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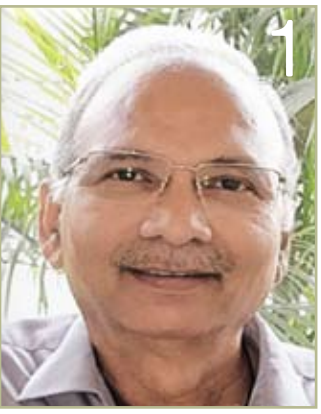
Kolhu's Bagasse: A new resource of agro based raw material for writing & printing grade paper

Abstract: *Demand of paper and paperboard is growing persistently, whereas the concerned raw material resources are not sufficient to fulfill the requirement. The world demand for paper and paperboard estimated to reach 490 million tons by the year 2020, which is an average growth rate of 2.8% per annum. Non-wood based paper mills contributing over 70% of total production in India, manufacture Eco friendly paper from Agro residues.*

BPML started to search the new resource in order to reduce gap of raw material to produce Pulp & Paper. A new raw material was found which is a residue of small Kolhu's crushers. This material is available near to the Mill and burnt for disposal, which was creating pollution to the environment.

The small Kolhu's crushers that make Jaggery from sugarcane produce residue crushed Bagasse as waste and it is received as raw material in the mill. BPML is pioneer in developing crushed Kolhu's Bagasse as a new raw material for making writing & printing grades paper. Mill has developed efficient techniques for converting Kolhu's Bagasse into suitable raw martial for pulping by efficiently removing left out sugar juice and cutting into desired size in installed crushing & cutting plant. During developing the crushing process, it was found that POL was reduced whereas PI increased; with reduction in moisture content resulting in increase of loose pith percentage. Also after crushing it was stored for four weeks in yard to loosen pith by photo-synthesis process for efficient dry & wet depithing and removal of pith before processing for pulping.

BPML has been continuously utilizing this as raw material since last 8 years and thus preventing the air pollution caused by the burning of Kolhu's Bagasse.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Key Words: *Kolhu: Country side Jaggery producing unit Kolhu's Bagasse, Crushed Kolhu's Bagasse, Mill Bagasse, POL (Polarization), PI (Preparatory Index)*

1. Vimal Kishore
Director
PE INDIA

2. Praveen Goel
Senior General Manager
BPML

Introduction

The supplies of fibrous raw material for pulp and paper making is not sufficient to match the growth in demand of paper and paperboard. Traditionally, pulp and paper industry is largely reliant on the native hardwood resources. The forest or hardwood resources would support the global pulp demand. However, the

increasing demand for fiber made the industry to look out at different fiber options for raw material.

Bagasse is fibrous matter that remains after the sugarcane stalks are crushed to extract their juice. A typical chemical analysis of washed and dried Bagasse shown (Refer table-1)

Table-1. Chemical Analysis of washed & dried Bagasse

Cellulose	45 - 55 %
Hemicellulose	20 - 25 %
Lignin	18 - 24 %
Ash	1 - 4 %
Pectine	0.6 - 0.8 %

Sugarcane production In India is on second position in the world after Brazil, cultivated in an area of over 48300 Km2, with an annual production of over 341 million tons of sugarcane (FAO, 2015). Uttar Pradesh is the leading sugarcane producing state in the India estimated to have current plantation area at 23400 Km^2 (DES, Ministry of Agriculture GOI 2017-2018). Out of this, 50% processed into white sugar, 40% into Jaggery and Khandsari, 3% for chewing as cane juice, and 7% as seed cane (Singh et.al.2011).

Bagasse fiber have 1.0-1.5mm length and 20-micron diameter that is similar fiber size to hardwoods like eucalyptus of 0.7-1.3mm by 20-30 micron. So Bagasse pulp can used to make paper in place of hard wood pulp.

Bagasse features require different treatment compared to general processing of wood chips.

- Storage of Bagasse for longer periods leads it to biological action that can rapidly lead the material to severe color degradation, yield loss and degradation of fiber properties. So, special methods of storage equipment and techniques are required to make the processed and non-processed Bagasse available during the non-season. In order to decrease the disadvantage of seasonal nature and maintain a constant production a large storage capacity must be developed. Challenge still lies in managing the storage of Bagasse because of its high in volume and low in density when compared with wood. The circumstances that need to be carefully controlled vary from individual storage and receiving site.
- in Bagasse 30% to 35% are Pith cells which are fine, thin walled, low cellulose content cells and do not produce paper making fiber. Pith cells consume large quantities of chemicals, results in a poor draining pulp.
- Silica in Bagasse is low relative to many other non-wood fiber sources typically at 0.5%. however it is twenty times higher than eucalyptus and it should be controlled while depithing to preserve the life span of refining disks.
- In Chemical recovery of Bagasse, silica is a major issue. Commercially, Bagasse is used to produce chemical, semi-chemical and several other types of mechanical pulp.

