

Environment Aspects in Processing Bagasse for Pulp and Paper Manufacture

RAO DR. N.J.*

1. INTRODUCTION :

The world paper production is expected to grow to 227.341 million tonnes in 1989 from 212 467 Million tonnes in 1984. The average growth rate is likely to be 1.4% per annum while the developing countries will register a growth rate between 2.3 to 3 0% in this period.¹ In India the paper production capacity is likely to grow to 4.25 Million tonnes by 2000 AD from the current capacity of 2.6 million tonnes in 1986. Non wood pulping capacity will grow at a faster rate than wood pulping capacity. The over all leaders in non-wood plant fiber are PR China, India, Taiwan, Mexico, Cuba and Italy. Among many agricultural fibres used for pulping making, sugar cane bagasse stands out more than any other. By 1990, it is expected that bagasse may contribute about 2 % of total paper making capacity in the world. The developing wood poor countries have ten times more sugar cane than developed countries². Nearly 15 MT of wet whole bagasse is produced annually in the sugar mills. It is expected that 39.2 MT of bagasse will be available by 2000 A.D. A paper capacity of 0.75-1 MT likely to be sustained by bagasse available in India.

Bagasse is composed of three principal components :

- (a) The rind fibres including epidermis, cortex and pericycle
- (b) The fibre-vascular bundles comprising of the thin walled rather short fibres with narrow lumen
- (c) Ground tissues (Parenchyma tissues) or pith fibre bundles distributed inequally. The portion of pith fibre bundles and epidermis (Rind fibres) vary considerably with age of stem, and the sugarcane variety. The fibre content of whole bagasse is around 65 %, piths around 30 %, and solubles around 5 %. The cold water solubles, hot water solubles, Alcohol benzene solubles and 1 % NaOH solubles in bagasse are nearly 5-8 %, 7.4 % and 41 % respectively. Bone dry bagasse has small quantities (upto 5 % sugar.

Bagasse is a renewable fibre with large supplies, does not need cutting into pieces like wood, requires less refining power, has less lignin (19 %) requiring less chemicals, has lesser quality of cellulose content (54 %) is short fibred (dia 20/um, length 1.7 mm) and is more hydrated requiring more steam for drying. Pith has no fibre and is a major disadvantage requiring its removal before cooking. Pith is highly absorbent and hence impurities are deeply absorbed and cannot be easily removed. This requires drastic cooking and bleaching needing more chemicals. If pith is not removed the paper will have more dark shining specs. Pith has a tendency to gel and turn gelateneous with caustic cooking and hence causes clogging of felt and wire and reduces drying rates. It results in the low strength. The pentosan contents are highest (30 %), ash content (4 %) is more than wood, but comparable to non woody plants. Bagasse has no resin acids and a lower contents of extractives than wood which is further reduced during bagasse has no resin acids and a lower contents of extractives than wood which is further reduced during bagasse milling and wet bulk storage³.

The environmental aspects on bagasse utilization for paper making can be seen as under :

- The morphological characteristics and Chemical composition suggest that bagasse cooking and bleaching are more easy than wood pulping.
- Kraft processes with lower sulphidity can be used with reduced aggressiveness of atmospheric emissions in larger mills.
- Soda process can be used with no aggressive gas emissions in small mills.

*Professor in Chemical Engg. and Director.
Institute of Paper Technology,
Saharanpur-247001 (U.P.) India.

— Absence of resin acids; removal of extractives in storage, non-presence of Sulphuric soda cooking liquid effluents. Lower sulphur in Kraft liquid effluents, lower volume of bleach effluents with lower Chlorinated compounds.

The above factors indicate the advantage of bagasse as a better material for paper making from environmental aspects. The environmental aspects are in various stages of processing are discussed.

2. Bagasse Handling and Storage :

Different combinations of depithing storage and handling are practiced by mills loose and baled bagasse are transported. Bagasse is stored in pyramid shaped piles with space between pills. The out side of the stacks are treated with a preservative like boric acid and stack is covered on top with asphalt coated sheet metal. In Ritter Biological treatment Process⁴, the bagasse is mixed with biological fluid is conveyed to an elevated channel and then flushed down to a special storage slab. The biological fluid consists of lactic acid bacteria cultured in a 2.5% molasses solution. The liquor is drained and recycled. Biochemical action loosens the pith. In bulk storage water or micro-biological liquor spray is used to control the degradation and temperature rise. The effluents from water spray system are more contaminated than from microbiological spray system as shown in table—1.

