Utilisation of Bagasse for Papermaking A Review

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INTRODUCTION

India entered the pulp and paper industry in an organised manner only towards the end of Ninteeth century. In 1950-51, there were only 17 paper mills with an installed capacity of 0.13 million tonnes (MT), which has now increased to 249 units with an installed capacity of 2 35 MT of paper and board and 0.23 MT of newsprint[1]. Today, the pulp and paper industry is under going rapid transformation all over the world. With fast industrialisation increased efforts towards literacy and improving living standards, the development council of pulp, paper and allied industries, have estimated that by 2000 A.D., the total installed capacity of Paper and Board will reach about 4 25 MT and that of newsprint 1.2 MT (Based on 80% capacity utilisation .[2] India is fairly self sufficient in its supply of paper and board. The only significant import is newsprint and efforts are being made to improve the self sufficiency of the country in this grade as well.

The task of meeting the raw material requirement of the paper industry by 2000 A D. appears quite formidable. About 30% of our Paper production is based on agriculture based raw materials and waste paper. This trend is expected to continue in future also. To produce 2.38 MT of paper and board (20% of 3.4 MT of paper and board which is based on 80% capacity utilisation of 4 25 MT), the requirement of forest raw material is about 6.7 MT of air dry bamboo and pulpwood. Keeping in mind the availability of bamboo and hardwood and intensive rejuvention operations in the natural bamboo areas, a shortfall of 3.55 MT of air dry pulpwood is expected. Similary, for newsprint 0.94 MT of air dry debarked pulpwood will be needed. To meet this requirement of 4.49 MT of air dry wood, 1.64 million hectares of plantation will be needed to be raised in a phased manner. The investment in 8 year period for plantation of 1.64 million hectares of plantion will be Rs. 900 crores in addition to the investment needed for raising fuel wood plantation.

In view of the scarcity of bamboo/wood and abundant availability of agricultural residues, the paper mills based on agro-residues and non-conventional raw materials will play a vital role in building up indigenous paper making capacity. The major agricultural residues and non conventional raw materials being used for papermaking are rice straw, wheat straw, bagasse, cotton linters, jute, hessian cuttings, rags and waste paper. Among the many agricultural fibers utilized for pulp and paper making, bagasse promises to become a major fibrous raw material for the pulp and paper industry in the world. It has a distinct advantage over other agricultural residues as it involves no problem of collection. Bagasse has all the requisites to replace the conventional raw materials like bamboo and wood for economic manufacture of paper. Huge quantity of bagasse is produced every year in our country but unfortunately most of the bagasse produced at present is burnt in the sugar mill as fuel to generate steam. Nearly 15 MT of wet whole bagasse is produced annually in the Indian sugar mills. It is expected that 39.2 MT of bagasse will be available by 2000 A.D.[3] On the basis of replacement bagasse, large sized paper mills (250—300 TPD) can be operated while on the basis of surplus bagasse, available from a cluster of sugar mills, it might be possible to set up 50—60 TPD paper plant. The Government of India has allowed excise duty exemption for a period of three years for use of at least 75% bagasse in the furnish to encourage use of bagasse for paper making. It is expected that by the end of this century, the bagasse available will be able to sustain the papermaking capacity to the extent of 0.75 M.T.

MORPHOLOGY AND CHEMICAL COMPOSITION OF BAGASSE :

Bagasse is the fibrous residue of the sugar cane (Saccharum Officinarum) left after the crushing and

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extraction process. Bagasse, which forms about 30% of the sugarcane consists of 50% moisture and 50% fibre along with pith cells. Whole bagasse is composed of three principal components.

(i) The rind, including the epidermis, cortex and pericycle.

(ii) The vascular fibre bundles, comprising thin walled conducting cells associated with relatively thin-walled fibers with narrow lumen.

(iii) Ground tissue (parenchyma) or pith with fiber bundles distributed irregularly.

The fiber content of the whole bagasse is around 65%, pith around 30% and solubles around 5% The dry composition of bagasse and composition based on moisture free water insoluble basis is given in Tables 1 and 2. Table 3 gives the comparison of bagasse with other fibrous materials like straw, bamboo, kenaf and hardwoods.

TABLE–1[4]

DRY COMPOSITION OF BAGASSE

(i)	Water solubles	8–10%
(ii)	Pith, dirt, epidermis and other fines (non water solubles)	35%
(iii)	Good Clean fiber (non water solubles)	55%

TABLE–2[4]

COMPOSITION BASED ON MOISTURE FREE WATER INSOLUBLES

(i)	Pith, dirt, epidermis and other fines.	39%
(ii)	Good Clean fiber	61%

Sugar cane bagasse stands out more than any other among the many agricultural fibers utilized for pulp manufacture. It promises to become a major fibrous raw material for the world's pulp and paper industry. This material is readily available and easily accessible in a great many countries. In fact, this raw material appears to satisfy the criteria, for being a successful fibrous raw material for manufacture of pulp, paper, paperboard and reconstituted panel board, better than any other crop fibre. It has a distinct advantage over other agricultural residues as it involves no problem of collection. From the stand-point of practically worldwide, bagasse is by far the most important nonwood plant fibre. This is easy to understand, since before its use as a fiber source, it has already been used to produce 5 to 10 metric tonnes of sugar per hectare. Relatively with little additional preparation only moist and wet depithing is required before it is ready for digestion. It can readily be made available to the pulp mill at the sugar mill conveyor at a cost - only slighly higher than that of replacing the bagasse in the sugar mill boilers with fossil fuel. None of the other non-wood plant fibers matches its economic advantages.