BPML (Bindals Papers Mill limited) was established in 2009 for manufacture writing, printing paper with a capacity of 70,000 TPA. BPML enhanced its production to 110,000 TPA by up gradation of machine. BPML is major consumer of Bagasse, wheat straw & wood as a raw material to manufacture paper. Pulp demand is meet by Agro pulp and wood pulp.

There is one continuous digester for cooking Agro raw material of 200 TPD pulp capacity. In raw material, a major part is agriculture residue; wood is use only 0-35 %. The ratio of Bagasse & wheat straw depends on availability of raw material.

Bagasse is receive in BPML from small Kolhu's crushers. Kolhu's Bagasse is a waste material of Jaggery production by small crusher from sugarcane. There are 850 small crusher around the BPML, hence this raw material is easily available. Some of Kraft paper units were using Kolhu's Bagasse but not writing & printing grade paper units. BPML is first company, started using Kolhu's Bagasse as raw material to produce writing & printing grade paper.

As Kolhu's Bagasse is residue of by small Jaggery producing unit, which is equipped with two stage crushing system. Kolhu's Bagasse coming from Kolhu's crushers is not feasible to be used directly for making writing & printing paper due to following characters of it:

1. It has high moisture approximately 58 -62 %.
2. High sugar content in Kolhu's Bagasse in comparison to sugar mill Bagasse
3. In Kolhu's Bagasse, fiber & pith are not separately sufficiently, so depithing is not possible.
4. Kolhu's Bagasse is in form of big bundles. The size of fiber & pith bundle of as such Kolhu's Bagasse is 50 mm to 250 mm.

Initially we tried to remove pith from Kolhu's Bagasse using Depithers but pith separation was very poor hence BPML developed a system to improve depithing efficiency by installing a system. Analysis of Kolhu's Bagasse and Mill Bagasse is in Table 2. The target was to reduce moisture, increase loose pith %, increase bagasse PI & reduction POL in Kolhu bagasse, which result in efficient depithing.

Table -2 : Analysis of Bagasse

	Kolhu's crusher Bagasse	Sugar Mill Bagasse
Fiber %	47-53	62-68
Bonded Pith %	24-26	2-3
Loose Pith %	8-9	30-32
Soluble %	15-18	2-6
Characteristics		
	Kolhu's crusher Bagasse	**Sugar Mill Bagasse**
Bagasse POL	4-5	1.3-1.5
PI	55-60	65-70
Moisture %	58-62	49-50

Materials & Methods

Kolhu's Bagasse is collected from local Jaggery producing Kolhu units. Kolhu Bagasse has 24-26% physically bonded pith with fiber with high moisture making separation unfeasible by Depithers. (Moisture in Kolhu's Bagasse samples were determined by TAPPI test method i.e. TAPPI/ANSI T 412 om-16.)

Polarization (POL):	The apparent sucrose content expressed as a mass percentage by measuring the optical rotation of polarized light passing through a sugar solution.
Preparation Index (PI):	The Preparation Index (PI) is the ratio of Brix in the ruptured cells to total Brix in cane expressed as a percentage. PI is an empirical method and uses the ratio of the Brixes obtained using two different cane preparation methods.

Preparation of Kolhu's Bagasse for Depithing:

Bindals papers mills developed and installed the crushing plant for efficient pith removal from Kolhu's Bagasse. Crushing of Kolhu's Bagasse is a continuous process which takes place by as following. (Figure-1, 2).