TABLE—1

Effluent Characteristics from Water Spray and Microbiological spray water system in bagasse storage⁵

	pH	COD	BOD kg/t bagasse	TS	SS	DS
Water Spray	4.8	51.8	32	27	17	26.6
Microbiological system	5.0	5.4	2.8	3.99	2.1	3.8

The colour of the effluents is between 405 mg/l for microbiological system while the figure is around 625 mg/l in water spray system. The BOD/COD ratio is high indicating easy biodegradable nature of effluents. In well manage system using microbiological system, the amount of water required can be reduced to about 1m³/t moist bagasse from the normal values of 4m³/t³. Periodic spraying during formation of bagasse piles to

raise compactness, avoiding temperature rise beyond 40°C, good water distribution and recycling can improve fibre quality and reduce pollution load.

3. Depithing of bagasse :

The depithing methods are dry, moist or wet. In dry depithing human shredders or other disintegrators remove pith from bagasse with 15—20% moisture. The fiber losses are high, dust problem is severe causing bagasses is an occupational hazard. The process is almost obsolete.

In moist depithing, wet bagasse with about 50% moisture is disintegrated. Nearly 60—70% pith is removed. In wet depithing, bagasse of 2—2.5% consistency is defibrated with 80—84% pith removal. The depithed bagasse is delivered at 20% consistency while pith is thickened to 40—50% by dewatering. This method eliminates other impurities like sand, colloidal particles and organic solubles. Wet depithing can use open or closed system. Dissolved organics from depithing is high if bagasse comes from storage with biological liquor recirculation since the bagasse is washed less intensively than with open water control.

The discharges from bagasse preparation section are shown in table-2. The release of BOD₅ 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—60 Kg/t bagasse. The discharges range 10—60 m³ water/t pulp.

TABLE—2

Approximate discharges from bagasse preparation operation⁶

Operation	BOD ₅ ——kg/t bagasse Pulp——	COD	SS
Storage dewatering and depithing	20—40	60—240	200—400

Since the dissolved organic solids mainly consist of low molecular weight carbohydrates and acids; and BOD/COD ratios are high, biological treatment aerobic or anaerobic is expected to yield good result. Suspended solids are small and relatively light. Mechanical treatment like sedimentation basin and dewater-

ing filter can reduce S.S. The biological sludges have good sedimentability. The high organic contents without the presence of incompatible substance make them potentially apt for irrigation.

4. Pulping of Bagasse.

Bagasse can be cooked by many methods to give a variety of finished products. The most common chemical cooking is using soda a Kraft process in batch or continuous digesters. The yields are of same magnitude as hardwoods. The cook is very short with low alkali demand and pulp yield is fairly low. Various modification to these processes are available like Cusi, Peadco the bleached yields are around 45%. Mechano-Chemical Processes using soda or lime produce corrugating medium with high yield.

Mechanical and thermomechanical processes produce high yield pulps for use as newsprint furnish. In these processes the refined pulps are bleached to desired brightness. There are several variations to this. The TNPL mill uses SPB-Beloit process with 85-100% blending of bagasse for newsprint production with mechanical pulp from TMP and CTMP lines and chemical pulp (7,8,9,10).

In mechanical pulping 2.5-10% substance, (low molecular carbohydrates, lignin and extractives) is dissolved. The yield loss in Chemi-Mechanical processes is 5-15%. The higher is the chemicals charged and the treatment temperature and the longer the time, the more substance is dissolved, a main part of the dissolved material is discharged as effluent. A decrease in yield results in an increase in pollution parameters. BOD and COD follows a straight line relation with pipe yield with minor deviations.

Spent liquors from Chemical/semi-Chemical pulping contain largest amount of dissolved organics. A portion of the organic component in spent liquors volatile and is released during blow. For normal washing efficiencies (85-98%) the BOD₅ following the pulp may range from 90 kg/t (Sulphite-Viscose) to below 5 Kg/t pulp (high yield sulphate). For mills with no recovery the BOD load ranges from 200-600 Kg/t. The total amount of BOD₅ in digester and evaporator condensates range from 10-70 Kg/t. The liquor carry overs, foaming drastically increase the BOD values.

In the sulphate and soda pulps lignin, hēmi-celluloses and some cellulose are degraded and dissolved. About 20 Kg/t of Carbohydrate is present as high molecular material in B. L. and the rest is degraded. All substances contributed to COD value. The colour of of the spent liquor is high due to high molecular lignin fractions. The main source of BOD is the degraded low molecular degradation products of lignin (phenols, phenolic carboxylic acids, vanillar and derivatives, methanol, ethanol). Organic sulphides, terpenes, methanol and ethanol are present in the volatile components of BL and condensates of digester and evaporators. Almost similar material is present from soda process with less organic sulphides.

The BOD, COD and colour values of organic substances dissolved in chemical sulphate and soda pulping of bagasse is given in table-3.