BAGASSE HANDLING AND STORAGE :

Bagasse is very bulky material and there is no standard method of its handling. In the sugar factories, the bagasse produced is continuously fed to the boilers for producing steam. Any excess bagasse is baled, stored and sold to the paper mills. The location of sugar mill and paper mill will be a deciding factor for the system to be operated for the handling and storage of bagasse. Some of the combinations of depithing, storage and transportation are shown in fig. 1 & 2 and 3[5]. If sugar and paper mills are on the same site, the

TABLE–3

MORPHOLOGICAL CHARACTERISTICS COMPARISION

	Wheat straw	Rice straw	Bagasse	Kneaf	Bamboo	Hardwoods
Average fibre length (mm)	1.5	0.5—1.0	1.7	1.5	2.3	0.7—1.6
Average fibre diameter (/μm)	15	8—10	20	25	18	20—40
Cellulose % (Cross & Bevan)	50	46	54	52	57—66	54—61
Lignin %	17	14	19	17	21—31	23—30
Pantosan %	25	25	30	22	15—26	19—26
AlPha–Cellulose %	33	32	38	35	25—43	38—49
Ash %	5	17	4	3	1.7–4.8	1 0
Silica	5	10	1	—	0.7	—

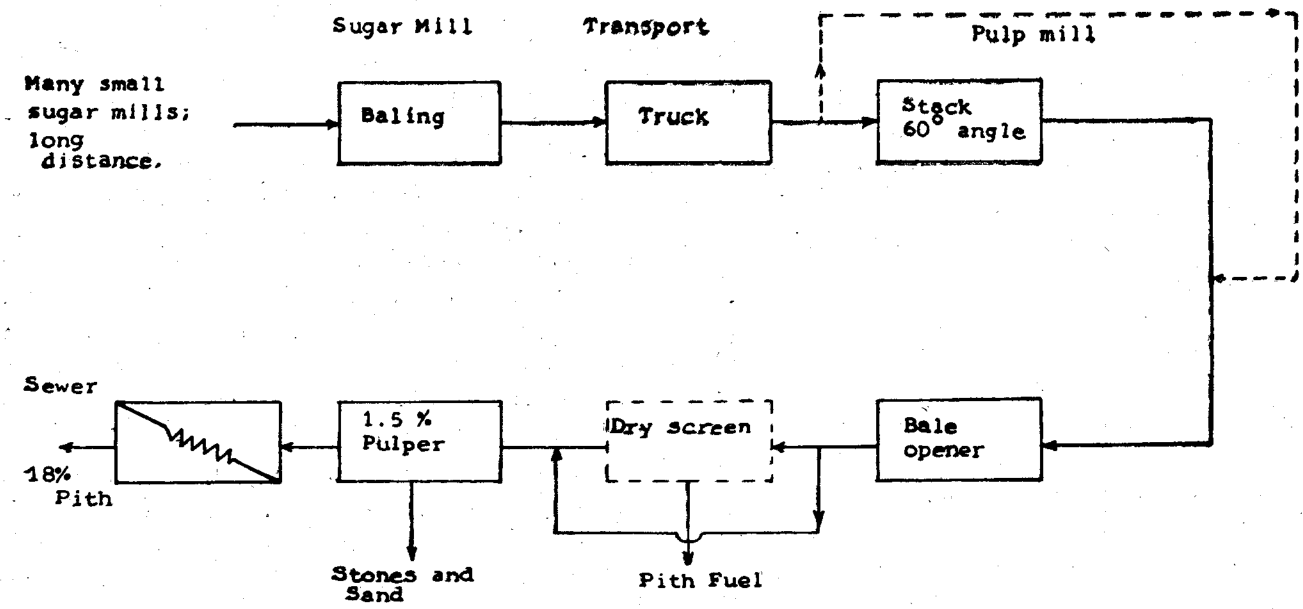

FIG. 1 SCOTT PAPER CO. SAN CRISTOBAL, MEXICO CITY

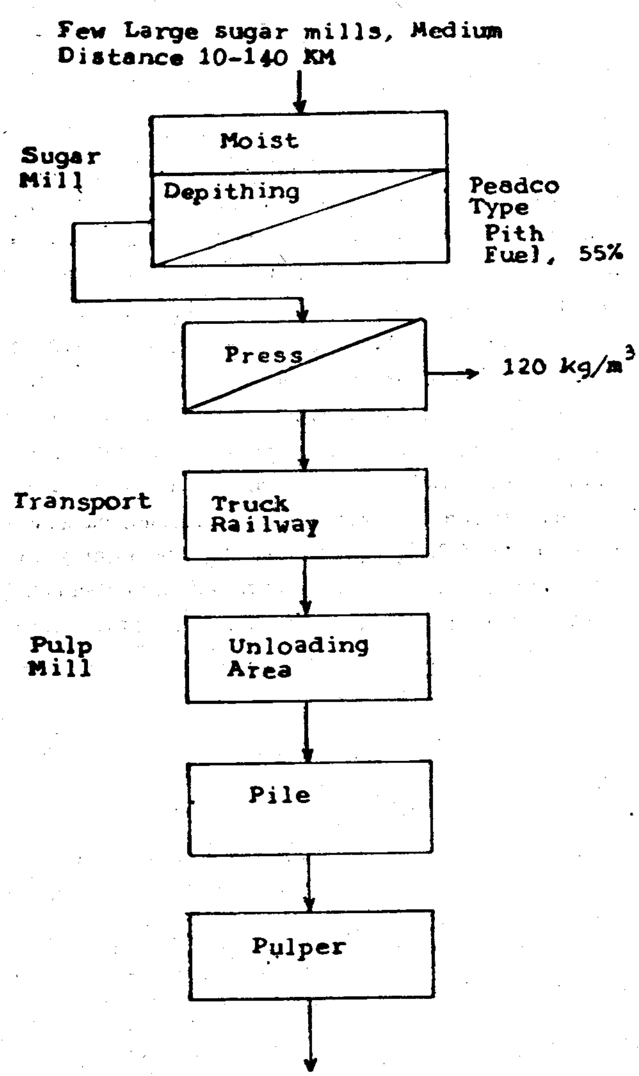

FIG. 2 KIMBERLY CLARK ORIZABA

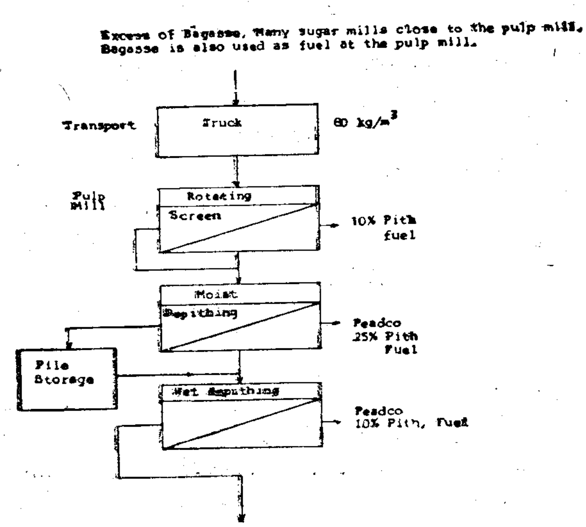

FIG. 3 : SIAM PULP CO., LTD., THAILAND

depith ng of bagasse can be carried out in sugar factory and pith can be utilised as fuel in the boilers. The depithed bagasse can simply be transferred to the paper mill either by high capacity centrifugal blowers or by using belt conveyors. The paper mill has to store the bagasse only during the off season. If the paper mills, are located at large distance from sugar mills, the bagasse is to be depithed at sugar mill and then transported by rail or road. The depithing is carried out in sugar mill, to save the cost of transport. Loose bagasse transport should not be attempted as it increases the transport and handling cost and also results in lot of wastage.

The paper mills have to store bagasse during the off season and it requires considerable open area at paper mill site. One widely used method suggests to stack the bagasse bales with about 50% moisture in pyramid shaped piles with space in between each pile. The bale size will depend upon the bale handling system whether manual or mechanical. In a country like India, the bale size may be from 25 to 50 Kg. The outside of each stack is treated with a preservative like boric acid and the stack is covered on the top with asphalt coated sheet metal. This allows the bagasse in the stack to dry at a controlled rate to prevent overheating and excessive build up of acetic acid generated by fermentation of residual sugar in bagasse. Recently many paper mills are using 'Ritter Biological Pre-treatment Process' for bagasse storage[6]. In this process, the whole or partially depithed bagasse is mixed with biological fluid, conveyed to an elevated channel and then flushed down to special storage slab. The biological fluid consists lactic acid bacteria cultured in a 2.5% concentrated molasses solution. The treated bagasse is piled up and the liquor is drained and recycled. Bagasse is removed from the storage area for further depithing. The pith is loosened by biochemical action during the storage and is removed easily in secondary depithing operation. Such treated bagasse produces superior quality pulp in higher yield.