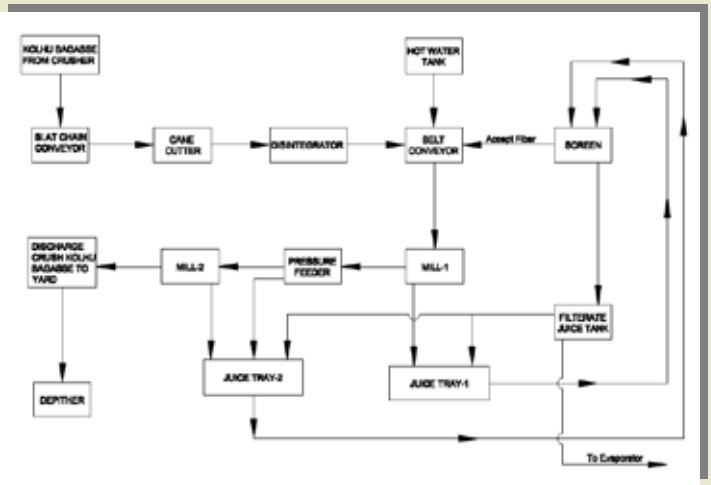

Figure-1: Block diagram of Kolhu Bagasse Crushing

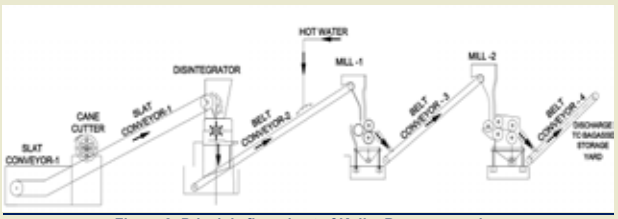

Figure-2: Principle flow sheet of Kolhu Bagasse crusher

1	Cutting of Kolhu's Bagasse	Kolhu's Bagasse is fed to slat chain conveyor hopper by tractors pushers. Kolhu's Bagasse feeding rate is controlled by Variable Frequency Drive (VFD) of slat chain conveyor. A set of knives (Cane cutter) are installed over the slate chain conveyor. Kolhu's Bagasse is passed through this cane cutter so that Kolhu's Bagasse bundles (Fiber & Pith) size is reduced by cutting action. Kolhu's Bagasse fiber bundle (size 50-250mm) cut into smaller pieces (of size 25-75mm).
2	Disintegration of Kolhu's Bagasse	After cutting of Kolhu's Bagasse, it is passed through Dis-integrator. Dis-integrator is equipped with hammers. Here beating of Kolhu's Bagasse takes place by hammer and fibrillation of both fiber & pith takes place. Kolhu's Bagasse disintegration process results maximum pith separation in Depithers
3	First Stage milling/Crushing	Hot water having temperature of 80^0C to 85^0C is sprayed on disintegrated Kolhu's Bagasse and after it, Kolhu's Bagasse is passed through a mill having rolls with hydraulic load (1.50KN/m2). During this process, following actions takes place: i. Juice is extracted from Bagasse ii. Physical bonding between fibers to pith becomes weak.
4	Second Stage milling/Crushing	Post first stage Kolhu's Bagasse is further passed through a mill having five rolls. Two rolls (Pressure roll) helps to push the Bagasse into Mill rolls to extract more juice & further reduction of Physical bonding between fibers to pith takes place. Rolls of Mill are under hydraulic load which can be adjusted by as per requirement. After 2nd stage crushing of Kolhu's Bagasse, it is discharged to yard where it is stored just like mill Bagasse and sent to Depithers house for Depithing. Now crushed Kolhu's Bagasse pith can be separated in Depithers more efficiently. By comparison (Table - 3) we analyzed that crushed Kolhu Bagasse is ready for Depithing and cleaning to produce Pulp.
5	Storage	After crushing bagasse is stored for four weeks in yard for loosening of pith by photo-synthesis process for efficient dry & wet depithing for removal of pith before processing for pulping.

Table-3 : Kolhu's Bagasse vs. Sugar Mill Bagasse

Day	Kolhu's Bagasse as such				Crushed Kolhu's Bagasse				Sugar Mill Bagasse			
	Moisture %	Bagasse POL	PI	pH of effluent	Moisture %	Bagasse POL	PI	pH of effluent	Moisture %	Bagasse POL	PI	pH of effluent
1	60.0	4.5	61.2	4.2	54.8	1.6	72.1	5.2	52.1	1.3	65.2	5.9
2	56.3	5.4	53.7	5.1	56.2	2.1	70.5	4.6	51.2	1.5	62.6	4.8
3	57.0	3.5	58.1	4.9	55.1	1.2	66.5	4.6	50.5	1.5	65.2	5.1
4	54.0	4.8	59.3	4.5	54.2	1.5	64.5	4.8	51.0	1.7	63.5	5.3
5	60.0	5.2	58.5	4.6	54.5	1.4	68.2	4.6	49.0	1.4	64.2	4.8
6	55.2	3.8	55.5	4.3	56.2	1.6	67.5	5.1	51.5	1.5	66.2	4.7
7	61.8	5.1	60.2	5.1	54.2	1.4	70.2	4.8	50.2	1.8	68.5	5.2
8	60.5	4.2	58.8	4.5	53.2	1.6	69.2	4.9	51.0	1.4	65.5	5.4
9	59.2	3.5	54.4	4.8	55.0	1.8	68.5	5.1	49.2	1.4	66.2	5.3
10	61.5	5.2	56.2	4.2	54.5	1.5	70.2	4.8	50.2	1.6	65.8	5.2
Avg.	**58.6**	**4.5**	**57.6**	**4.6**	**54.8**	**1.6**	**68.7**	**4.9**	**50.6**	**1.5**	**65.3**	**5.2**

Pulping

1. Bagasse Handling and Cleaning

To produce Pulp from stored Bagasse it requires Depithing and Cleaning. Bagasse from yard is fed to Depithers to remove Pith. Separated pith is sent to Powerhouse for burning and Accept fiber is sent to Screw Pulper where it is diluted with back water, at the same time heavy stones and material settle down. Slurry of Bagasse is taken to Aqua separator, where water is filtered and cleaned Bagasse is fed to Continuous digester to Produce Pulp. Filtered water from Aqua separator is passed through Sand, pith filters, Conical tank, Sand Riffler and Clarifier, and clean water is recycled. Sand and removed sludge is sent to Board Plants. (Refer Figure-3)

When we compared pith, moisture of crushed Kolhu's Bagasse & Mill Bagasse after wet washing, we found that pith & moisture are approximately same (Refer Table-4, 5)

After wet washing of crushed Kolhu's Bagasse pulping is done as per conventional method same as Mill Bagasse.