Table-3 :—The BOD₇, COD and Colour of the Organic substances dissolved in Soda and Sulphate pulping of Bagasse⁶

	Pulp yield ./	Kappa No.	BOD ₇	COD Kg/t 90	Colour
Soda Pulping	80	—	265	750	—
Sulphate Pulping	48	15	350	1340	950

The main part of water pollution originates from spent black liquors, and this depends on yield. Some typical figures for total black liquor content expressed as BOD₅ for bagasse pulps is given in table-4.

TABLE-4
Black liquor BOD Vs. Yield¹¹

Process	Cold Soda	Kraft	NSSC
Yield, ./	80	48	70
BOD ₅ /t Pulp	150	350	200

Better washing, retention of spills and other inplant Measures can reduce Pollution load.

5. Washing, Screening and Bleaching :

Bagasse has higher hydration as compared to wood and bamboo and hence has slow drainage. The loading

factors are low (0.5–4 t/m² day) requiring larger surfaces for filtration. The washing is normally performed in 2–4 drum filters in series (counter current operation). The slow drainage results in a practice of rather high dilution factors for non wood pulps e.g. 3–6 m³/t pulp compared to 1.5–3.0 for wood pulps resulting in weak black liquors with low solids contents (11–13% or even lower). Washing losses decrease (efficiency increases) with increased dilution. The pollution load washing comes foaming and spills. The BOD values from this section range from 25–80 Kg/t pulp depending on washing efficiency.

Centrifugal screens are used to remove extraneous matters like sand, dirt etc. Traditionally 3 stage-CEH sequence is used for bleaching non wood pulps. Chlorine consumption is between 3.5–5% based on moisture free unbleached pulp. Chlorine (Chlorine dioxide, Hypochlorite) and alkali removes the dark coloured lignin residues. In peroxides and dithionite bleaching low molecular compounds (acetic acid) gets dissolved with BOD discharges around 10–30 Kg/t. In case of TMP/RMP pulps, the dissolved solids increase with increase in the charge of peroxide and alkali. The colour of the effluent is linearly related to the amount of lignin dissolved which is directly proportional to the amount of lignin, in original pulp.

Chlorine charge, alkali charge, pH and temperature influence the pollution load. In bleached soda/sulphate pulps, there is little variation in BOD (14–16 Kg/t) and COD (60–80 Kg/t) for different species, but colour variations are significant (70–100). The chlorine bound to organic molecules in bleach plant effluents are significant as they show a slow degradation biochemical oxidation and tend to accumulate in organic tissues. The substitution of chlorine by chlorine dioxide and oxygen, organic chlorine reduced from 13 Kg/t to below 5 Kg/t besides reducing BOD (upto 35%) and colour (upto 75%). These process modifications require changes in processing equipment and will increase investment and operating costs.

The characteristics of individual waste waters from typical Indian small mills using bagasse and straw without chemical recovery is shown in table—5.

TABLE—5

Characteristics of Individual Waste waters from a 23 TPD mill using bagasse and straw Soda process without chemical recovery (12)

Section	PH	Alkali-nity CaCO ₃ mg/l	TS	SS	BOD	COD
BL	9.5	1570	68930	2340	10200	53600
Pulp Wash	9.2	940	14440	1850	2450	8800
Bleach	6.8	210	3640	440	290	1020
Paper m/c	6.9	130	1200	480	180	580
Combined effluents	7.5	510	3230	850	330	1100

From towers and fillers residual chlorine and chlorine dioxide are vented ranging from 1–3kg/t (as chlorine).

6. Stock Preparation and Paper Making⁴⁹

Bagasse stock is well hydrated with slow drainage characteristics. It normally requires less rosin size and more alum than conventional wood fibres. Modifications in machine design are required to improve drainage. Due to low wet web strength closed draws like suction pick up are necessary to transfer the web from the wire to the press part. The wire part should be longer with modern drainage elements like multiple blade foils systems, more suction boxes. The felts should have high porosity. Felts tend to clog due to higher amount of fines. The drying curve for bagasse furnish is greatly flattened compared to conventional fibres requiring more drying surface.

The white water system from paper machine needs closure. The pollutants consist of SS (fibres, inorganic fillers), DS (non-wood plant components, additives). Closing white water system reduces fibre loss and water consumption. With complete open system fibre loss is as high as 50–150 Kg/t with partial recirculation this can be brought down to 25–50Kg/t paper. Further white water system closure is possible¹³. The white water discharges in such a case are 10–50m³/t. with fibre losses in the range of 5–25 kg/t. This requires advanced internal measures. White water system closure is limited due to deterioration in quality (build up of DS) leading to reduced retention, slower dewater-

ing foaming, bad sizing, picking, linting, deposits on machine components and even deterioration of paper strength and printability.