DEPITHING OF BAGASSE :

Crude bagasse or partially depithed bagasse can be used for low grade corrugating medium, insulating boards and similar varieties. Depithing is an important and necessary step to upgrade bagasse for the production of high grade pulps. Depithed bagasse requires less chemicals in cooking and bleaching, increases yield and improves the brightness and strength properties of the pulp. There are three methods of depithing bagasse dry, moist and wet.

DRY DEPITHING :

This was adopted till 1950 when the other methods had not been developed. Dry depithing is carried out on stored bagasse at a moisture content of about 35%. Hammer shredders, disk mills or the like are used in the separation of pith from bagasse. The disadvantages of this process are heavy wear and tear of the produce equipment, loss of valuable fiber along with the pith and production of lot of dust etc.

MOIST DEPITHING .

This is generally done at the sugar mills when the wet bagasse has about 50% moisture. Several types of depithers such as Horkel, Rietz, Gunkel, Peadcco, SPM and others are commercially used for this purpose. All the machines use the same principle. These depithers are designed to break open the fiber bundles and to dislodge the pith by mechanical rubbing and mild disintegrating action. The units consist of a rotor with sewing or rigid hammers attached to it. The hammers are enclosed fully or partially by perforated screen plates through which the pith fraction is discharged. The bagasse feeding to depithers is along either the horizontal or vertical axis of the unit depending upon the construction. The depithed fiber is discharged at the end of the rotating axis. About two-thirds of the pith is removed by this method.

WET DEPITHING :

This method is more applicable at the pulp mill for the final cleaning and depithing just before bagasse enter the digester. The process is suitable for either baled bagasse or bagasse delivered from bulk storage. A typical layout of wet depithing system feeding directly to the digester house is shown in fig. 4 The bagasse is fed to the hydrapulper where it is thoroughly wetted and broken up at a consistency of around 2 to 2.5% which maintained by continuous recirculation of process water The slurry is pumped to the depithed machine where defibrating operation is completed. The pith passes through the perforated screen. The depithed bagasse is delivered at about 20% consistency to the pulping unit and the pith is separated and thickened by dewatering press before disposal. The complete information about bagasse storage[9] and depithing machines in 'commercial use[10] are compiled by Atchison.

A typical analysis of depithed bagasse is given in Table-4.

TABLE—4

FIBRE AND PITH CONTENT OF BAGASSE[11]

Particulars	Whole Bagasse %	Depithed Bagasse %
Fibre	62 0	86 2
Pith	32.0	9.0
Solubles	6.0	4.2

About 9–10% of total pith will still be carried forward in to the digester.