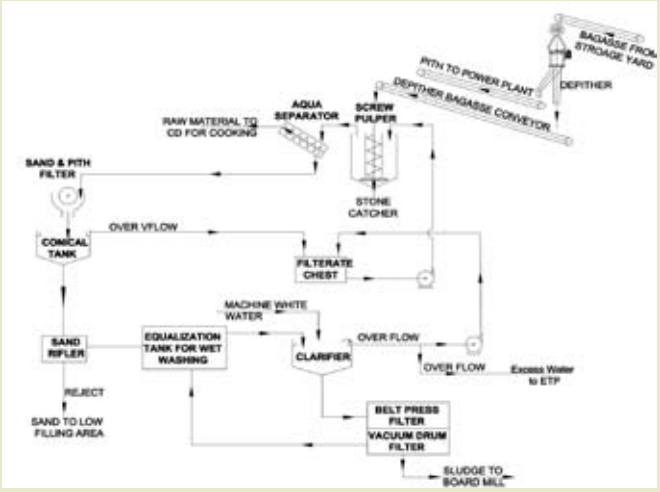

Figure-3: Principle flow sheet of Bagasse handling & cleaning system

Kolhu Bagasse | Kolhu Crushed Bagasse | Mill Bagasse

2. Continuous Digester (Cooking)

Cooking of crushed Kolhu Bagasse is done in continuous digester. BPML has continuous cooking digester with two tubes. It is established fact that continuous digester is more advantageous in comparison to batch digester. Advantages in Continuous digester are less medium pressure (MP) steam consumption, less chemical consumption, consistent cooking (kappa no is consistent). (Refer to Figure-4) Cooking of crushed Kolhu Bagasse conditions in continuous digester are same as Mill Bagasse cooking for Caustic consumption, MP steam consumption, cooking times. Kappa numbers of Pulp produced after cooking are also same as of Mill Bagasse (Refer Table-6).

Cooking condition of bagasse in continuous digester

●Digester tube temperature -165^{0}C ●Cooking time - 20 minute ●Caustic - 16 % (as NaOH) on BD Bagasse

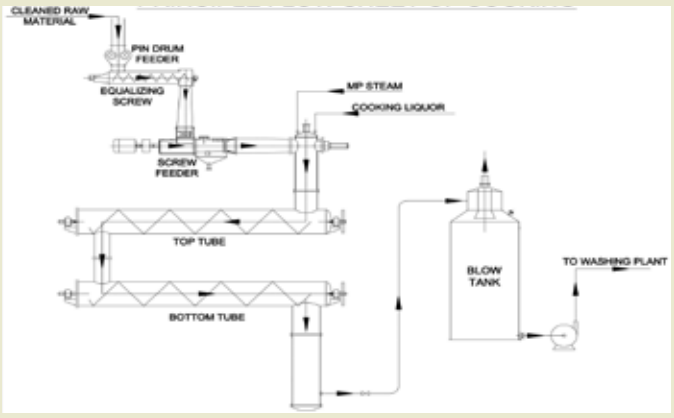

Figure-4: Principle flow sheet of Cooking

3. Washing & screening plant

Crush Kolhu's Bagasse pulp is screened through knotters, where uncooked material is separated. The uncooked material is recycled in digester. After

Table -4 : Mill Bagasse Moisture & Pith Percentage at Different stages

Day	Mill Bagasse as such		Depithed Mill Bagasse		Pith		Mill Bagasse After Wet Washing	
	Moisture %	Pith %	Moisture %	Pith %	Moisture %	Pith %	Moisture %	Pith %
1	50.1	32.30	52.25	9.5	50.30	70.0	78.40	8.10
2	51.28	31.20	49.35	9.8	51.10	70.65	77.10	8.80
3	50.53	33.10	52.32	9.10	49.25	68.30	78.95	8.65
4	51.0	32.10	50.40	10.20	50.1	69.10	79.10	8.20
5	49.35	31.45	51.10	11.10	51.28	68.85	77.25	8.45
6	51.10	32.10	49.25	10.30	49.25	69.50	78.20	8.30
7	50.40	31.75	50.1	9.85	50.35	70.20	78.80	9.15
8	51.10	32.65	51.28	10.15	52.10	70.55	77.45	9.18
9	49.25	32.20	50.53	9.20	50.18	71.20	77.95	8.25
10	50.35	33.00	51.0	9.45	51.28	68.90	77.10	8.45
Avg.	**50.45**	**32.19**	**50.76**	**9.87**	**50.51**	**69.72**	**78.03**	**8.55**