In the paper mill the dissolution of fibre material occurs at refining stage (2-4% in high yield pulps and negligible in chemical pulps) with a BOD₅ load of 1-5 kg/t. The discharge of BOD load is not effected by systems closure. The external treatments like sedimentation basin or biological treatment or chemical flocculation should be used in addition to system closure to reduced BOD loads.

The cylinder mould machines and fourdrinier machines require 1-4m³/t pulp shower water. The effluents from this section can be reused. The characteristics of waste water from paper m/c. of a bagasse chemical pulping unit are shown in table-6.

TABLE-6

Characteristics of Waste Waters from Paper Machine Drain^{12,14}

pH	Alkali-nity	COD	TS mg/l	DS	SS
4.5	44	3435	2352	116.4	1182

7. Chemical Recovery⁴⁹ :

The chemical recovery system is similar to the ones used for wood pulping. They consists of counter current brown stock washers, MEE, recovery boilers and recausticization. The major draw backs relate to high silica content (1-3% of dry solids), high viscosity due to higher pentosans and lower heat value due to lower lignin content and higher carbohydrate content resulting in lower carbon content. Bagasse B.L. is not as foamy as wood B. L. Due to difficulties in washing bagasse pulp, larger amount of water is used giving higher sodium losses, decreased recovery efficiency and reduced total solids in weak Black Liquor. High silica is transferred to lime mud as calcium silicate during recausticization. This reduces the efficiency of lime mud recovery and decreases CaO content of lime produced by reburning.

A relatively high concentration of free alkali (at least 8 gpl of NaOH) in weak B.L. can be maintained by adding white liquor before evaporation. A low

storage time for BL, as constant as possible temperature profile throughout evaporation, low fibre content in BL through installation of fibre fillers before evaporation, good periodical washing including a spare unit for final effect can improve performance. The evaporation is carried out in 4-5 effect long tube vertical raising film evaporators. The first bodies get plugged by organic matter, Ca-Carbonate scales stay in middle effects and silica as Aluminium silicate remain in last bodies. To reduce serious silica scaling the dissolved solids concentration at outlet of evaporators is limited to 35-40%. It is then further concentrated in direct contact evaporators to 55-60%.

The chemicals are recovered from furnace as smelt and dust of Na₂CO₃ in soda liquors. In Kraft process conventional Tomlison type boiler is normally used. 10-20% lower heat value of bagasse B.L. require supporting oil firing. To achieve proper liquor droplet distribution, liquor pressure at the gun is kept substantially higher than for conventional liquors. In some cases steam shattering may be utilized. The thick black liquor lines may require steam tracing as they may get stuck at lower temperatures. The BL tank needs indirect steam heating. The furnace design, particularly dimensioning, tube pitch, scope for soot blower and possibility of hand lancing need to be considered to ensure that ash generated does not deposit on tubes as it is very difficult to remove. The spout for removing smelt should be short and properly inclined with high furnace bottom temperature. As the risk of building up deposits on boiler tubes partly depends on tube metal temperature, it is favourable to select low boiler pressure and low super heat (below 400°C).

The smelt after dissolving is clarified and mixed in a slaker with lime and goes to causticizers and white liquor clarifies. The sludge is thickened and disposed off. In causticization, the silica is transferred to lime mud making reburning difficult.

The steam condensates from stages other than the first are usually contaminated with methanol and other sulphur compounds. The odourous gases from kraft mills are chiefly H₂S, M.M. and organic sulphides. Soda mills have very little sulphur except when lime reburning is practised. The amount of odourous gases emitted from evaporation plant is 0-1-1 Kg S/t; TRS from DCE range 80-500 ppm. This can be reduced

with black liquor oxidation. B.L. in DCE serves as an absorber both for SO_2 and Na_2SO_4 . Cascade evaporator removes 15% dust. Evaporator scrubbers reduce SO_2 emission by 50–80% and dust emissions by 15–25%. The range of total emissions from recovery department are exemplified below.

TABLE—7
Emissions from Recovery Section,

	T RS Kg S/t	SO_2 Kg/t
Evaporation	0–2	—
Recovery Boiler	0.1–4	0.2–4
Causticizing	0.02–0.2	0.2

Water pollution from evaporation is contaminated condensates and spills, from recovery boiler spill and from causticizing due to lime mud, grits, dregs and spills. Evaporator cleaning, carry over from separators add to pollution. The range of total discharges to water from recovery department are as shown in table 8.

TABLE—8
Effluents from Recovery Section

	BOD	COD	SS
	Kg/t		
Evaporation	10–30	15–80	—
Recovery Boiler	1	5	1
Causticizing	—	10	5–250

Malodourous gases can be treated by dilution scrubbing. Dust emissions can be controlled by proper EPS operation.

