

5. Recycling causes loss in tensile and burst strength of sarkanda pulps in a manner similar to softwood pulp. Tear index increases on recycling of sarkanda pulps. The rise in tear index and loss in tensile index and burst is attributed to loss in bonding between the fibers.

6. The wheat straw pulps have higher recycling potential than do the softwood and sarkanda pulps.

7. The loss in tensile and burst index on recycling of R48 fraction of sarkanda pulpis quite less than the loss for P48R200 fraction and separately retained R200

fraction. This indicates that the loss in tensile index of sarkanda pulp is mainly due to loss of bonding ability of fiber fraction that pass 48-mesh screen.

8. The loss in fiber swelling in terms WRV not necessarily means the loss in tensile strength on recycling. The sarkanda, softwood and wheat straw pulps show similar level of drop in WRV on recycling but the loss in tensile strength is greatly varied.

Chapter
SIX

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