Table -5 : Kolhu's Bagasse Moisture & Pith Percentage at Different stages

Day	Kolhu Bagasse as such		Crushed Kolhu Bagasse		Depithed Crushed Kolhu Bagasse		Pith		Crushed Kolhu Bagasse After Wet Washing	
	Moisture %	Loose Pith %	Moisture %	Loose Pith %	Moisture %	Pith %	Moisture %	Pith %	Moisture %	Pith %
1	58.2	8.7	55.2	18.5	54.4	9.8	55.8	49.8	79.1	8.4
2	61.8	9.1	55.2	19.5	54.3	10.0	58.4	48.4	76.1	8.9
3	56.2	8.5	54.7	19.2	55.8	9.8	52.8	50.4	75.1	8.4
4	55.2	9.6	55.2	20.1	52.8	9.8	54.4	42.5	79.1	8.8
5	60.0	9.5	54.8	20.6	51.4	9.1	54.3	45.7	76.6	8.4
6	56.0	10.2	53.8	18.5	53.4	9.2	55.4	48.9	75.4	8.5
7	58.2	9.5	54.6	19.5	53.7	9.5	55.2	48.5	76.7	9.0
8	56.0	9.2	53.8	19.4	53.2	9.7	54.3	45.7	77.2	8.1
9	56.5	10.2	53.6	19.8	54.5	9.5	54.9	46.8	76.5	8.4
10	57.0	8.6	54.4	19.8	54.4	9.3	54.8	47.2	78.5	8.3
Average	**57.5**	**9.3**	**54.5**	**19.5**	**53.8**	**9.6**	**55.0**	**47.4**	**77.0**	**8.5**

knotters, screen accept pulp is washed in four stage counter current brown stock washer. For washing only foul condensate from Evaporators is used (Refer Figure-5). After washing, pulp is screened. Screening plants consists of HD cleaner, pressure screens and Centricleaners. All screening system is closed. Centricleaners reject is sent to Board plant (Refer Figure- 6).

4. Bleaching

Bleaching of crush Kolhu Bagasse unbleached pulp is done with same bleaching sequence (as in Mill Bagasse pulp) having same conditions (Refer table-7). BPML is adopted art of technology for Bleaching of Pulp (ECF). Bleaching sequence is Do -Ox -D1 (Refer Figure-7). Ox is Oxidative chemical stage; this is replacement of hydrogen per oxide. BPML introduced this oxidative Bleaching Technology in 2015. This sequence of bleaching is successfully running

Table-6 : Comparison of Unbleach Pulp after Cooking (Crush Kolhu Bagasse Unbleach Pulp vs Mill Bagasse Unbleach Pulp)

	Crushed Kolhu Bagasse unbleached Pulp		Mill Bagasse unbleached Pulp	
	Kappa number	Residual active alkali(RAA) as NaOH gpl	Kappa number	Residual active alkali(RAA) as NaOH gpl
1	12.50	8.50	12.20	9.00
2	12.20	8.50	12.20	8.50
3	12.70	9.00	12.50	9.00
4	12.80	8.50	12.80	8.50
5	12.40	9.00	12.60	8.50
6	12.20	8.50	12.60	8.50
7	12.70	9.00	12.60	8.50
8	12.80	8.50	12.80	8.00
9	12.70	9.00	12.70	8.00
10	12.20	8.50	12.60	8.50
Average	**12.5**	**8.7**	**12.6**	**8.5**