8. Pollution Control Strategy⁴⁹

The fibrous materials used in Pulp and Paper Industry has components like lignin, hemicelluloses, sugar, alcohols, organic acids and inorganic acids part of which are not reclaimed or recycled and are discharged to receiving waters or atmosphere. Similarly process chemicals cannot be entirely recycled. A small fraction of good cellulose fibre is also lost. Pollution abatement is started with internal as well as external measures. The capacity of the receiving body to cope with discharges has to be estimated.

The potential effluents (particulates, gaseous emissions, water effluents and solids) and their sources need to be identified for proper internal measures. The situation is serious when mill, particularly small ones do not have recovery systems.

8.1 Internal measures.

The discharge of dissolved organic substances in mill with chemical recovery in a bagasse based mill can be reduced with measures in following order of priority.

- Improved Washing efficiency,
- Reduced Spills of black liquor,
- Treatment and reuse of selected cooking and evaporation condensates.

It is possible to improve washing efficiency by adding one additional washing unit when efficiency is in the normal range of 75–90% compared to external treatment. The following measures can improve performance of existing units significantly.

- Operate to washing at as constant pulp flow as possible with no over loading.
- Keep dilution factor constant.
- Keep Kappa number of pulp constant.
- Keep wash water temperature constant in the range of 65–75°C
- Keep proper distribution of wash water over the whole filler.
- Minimise dilution of B.L. by addition of sealing water etc. through good maintenance and control.
- Avoid spills by controlling uneven production rates, equipment breakdown, proper buffer volume, good house keeping and avoiding human errors,
- Spills should be properly collected in dump tanks.
- Contaminated condensated be treated separately with steam stripping.
- The SS solid emissions from treatment of bagasse can be checked by separately pretreating the effluents in sedimentation units. Otherwise they represent a large BOD load.
- Fibre losses in excess white water can be checked by increasing degree of closure and condition of wires.

The excess white water ranges from 100–200m³/t can be reduced to 10–50 m³/t by system closure.

— Proper operation of ESP can keep the dust emissions under control from recovery.

— Proper functioning of dust extractors can reduce dust from bagasse handling sections.

The total result of internal measures are illustrated in table-9.

TABLE—9
Emission of BOD, SS in Kg/t from bagasse Pulping.

	Raw material		Washing		Recovery		Bleaching		Spills		Total	
	BOD ₅	SS	BOD ₅	SS	BOD ₅	SS	BOD ₅	SS	BOD ₅	SS	BOD ₅	SS
A. Without Recovery	50	100	300	20	—	—	10	5	—	20	365	145
B. With Recovery 85 % washing Efficiency	50	100	45	20	10	290	10	5	15	20	115	365
C. With Recovery 95 % washing Efficiency Condensate treatment special recovery system.	50	100	15	10	5	220	10	5	3	5	83	340
D. C. above plus External primary and secondary treatment											15	40

As can be seen in the table, raw material handling represents a considerable share of emissions of both BOD and SS. Large amount of SS are emitted as inorganic substances from recovery department. Only a minor part of the suspended solids is represented by fibres and fibre fragments.

8.2 Large Mills with Chemical Recovery¹⁹.

The large mills have chemical recovery. The gaseous emissions from Kraft/Soda mills contain Mixtures of SO₂, H₂S, Dimethyl Sulphide, Dimethyl disulphide and methyl mercaptan. The sources include Recovery furnace, DCE, digester relief and blow, Lime Kiln, MEE and smelt dissolving tank. The Soda pulping system has practically no sulphur emissions. The main emissions of TRS compounds are shown in table—10.

Table—10
Main Emissions of Reduced Sulphur Compounds
from Sulphate/Soda pulping⁶ (kg S/t₉₀)

Emission	H ₂ S	CH ₃ SH MM	CH ₃ SCH ₃ DMS	CH ₃ SCH ₃ DMDS
Digester, Batch	0-0.15	0-1.3	0.05-3.3	0.05-2.0
Continuous	0-0.1	0.5-1.0	0.05-0.5	0.05-0.4
Washing	0	0.05-1.0	0.1-1.0	0.1-0.8
MEE	0.05-1.5	0.05-0.8	0.05-1.0	0.05-1.0
Recovery furnace with DCE	0-25	0-2	0-1	0-0.3
Recovery furnace without DCE	0-1	0.01	0.01	0.01
Smelt Dissolving tank	0-1	0-0.08	0-0.5	0-0.3
Lime Kiln	0-0.5	0-0.1	0-0.1	0-0.1
Settling Basins	0-0.5	0-0.02	0-0.01	0-0.02

The bleach plant is likely to emit Cl_2 (0.1-3kg/t), ClO_2 (0.1-1kg/t) and SO_2 (0.1-1kg/t). The SO_x and NO_x emissions are likely from recovery furnace, lime Kiln and smelt dissolving tanks. Water vapour emissions range 5-8 t/t pulp. Particulate emission come from recovery furnace, lime Kiln and smelt dissolving tank. The dust is mainly Na_2SO_4 , and Na_2CO_3 . Particle size range from $0.1/\mu m$ to $10\mu m$ for uncontrolled emissions and from $0.1\mu m$ to $10\mu m$ for controlled systems. The emission rates are highest after DCE (7-60 kg/t or 900-5000 mg/m³).