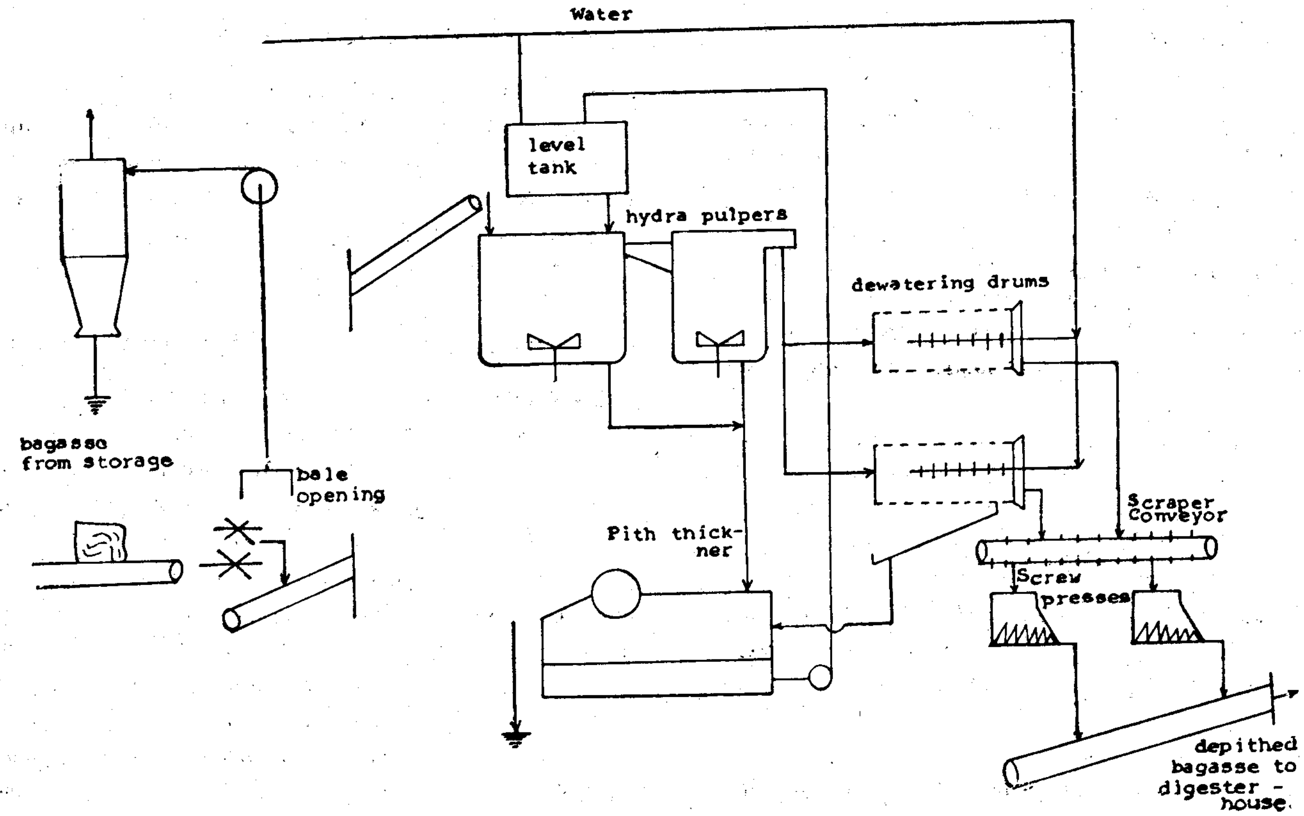

FIG. 4 : TYPICAL LAYOUT OF WET DEPTTHING SYSTEM FEEDING DIRECTLY TO THE DIGESTER HOUSE.

PULPING OF BAGASSE :

All types of pulp ranging from mechanical to high quality bleached can be produced from bagasse. The pulping process and the type of cooking chemicals depend upon the end product required. Bagasse pulp with or without long fibered pulp is now used practically in many grades of paper like toilet tissue, towelling, glassine, corrugating medium, writing-printing papers and newsprint. The following processes are commonly employed for bagasse pulping.

SODA, SULFATE AND NEUTRAL SULFITE PROCESS :

Lime-soda process is used in some countries to produce unbleached grade paper. The pulp can be bleached to lower brightness level for the manufacture of low grade writing printing papers. Bleachable-grade pulp is produced by the soda process in a Pandia continuous digester[12].. The following conditions are maintained during cooking.

Digester pressure	= 6.5 to 7 kg/cm^2
Temperature	= 165 to 170°C
Cooking time	= 10 to 12 min.
Liquor to dry bagasse ratio	= 1 : 3.5
Total Active alkali as NaOH	= 12%
Unscreened yield	= 50—52%
Permaganate nuuber	= 9.5—10

A rapid continuous digester is used in a mill in India to give bagasse pulp of acceptable quality with good strength properties in a shorter time cycle[13]. The batch pulping process using rotary spherical digesters are also used at elevated temperature and pressure for bagasse pulping. The neutral sulphite process for bagasse pulping gives weak pulps with higher yield and brightness values compared to sulphate process. Celdecor Pomilio process[14] is used to produce unbleached coarse pulp at about 65% yield and bleached pulp at 45% yield from depithed bagasse with a brightness of 80 or above.

(a) CUSI PROCESS :

Cusi process[15] was developed by cusi in a bagasse pulp and paper mill, Cia Industrial de Sen cristobel in Mexico. The whole loosened bagasse after the milling operation in a sugar mill is screened in the pulp mill to remove fines and free pith. The depithing is carried out in a specially designed depither which operates at high speed and the pith is removed by mechanical scraping. The pith is mixed with molasses for animal feed. The fiber fraction is given a mild treatment by the soda or sulphate process. The raw cooked pulp ts screened employing special techniques and separated into two fraction corresponding to the fibers derived from the central and the rind-vascular bundles respectively. The accepted fiber (central vascular fiber) from the screening operation needs little refining and has excellent fiber-bonding characteristics. The second fraction (fibers from the rind-vascular bundles) is subjected to more drastic pulping and produces the pulp having good tearing resistance and strength properties. This pulp is refined to the desired degree and recombined with the first fraction to provide a wide variety of papers. The important aspect of cusi process is that maximum bagasse–pulp is utilized and dependence on long-fiber wood pulp is reduced.

(b) Peadco Process[16] :

This process is in use in Peru, Mexico, Venezuela and Taiwan.