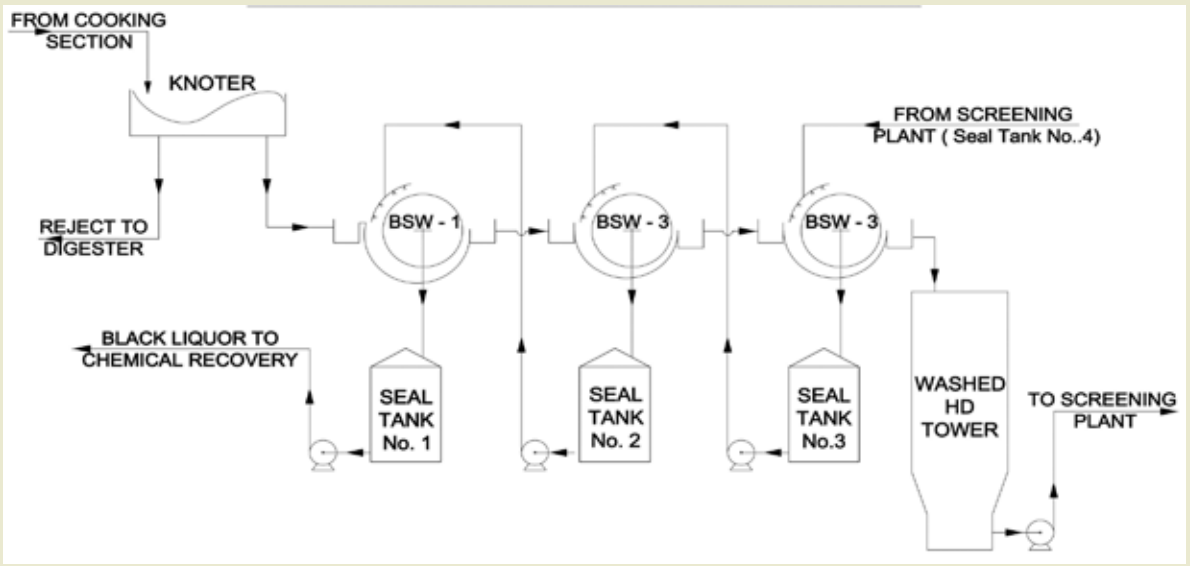

Figure-5: Principle flow sheet of pulp washing

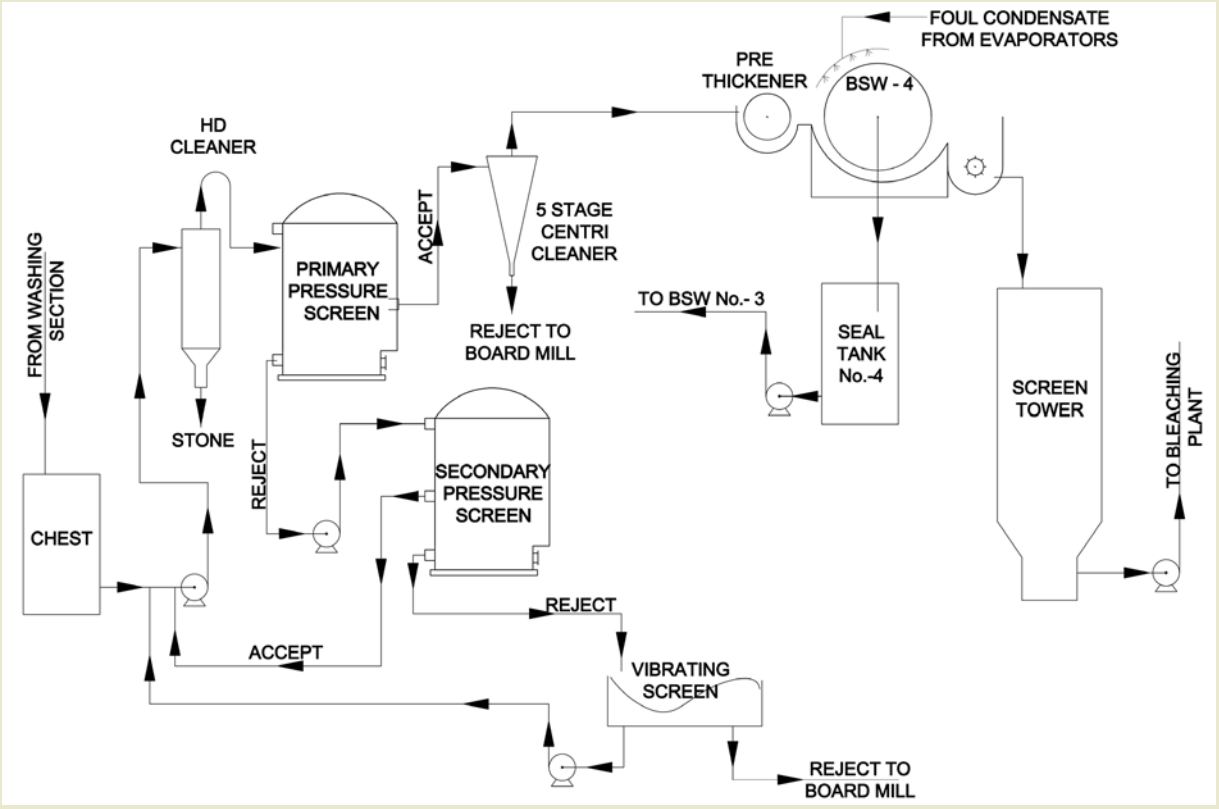

Figure-6: Principle flow sheet of screening plant

to bleach pulp with many advantages. Oxidative chemical helps to reduce the pollution load i.e. reduction in COD, reduction in color etc.

After bleaching, Properties of Bleach Pulp are studied and comparison of quality of Kolhu's Bagasse pulp and Mill Bagasse pulp given in Table-8.