The waste waters come from digester house leaks, spills of BL, gland cooling water pulp washing, decker washings centricleaner rejects with high concentration of fibres and grit, bleach plan effluents of low pH with chlorolignins, Caustic extraction effluents of high pH and colour, white waters with fibres and talc, foul condensates. The combined waste water volume ranges 214-352 m³/t paper with pH between 6.5-11.8. The dark brown colour is due to lignin derivatives. The characteristics of combined waste waters are shown in table-11.

Table-11 : Characteristics of waste waters

Volume, m ³ /t Paper	305
SS Kg/t	131
BOD ₅ Kg/t	51
COD/t	217
% Na	47

Since bagasse has no resin acids, the toxicity is expected to be low.

The solid wastes come from bagasse handling (42 Kg/t), lime mud from causticization (500-600 Kg/t), ash (1.3 t/t) from boiler, Solid/semisolid wastes from centricleaners (10 kg/t) and primary settling waste (26 kg/t).

8.3 Small Mills without Chemical Recovery¹⁰

The Small Mills use lime/soda as cooking chemical. CEH bleaching sequence is mostly followed. There is no chemical recovery due to economic reasons. Waste waters are generated from BL, pulp washing, beaters,

bleaching section, thickness and paper machine. The paper machine waste waters are recycled to varying degrees in pulp washing (42-157 m³/t, av 71 m³/t).

Black liquor is the most polluting stream and contributes nearly 80% of the pollution load. Only a few mills use counter current washing in two stages. Paper machine waste water is least polluting but has appreciable SS. The characteristics of combined waste waters from small mills is shown in table-12.

There is appreciable variable in flow and characteristics of waste waters from different mills. The BOD load of a kraft mill with chemical recovery is 50 kg/t paper against 176 Kg/t paper for small mills with no recovery i. e. nearly 3-5 times more polluted. The sodium absorption ratio (SAR) and percent sodium values of combined waste waters are high in mills where unbleached papers are made using soda process. The values of SAR ranged between 3.5 to 7.6 (in most cases between 3.5 to 5.5). If the proportion of Ca to Na can be increased, the combined waste waters can be used for irrigation after suitable dilution to keep TDS and BOD within recommended range.

Table-12 : Range and Average Characteristics of combined waste waters based on Agricultural Residues (based on 7 mills, 7-30 TPD capacity)¹².

	Mills with no chemical recovery		Mills with chemical recovery*	
	Min	Max	Ave	(14)
Volume, m ³ /t paper	187	383	252	455
pH	6.0	8.5	—	5.6-6.3
SS mg/l	400	1115	615	816
Kg/t	88	239	155	371
BOD ₅ mg/l	220	1067	698	350
kg/t	85	267	176	159
COD mg/l	2120	4563	2940	1275
kg/t	497	741	—	581
Lignin mg/l	320	700	563	—
kg/t	93	197	142	—
Sodium mg/l	200	548	398	—
kg/t	48	142	98	—

* Bagasse Chemical Pulp (Soda)

The non biodegradable fraction of COD is high and is mainly due to lignin in BL making its reduction difficult by biological treatment. Thus colour removal may have to be tried chemically. Nitrogen and phosphorous contents are lower than required for biological treatment and hence these are to be supplemented.

The solid wastes are generated from material handling (440–660 kg/t), rejects, primary and secondary sludges from waste water treatment systems (220 kg/t) and coal and boiler ash (1–3t/t), Small mill handle on an average 0.6 t/t organic solid wastes.

The air pollution problems are negligible. Digesters release about 1.4 t steam/t pulp alongwith organic volatiles. There could be particulates from boiler house.

Only a few small mills have primary and or secondary treatment facilities.

8.4 External Measures⁴⁹ :

At first a pretreatment is done to remove grit, debris and floating materials. The primary treatment of contaminated common waters to reduce discharge of SS to recipient is generally recommended. Sedimentation, some times with flocculation (by Alum) in rectangular clarifiers with a surface load of 0.6–1.0 m/h (m^3/m^2h) and depth of 4–5 m is widely used. The sludge should be removed. The resulting effluent has less than 20 mg/l SS (70% reduction) and BOD is reduced by 25–50%.