It is an integrated process, which includes depithing and pulping operations. The bagasse from the bales is sent to the depithing unit. The swinging blades of rotor disintegrate the incoming material and the fiber and pith are separated due to the rubbing action. The pith is removed through the screen pneumatically and the depithed fiber is discharged at the end of the dipither. The fiber is compacted in a screw feeder and is sent to the horizontal, high pressure digester. The pulping is carried out at 125 psi in vapour phase with a retention time of 18 to 20 min. The chemicals and steam are injected at the same point in the digester as the raw material. The pulp is blown from the digester at high consistency to a disc refiner at 145°C. The pulp is transferred to a blow tank. It is washed, screened and cleaned and the rejects from screening are sent back to the digester.

(c) MECHANO-CHEMICAL PROCESS :

This process is mainly used for producing high yield coarse pulp for the manufacture of corrugating medium. The process uses either caustic soda or lime alone or in combination with other alkalies. A mill in Cuba uses 100% bagasse pulp for the manufacture of corrugating medium[17].

HIGH YIELD BAGASSE PULP FOR NEWSPRINT :

Mechanical and Thermomechanical pulping processes produce the high yield pulp which can be used in the newsprint furnish In a refiner mechanical pulping, the well depithed bagasse is ground and refined in double disc refiners at about 6–7% consistency. The partially refined pulp is thickened in a screw press to about 30% consistency. The refined stock is screened, cleaned and bleached to the desired brightness of 60 to 63[18]. The freeness of screened pulp is about 36°SR. Asplund Defibrator A.B., Sweden developed a TMP process wherein depithed bagasse in defibrated in a disc refiner with preheating arrangement at about 130°C. The final screening is carried out in the second stage with reduced disk clearance. The pulp is screened and cleaned. The freeness of the accepted stock is 63°SR.

There are several chemi-mechanical processes used for bagasse pulping. In Simon Cusi process, a mild caustic impregnation is carried out at low consistency and 7 to 8% caustic soda is obsorbed in a rapid pulping cycle. The pulp is coarse screened after digestion. The rejects about 50% are defibrated in a disk mill. The refined rejects are recombined with the accepts from the coarse screening prior to washing, screening and cleaning. The unbleached yield of the pulp is about 70% based on dry depithed bagasse. The pulp is bleached in two stages using hypochlorite to 62 brightness. The bleached yield is approximately 62% on depithed bagasse and 46% on whole bagasse[19].

The dela Rosa process developed in Cuba involves two stage digestion of whole bagasse. The first stage is a water prehydrolysis at 160°C and the second stage is a standard sulfate digestion with 12% alkali on the moisture free bagasse. The yield of prehydrolysed bagasse is 70 to 75% of the whole bagasse and the cooked but unbleached pulp yield is 65%. The semi-bleached pulp has an overall yield of 48%, and is bleached to 65% brightness with 5% chlorine[20].

A Zell.stoff[20] process was developed for partially depithed bagasse which is subjected to water prehydrolysis at 160°C. This prehydrolyzed bagasse is pulped using neutral sulfite liquor of about 8.5 pH at 160°C. The pulp is refined, washed and screened to produce unbleached pulp of 55 brightness. In Grace Peadco Process[21], the accepted cleaned fiber after wet depithing is rapidly prehydrolyzed at 175°C at a pH of 4 to 5. The prehydrolyzed bagasse is cooked in vapour phase with 2% $NaHSO_3$ and 1% Sodium Silicate in continuous digester at 175°C for 10 min. at a pH of 8.0. The pulp at high consistency is blown to a disc refiner where the fiber bundles are defibrated at 145°C. The sodium silicate prevents discoloration of pulp, The pulp yieldis 85% and brightness 55.

In Cuban Research Institute for Sugarcane Derivative, Chemimechanical pulps were produced using modified soda and alkaline sulphite treatment prior to refining. The pulps were of acceptable qualities for newsprint[22]. The alkaline sulphite process gave brighter than the soda and mechanical pulps. In India, an integrated paper mill, TNPL, Tamilnadu[23] used 100% bagasse for the newsprint production. The mechanical bagasse line comprises of two TMP refiners (56" Beloit Jones) and one CMP refiner (atmospheric). After TMP refinings the pulp is fractionated and the coarse fiber fraction is given a mild chemical treatment followed by atmospheric refining. The combination of both TMP and CMP fractions is taken as the mechanical bagasse pulp. Chemical bagasse pulp is prepared using 10–12% NaOH Na O in sunds continuous digester to a Kappa number of 12–15 with a brightness of 35–40. This is further bleached to a brightness of 78–80 in CEH sequence. Bagasse chemical pulp has a freeness of 450–500 ml CSF and does not require any refining in stock preparation section. The bagasse chemical and mechanical pulps are blended in suitable proportion to produce the newsprint.

WASHING AND SCREENING :

The bagasse has a higher hydration as compared to bamboo or wood and therefore the drainage is very slow as compared to conventional long fibered pulp or hardwood pulp. This needs higher area for washing The loading factor for wood pulp is about 0.16 Tonne/sq. ft./24 hrs. and for bagasse it should be around 0.06 tonne/sq. ft., 24 hrs.[24]. A countercurrent washing system is suitable for efficient washing. Usually three stages of washing are used as a recovery plant is installed[5,26]. A large amount of foam is produced during the washing operation and the filtrate tanks are completely enclosed with connection to a common foam tank equipped with foam breaker. The filtrate obtained in each stage is used for washing the pulp in the previous stage with the exception of the last washer, where hot water is used for screening the extraneous materials like sand, dirt etc. Two or three stages of centrifugal cleaners is used depending on the final use of the pulp being produced.