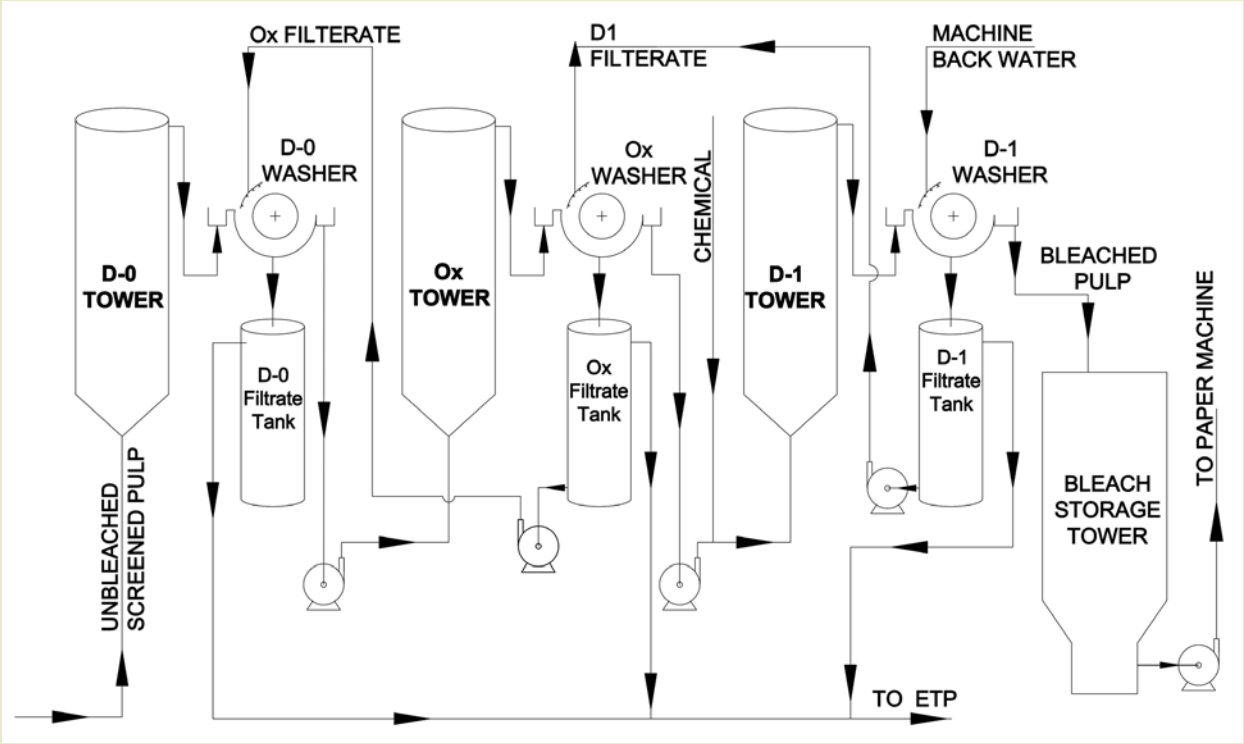

Figure-7: Principle flow sheet of Bleaching plant

Table-7 Bleaching condition at different stage

	Temperature (deg C)	Reaction Time (Minute)	% ClO2	% NaOH	% Oxidative chemical
Do- Stage	50	30	0.95	-	-
Ox- Stage	65	105	-	1.2	0.7
D1- Stage	75	225	0.70	-	-

Table-8 : Bleach pulp Quality of Crushed Kolhu's Bagasse vs. Mill Bagasse

	Crushed Kolhu's Bagasse Bleach Pulp				**Sugar Mill Bagasse Bleach Pulp**			
	Pulp Brightness (ISO)	**Tear index**	**Breaking length (Meter)**	**Degree SR**	**Pulp Brightness (ISO)**	**Tear index**	**Breaking length (Meter)**	**Degree SR**
1	84.04	50.30	2793.33	21.00	83.98	51.20	2722.50	20.00
2	83.19	51.00	2694.67	19.00	84.27	50.30	2754.33	21.00
3	83.44	49.80	2682.50	20.00	83.98	51.20	2711.33	20.00
4	83.90	51.00	2719.67	22.00	84.55	50.60	2885.67	19.00
5	83.75	50.20	2702.00	19.00	83.96	50.60	2776.33	19.00
6	83.38	50.50	2706.33	21.00	83.77	51.20	2720.00	20.00
7	84.21	50.30	2721.67	20.00	84.07	51.30	2831.33	21.00
8	83.82	51.10	2684.00	19.00	83.84	50.60	2818.00	20.00
9	83.90	50.20	2704.00	20.00	84.46	50.30	2803.33	21.00
10	83.73	50.60	2684.00	19.00	84.19	49.20	2660.00	20.00
Average	**83.7**	**50.5**	**2709.2**	**20.0**	**84.1**	**50.7**	**2768.3**	**20.1**

Results and Discussion

After processing of Kolhu's Bagasse in different stages (i.e. crushing, cooking, washing, screening & bleaching), the obtained results are compared with sugar mill Bagasse.

1. Bagasse POL reduction in Kolhu Bagasse after crushing is from 4.5 to 1.6 and sugar mill Bagasse average POL is 1.6. If we compare Bagasse POL of Sugar mill Bagasse & crushed Kolhu's Bagasse in Figure-8. We see that both line are in the near to 1.5. (Table-3).