Biological treatment is most common secondary treatment method in Pulp and Paper industry. This reduces the soluble organics. There are several biological treatment methods in use. These are anaerobic lagoons, activated sludge systems, oxidation ponds. The fundamental characteristics of different methods are approximately same. Biological waste water treatment processes utilize a mixed population of microorganisms which convert the dissolved organic matter to new cellular material. Aeration time and temperature are important in their operation.

Anaerobic lagoons with a detention time of 20–22 days reduce BOD level from 800 to 90 mg/l (80–90% reduction). Aerated lagoons need large land area with 4–6 days retention and can remove 80–90% BOD red-

uction. Trickling filters can reduce 40–60% BOD. Activated sludge process require Nitrogen and phosphorous supplementation at the rate of 4.3 kg and 0.6 kg respectively for every 100 Kg BOD removal. Nearly 90% BOD removal is possible by this method. Sludge dewatering requires careful consideration in all these methods.

Colour removal and final polishing can be achieved by absorption. However no commercial scale installations exist. The table 13 shows the summary of the pollution control methods used in mills.

TABLE—13

Summary of Pollution Control methods used in Paper Industry¹⁵

Section	Method
Raw material handling and Storage	— Reduced water consumption by recycling. After removing SS, combined effluent goes for treatment.
Chemical Pulping	— Water recycling, Improved washing and screening, Prolonged cooking, O_2 -prebleaching use of ClO_2 in 1st bleaching stage. Separate treatment of contaminated condensate prevention of accidental losses, use of scrubbers to reduce TRS and SO_2 .
Mechanical/CMP	— Closure of water system, Reduction of discharges of rejects, control of accidental spills.
Paper Making	— Closure of white water system. Use of efficient saveall, efficient fibre recovery.
External Effluent Treatment	— Pretreatment, Primary treatment (Sedimentation with or without chemical) to reduce SS, BOD Secondary treatment to reduce BOD toxicity (Stabilization pond, aerated lagoons, ASP, Trickling filters, anaerobic treatment).

Section	Method
Bleach Plant Effluents	Chemical treatment with lime, Anaerobic/aerobic treatment, Adsorption, with Aluminium oxide, ion-exchange, UF - They reduce colour, COD.
Sludge Dewatering	Dewatering of sludge (Thickening, mechanical dewatering by vacuum filters, presses, belt filters press), Incineration, composting or land fill of sludge.

A flow sheet for water treatment plant with primary and secondary stages is shown in Fig. 1

In small paper mills without chemical after flow equalisation, the combined effluents are sent to a primary clarifier with sludge drying. For anaerobic systems nutrient addition is made such that BOD:N:P is 100:2:0.5. For aerobic system it is 100:5:1. The alternative secondary treatments are shown in table 14.

TABLE—14
Treatment Alternatives for Small Mills without Chemical Recovery¹²
Equalisation of flow, Primary clarifier and sludge drying precede the treatment

Alternative							Treated effluent mg/l
1.	Nutrient Addition	Anaerobic Lagoon DT-20 D (Reduce foaming)	Aerated Lagoon DT-4 D	Polishing Pond DT-2-3 D	SS BOD ₅ COD	—	30 40-50 1000+
2.	—do—	—	6DT	3-5D	SS BOD ₅ COD	—	50-60 30-50 100+
3.	—do—	—	Oxidation Ditch (Foaming Problems)	SST Sludge Drying	SS BOD ₅ COD	—	20-30 30-50 1000+
4.	Anaerobic Lagoon DT-25D	Nutrient	Aerated Lagoon DT-4D	Polishing Pond DT-4D	SS BOD ₅ COD	—	30 40-50 1000+
5.	Aerated Lagoon DT-6D	SST Sludge Drying	—	—	SS BOD ₅ COD	—	50-60 30-50 1000+

The industry will strive to use a combination of suitable technology, inplant measures and external treatments to reduce pollution loads of the effluent streams.

9. Pollution Abatement and Control Technology trends :

The pulp and paper industry will concentrate on various means of reducing pollution loads from being