BLEACHING :

Depithed bagasse is considered to be easily cooked and bleached of all the non-wood fibrous materials pulp produced from well depithed bagasse requires the smallest quantity of bleaching chemicals and the shortest retention time in different stages of bleaching sequences. The CEH sequence can be adopted for producing bleached pulp within the brightness range of 82–85 GE. A brightness level of 90–91 GE with minimum degradation of pulp characteristics can be obtained by using CEHD sequence. The chlorine consumption ranges between 3 5–5% based on moisture free unbleached screened pulp. Bleaching shrinkage varies from 4–6% and the bleached yield based on well-depithed bagasse ranges from 45–48%. Dissolving grade pulp can be produced soda or sulphate process with steam hydrolysis The pulp can be bleached by CEHD bleaching sequence to a brightness of 90–93 GE[27].

In a particular study[28], the bagasse was cooked down to a Kappa Number of 14 using the Ritter wet bulk storage system and cooking. The pulp was bleached to a brightness of 85 GE after bleaching with chlorine, caustic Extraction and hypochlorite. The reduction in pulp viscosity and tear were the limting factors to obtain higher brightness. It is possible to obtain a brightness of 86 GE with acceptable viscosity and tear values after improving the depithing, storing and pulp cleaning. A brightness of 87 GE was obtained using peroxide after the hypochlorite stage with better pulp aging characteristics. The bagasse pulp bleaching can be improved by changing the operating conditions[29]. Cooking of old bagasse causes quality and technical problem during the pulp bleaching. Old bagasse pulps have lower strength properties, give high Kappa number, dirty in color than fresh bagasse. The kind of process utilized for depithing bagasse affects the physical properties as well as the easiness to perform the bleaching of pulp. Brightness reversion in bleached bagasse pulps is not a critical factor and will depend on the type of paper produced.

STOCK PREPARATION :

The bagasse during pulping and bleaching absorbs higher amount of chemicals and the stock is well hydrated which shows slow drainage characteristics. Only a very mild refining in disc refiners is carried out for bagasse pulp to bring about fiber uniformity out of heterogenous fiber bundles of bagasse. The bagasse pulp can also be blended with the refined long fiber pulp and treated in the finishing jordans which is sufficient for necessary difibration and dispersion of stock on the wire. It is believed that the bagasse fiber being short can not be made into paper based on 100% bagasse furnish. It has been the practice in American countries to mix 50% of long fiber pulp with bagasse pulp for making normal standard varieties of paper. It has been possible to manufacture acceptable quality of paper both for writing and printing papers using more than 90% bagasse furnish[30]. The machine wet and both wire and press parts may have to be designed to suit this high percent of short fiber for the better runnability.

Due to unique fiber characteristics and excellent bonding properties, bagasse pulp requires much less rosin-size compared to paper made from conventional fibers. The alum requirement may exceed the quantity normally used for conventional paper making mainly due to low pH conditions required in the white water system to prevent press stickiness. When the proportion of bagasse pulp increases and approaches 80%, considerable changes in the machine design and operation are necessary to maintain high degree of mechine efficiency[8]. In a paper mill in India, TNPL, Tamilnadu 100% bagasse is used for newsprint production[31]. Mechanical pulp is produced by CMP and TMP process which is bleached by hydrogen peroxide and sodium dithionite. The chemical pulp is produced in continuous digester by using NaOH. The chemical pulp is bleached by CEH sequence. The chemical and mechanical pulps are mixed together to produce the satisfactory newsprint.

PAPER MACHINE :

Fourdrinier paper machine can be used for produing conventional grades of paper. The water holding capacity of bagasse pulp is much higher compared to other conventional raw materials. It is necessary that the wire part should be longer with modern drainage elements. The multiple blade foil system, and more number of suction boxes are needed for higher drainage. The initial wet web strength is comparatively low when high proportion of bagasse pulp is used in the furnish. A closed draw like suction pick up should be provided for the transfer of web from wire to press part. The modern presses should be installed to achieve higher dryness after the press section. The felts used should have high porosity for better and efficient water removal. An efficient felt cleaning system is to be employed to keep the felts and roll perforations clean. The felts tend to clog because of higher amount of fines and high pressure showers with automatic controlled movements are needed to clean the felts and rolls.

The bagasse fiber is more hydrated and carries more moisture to the dryer section as compared to the conventional fiber, requiring, more drying surface in the dryer section. The drying curve in case of paper web having bagasse is greatly flattened compared to the hyperbolic curve for conventional fibers. This necessiates to maintain uniform temperature over an extended number of dryers. The smaller dryer groups are preferred to have better control on rate of drying.

Fourdrinier paper machines are considered obsolute for newsprint production. High speed twin wire formers with better wet end control, closed draw arrangement, efficient water removal system, modern press arrangement are now used, for producing newsprint from all kind of furnishes. A voith Bel Bai–II former is used in TNPL India[31] for producing satisfactory newsprint from 100% bagasse furnish. Table–5 gives the properties of some paper grades made from different furnish mix using bagasse.

CHEMICAL RECOVERY :

The chemical recovery plant for the soda/sulphate process is a conventional one consisting of counter current, brown stock washers, multiple effect evaporators, TABLE—5[13]

PHYSICAL PROPERTIES OF PAPER GRADES HAVING BLEACHED BAGASSE PULP.

Quality	Furnish	Substance g/m²	Burst Factor	Tear Factor	Breaking Length (m) Average	Double Folds
Cream wove	70% Bagasse 30% Imported sulphite pulp	60	16	42	3000	8
Duplicating	80% Bagasse 20% Imported sulphite pulp	75	14	57	3150	7
Duplicating	100% Bagasse pulp	75	17	48	3100	9
Manifold	70% Bagasse, 30% Imported sulphite pulp	33	22	57	4000	7
White Printing	90% Bagasse 10% Imported Sulphite pulp	60	18	60	3707	10
White Printing	100% Bagasse Pulp	60	17	50	3001	8
White Printing	100% Bagasse Pulp	67	17	50	3400	8

recovery boiler and a recausticizing plant. In comparison to other raw materials, the difficulty in washing the bagasse pulp requires the use of a larger amount of water producing higher sodium losses, decreasing the recovery efficiency and reducing the total solids in the weak black liquor. The bagasse has a high silica content which is transferred to the lime mud as calcium silicate during the recausticizing operation. The presence of calcium silicate reduces the efficiency of the lime mud recovery and decreases the calcium oxide content of the lime produced in the lime kiln.