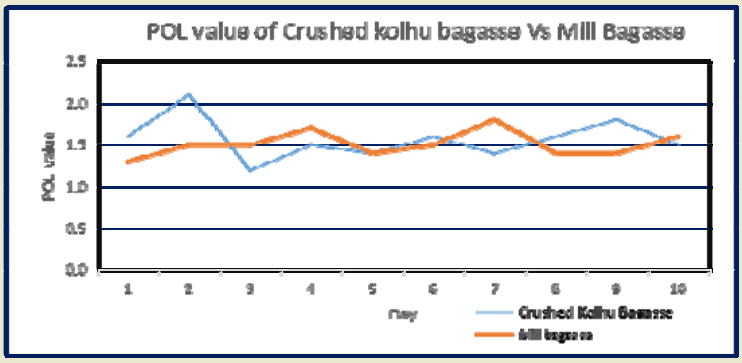

Figure-8: POL value of crush Bagasse Vs Mill Bagasse

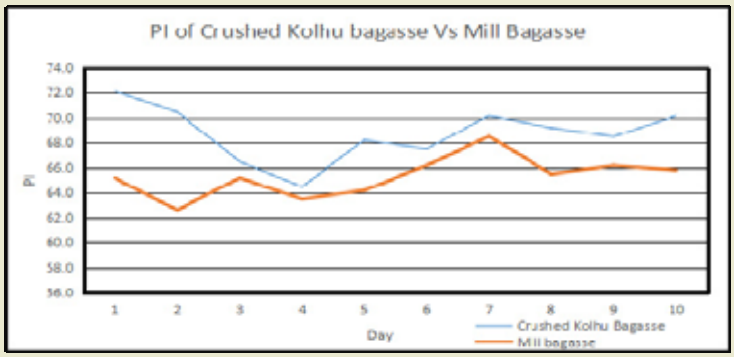

Figure-9: PI of crush Bagasse Vs Mill Bagasse

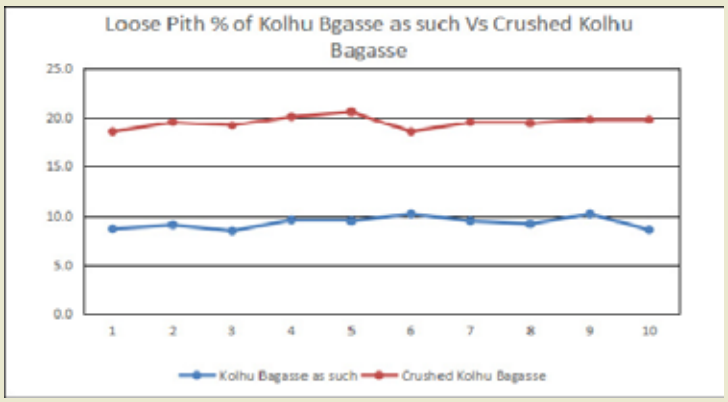

Figure-10 : Loose pith % of Kolhu Bagasse Vs Crushed Bagasse

2. PI of crushed Kolhu's Bagasse increased from 57.6 to 68.7 and sugar mill PI is 65.3 .When we compare of Bagasse PI of Sugar mill Bagasse & crushed Kolhu's Bagasse in figure-9 we see both have approximately same value. (Table-3).
3. Increase in pH of Crushed Kolhu Bagasse effluent from 4.6 to 4.9. And sugar mill Bagasse effluent pH is 5.2. When we compare sugar mill Bagasse & crushed Kolhu Bagasse effluent we found that both have approximately same. (Table-3).
4. Average Moisture of crushed Kolhu Bagasse is reduced from 58.6 % to 54.8 % and sugar mill Bagasse moisture is 50.6 %. (Table-4 & Table-5).
5. Loose Pith of crushed Kolhu's Bagasse after crushing is doubled i.e. 9.3% to 19.5 % (by lab analysis) (Figure-10), Now pith can be easily separated from crushed Kolhu's Bagasse in Depithers .Also when we check pith % after wet washing bagasse (feed to digester) we found that both mill bagasse & crush bagasse have approximately same pith % (Table-4 & 5) so that our target to remove maximum pith from fiber is achieved.
6. After cooking in continuous digester (same condition) Crush Kolhu Bagasse unbleached pulp kappa no & RAA are same as mill Bagasse unbleached pulp (Table-6),
7. Bleach pulp quality produced from Crushed Kolhu Bagasse and Mill Bagasse are same. (Table-8).

Conclusion

In sugar mill Bagasse, pith separation is done easily by physical separation methods due to low moisture and high fibrillation, hence, sugar mill Bagasse is a favorite raw material for Agro based writing and printing grade Paper mills, whereas Kolhu's Bagasse is in bundle form with high moisture and poor fibrillation so pith separation from Kolhu's Bagasse is very difficult.

Papermaking was not possible by Kolhu's Bagasse without removing pith from Bagasse. BPML has developed a new technology and installed a crushing & cutting plant for Kolhu's Bagasse. Where Kolhu's Bagasse fiber bundles are fibrillated, moisture is reduced along with sugar content. This increases the loose pith percentage in crush Kolhu Bagasse, so that Crush Kolhu's Bagasse depithing is possible by Depithers. Further bleach pulp (crushed Kolhu's Bagasse) quality found same as mill Bagasse bleach pulp and there is no change in paper quality made by bleached pulp produced from it. Today BPML is running crushing system of Kolhu's Bagasse process successfully making paper by using 100% Kolhu's Bagasse and Mill Bagasse has been fully replaced by Kolhu's Bagasse. Moreover it fulfills an important social function in enhancing farmer's income and preventing the use of Kolhu Bagasse in burning that pollutes the air, reducing carbon footprint to a handsome extent.

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