In a particular study carried out at Ledesame bagasse recovery plant[32], the depithed bagasse is cooked in two Pandia Continuous digesters. The pulp is washed in three Impco counter-current rotary vacum filters. The chemical composition of weak, black liquor is given in Table-6.

TABLE—6[32]

CHEMICAL COMPOSITION OF THE WEAK BLACK LIQUORS

Solid concentration	8.13 %
Ash content in the solids	38.70 %
Silica in the solids as SiO_2	1.20 %
Residual cuastic soda as Na_2O	1.16 gpl
Sodium carbonate as Na_2O	7.24 gpl
Sodium sulphide as Na_2O	1.70 gpl
Volume per 100 BDMT/day	13.90 m³/day
pH	13.30
Total chemical as Na_2O	13.10 gpl

The weak black liquor is filtered before evaporation to reduce the concentration of fines in the weak black liquor. These fines are composed by fragments of short fibers, vessel segments and pith.

The evaporation of weak black liquor is carried out in long tube vertical evaporators. The high silica and short fiber content of the bagasse black liquor requires frequent cleaning of the evaporators. Table-7 gives the scale analysis in the different effects of the evaporation.

TABLE–7[32]

CHEMICAL ANALYSIS OF THE SCALE IN THE EVPORATORS

Scale	IV and V Effects	III Effect	I and II Effects
Silica as SiO_2	3.0	9.1	44.6
Aluminium and Iron oxides	4.3	3.9	13.7
Calcium carbonate	18.3	31.6	1.3
Organic Matter	67.0	40.9	27.0

From this table it seems that the organic matter mostly plugs the first bodies in contact with the weak black liquor, the calcium carbonate scale stays in the middle of evaporation and the silica, as aluminium silicate, remains at the last bodies. The silica scale is very difficult to remove. One of the methods is to boil the scale in a solution of sodium acid sulphate at 20% concentration for two hours This is followed by mechanical cleaning to remove the scale which was loosened by mechanical cleaning. The calcium carbonate scale is removed by the circulation of an inhibited solution of HCL at 4% concentration and the organic matter, mostly short fibers and fines, is removed by boiling water and draining the bodies. It was found to be convenient to operate at a liquor concentration not higher than 40% at the outlet of the evaporation in order to avoid serious silica scaling. The liquor is further concentrated in a cascade evaporator. To control the viscosity of the Black Liquor a certein temperature is maintained at cascade evaporator and black liquor business The cascade drive is oversized due to the high viscocity of the bagasse liquor.

The smelt after dissolving in water or weak liquor is sent for further processing. The small amount of sulphur present in the green and black liquor is originated in the digestion as a consequence of the content of sulphates in the bagasse sugarcane. The dregs of the green liquor are separated of a clarifier and washed in a dreg washer. The clarified green liquor is mixed in a slaker with time and goes to causticizers and then to the white liquor clarifier. The strong white liquor obtained at the white liquor clarifier is sent to digestion. The sludge is thickened and filtered on a rotary drum filter to recover the valuable alkali. The sludge is either washed or converted in to active calcium oxide either in a fluidized bed calciner or in a rotary lime kiln.

ENVIRONMENTAL POLLUTION :

The effluent is generated in the following departments of a mill using bagasse as raw material

(i) Bagasse preparation section,
(ii) Digester house,
(iii) Brown stock washing and screening section,
(iv) Bleaching Section,
(v) Recovery and utilities sections,
(vi) Paper machine.

Fig. 5 shows the discharges to water of both dissolved organic substances and suspended solids from

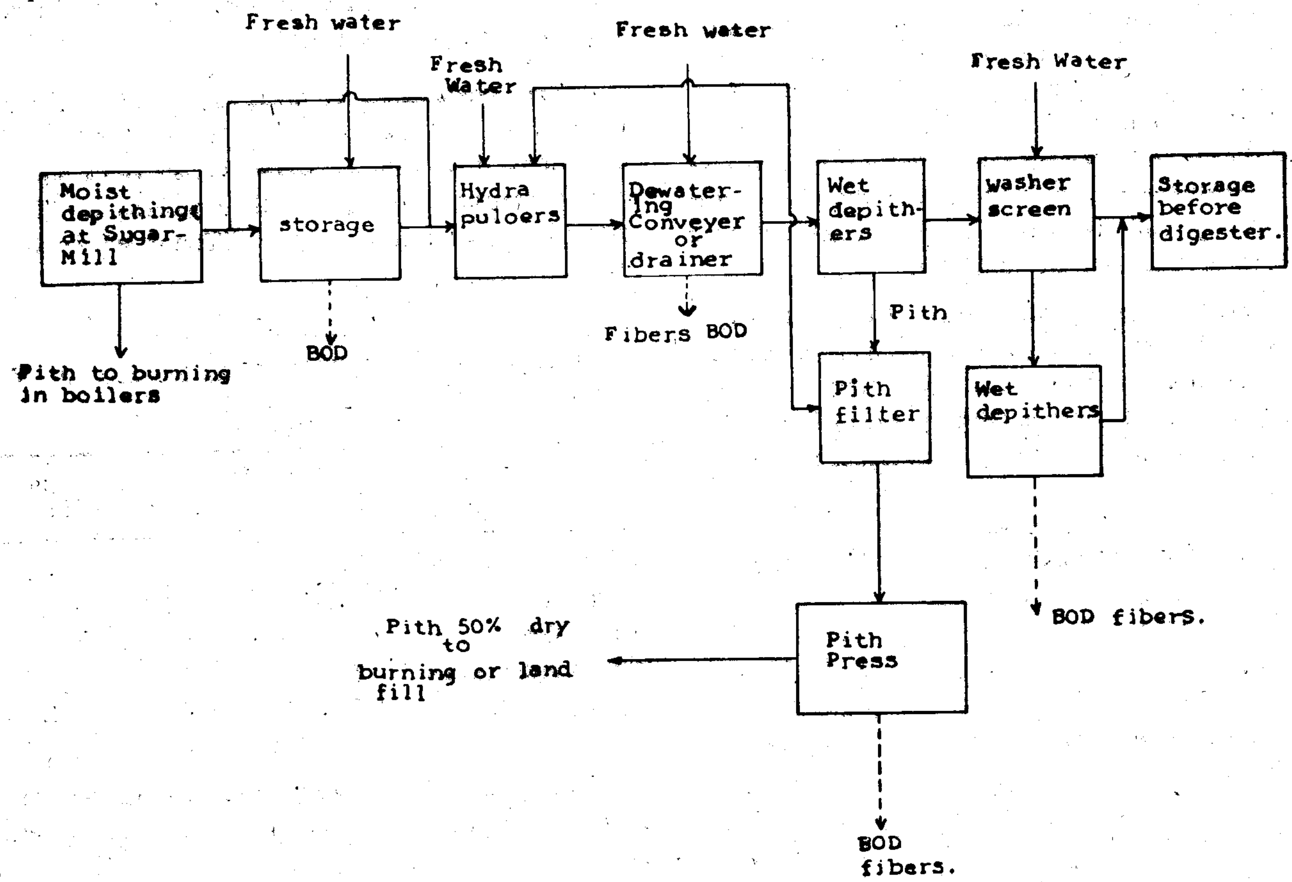

FIG. 5 : FLOW SHEET OF BAGASSE PREPARATION PLANT SHOWING THE EFFLUENT DISCHARGE

bagasse preparation plant. The storage is dry in bale form or wet, in bulk form (Ritter storage system). The liquid used in the latter case in reused for slushing or sprinkling the pile. The discharges from the bagasse preparation section are given in Table—8[33]. The figures are based on a very limited number of investigations and should therefore be regarded as indicative only. Available information shows that the total release of BOD_5 from a well controlled bulk storage is of the order of 20—25 kg/Tonne 90% pulp. In an ordinary pile storage system, the release may be upto 50 kg/tonne of bagasse. Table—9[33] gives the BOD_7, COD and colour of the organic substance dissolved in soda and sulphite pulping. Table—10[34] gives the characteristics of combined effluent in an integrated pulp and paper mill in India. The combined effluent is treated by staandard methods such as

(i) The primary clarification combined with a rated lagoon.
(ii) Primary clarification with secondary treatment by trickling filter method.
(iii) Primary clarification with secondary treatment by activated sludge recirculation method.
(iv) Any variation of the above methods.

TABLE–8[33]

The approximate discharge of dissolved and suspended solids from the bagasse preparation operating. Data are given in kg/tonne of bagasse pulp.

Operation	BOD_5	COD Kg/tonne	Suspended solids
Storage, dewatering	20—40	60—240	200—400

Table—9[33] gives the BOD_7, COD and colour of the organic substance dissolved in Soda and sulphate pulping.

TABLE–9[33]

BOD_7, COD and colour of the organic substance dissolved in Chemical Pulping :

Fibrous Raw Material	Pulp Yield	Kappa Number	BOD_7	COD Kg/tonne 90	Colour
Bagasse (Soda Pulping)	80	—	265	750	—
Bagasse (Sulphate Pulping	48	15	350	1340	950

Table—10[34] gives the characteristics of combined effluent in an integrated Pulp and Paper mill in India.

TABLE—10[24]

Chararacteristics of Combined effluent

Description	Units	Quantity
Flow	m^3/Tonne Paper	401
pH	—	6.3
Alkalinity	mg/litre	218
BOD	ppm	340
COD	ppm	1128
Dissolved solids	ppm	716
Suspended solids	ppm	648

PAPER MILLS USING BAGASSE IN INDIA :

In view of the shortage of forest based raw materials and abundant availability of bagasse, the Government of India has inroduced various incentives for establishing the bagasse based mills. Any mill using more than 75% bagasse in the furnish is totally exempted from excise duty. This has encouraged many mills for using higher percentage of bagasse in the furnish. Mandya National Paper Mills Ltd., Belagula, Karnataka is the first bagasse based plant in India which was established in 1961. The mill uses the surplus bagasse from the neighbouring sugar factories. for producing around 60 tonnes/day of various grades of paper like writing, printing, manifold and duplicating in the basis weight range of 30 to 200 g/m². The bagasse component in the furnish is more than 75%.

A large integrated paper plant (Tamilnadu Newsprint and Papers Ltd.) is being established in the the Tamilnadu State with the assistance of world bank. The annual installed capacity is 90,000 tonnes of newsprint and writing and printing papers. The plant is getting the bagasse from the six neighbouring sugar fectories. The coal fired boilers have been installed in the sugar factories. It is the responsibility of the paper mill to make arrangements for the supply of coal to sugar factories in place of bagasse. The expenditure in this regard is completely borne by the paper mill. The plant is working satisfactorily, and it is proposed that 100% bagasse furnish will be used for the paper production. Encouraged by this concept, the State Governments of Uttar Pradesh, Bihar and Maharashtra are proposing to establish similar units.

There are some paper mills in India using bagasse which is saved and sold by the sugar factories. Some sugar mills are also trying to establish their own small paper plants based on the bagasse which can be saved by improving the efficiency of the boilers. Two or three owners of paper factories in India are also establishing sugar factories for obtaining the entire bagasse for paper making. In view of the raw material shortage and incentives offered by the Government of India, many more paper mills are trying to use as much bagasse as possible. With all these developments taking place, India in future will be the leading country in the world to make use of bagasse for the manufacture of paper.

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