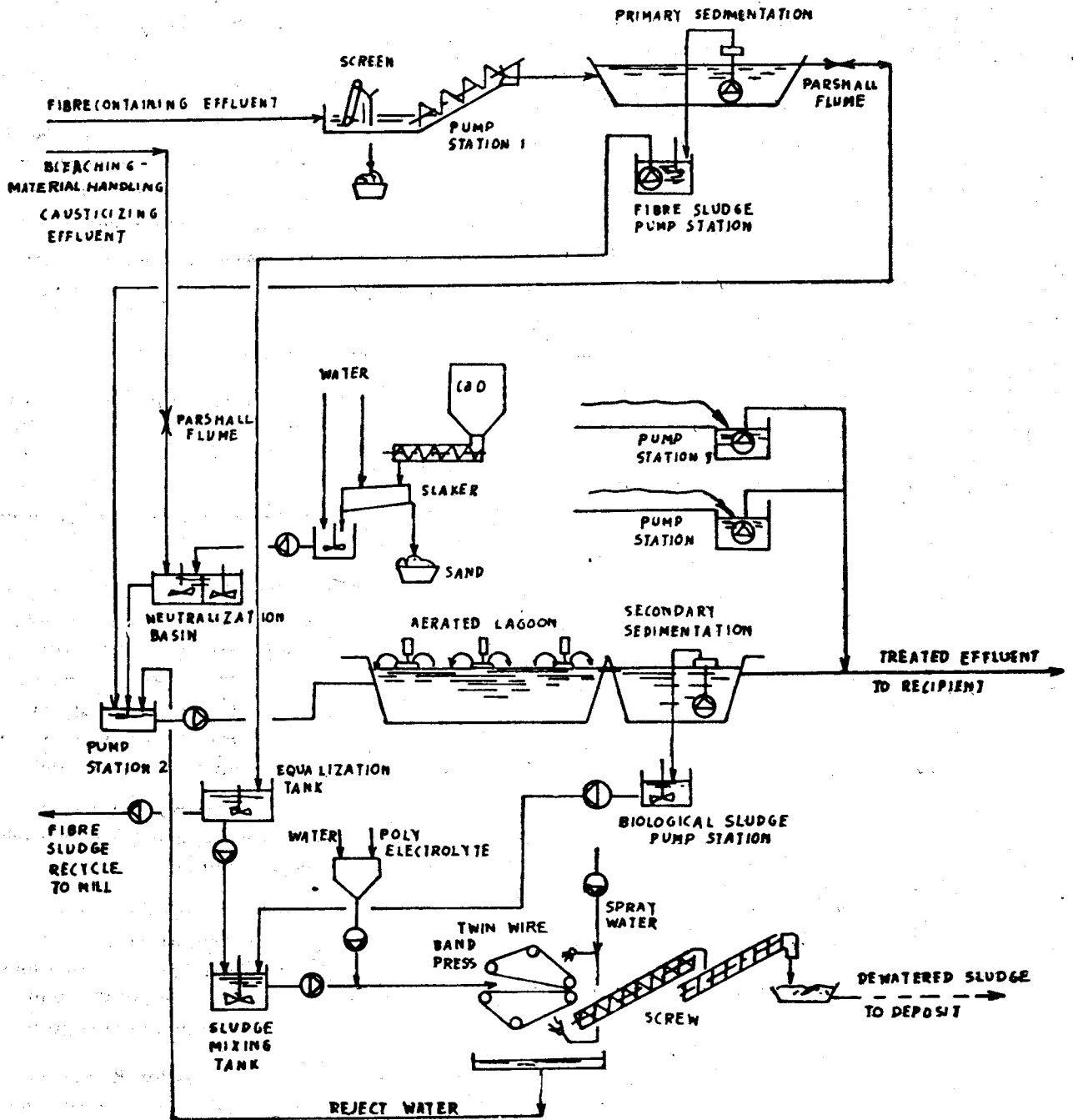
generated and will control them to acceptable limits. An excellent review of current trends is available¹⁵.

The pollution load arises from material handling and storage, pulping (Chemical/Mechanical), bleaching and papermaking. The treatment of pollutants in addition to inplant measure like closure of water systems, reduction of discharges of rejects, control of accidental spills, includes external treatment methods.

SEALING AND COOLING WATER

LOW CONTAMINATED WATER TO

RECIPIENT



The aim in next decade will be to go in for zero effluent discharges¹⁶ and total recycle concept. This can be achieved by choosing proper technologies which increase yields, use chemicals which are less polluting and toxic, adopt more recycling techniques and convert wastes to wealth. A brief description is given below of the likely trends in the years to come which will have a significant impact on reducing and controlling pollution.

9.1 Pulping Bleaching :

- The trend towards high yield pulping (TMP/CTMP) will increase reducing dissolved solids in effluent streams.
- Use of organosolve process^{17,18,19} with different alcohols or phenol or ammonia-Ketone solvents to reduce water pollution and help recover lignin.
- Use of bio-pulping methods hold promise for abating pollution arising out of chemicals³
- Use of oxygen delignification²⁰ continuous cooking with high pressure/impregnation, use of Antroquinone and polysulphides to increase yield are likely to reduce pollution load significantly²¹.
- Holopulping at atmospheric pressure by using selective delignification oxidants like ClO_2 is likely to give 70% yield, reduced odour and pollution load with possibilities in chemical regeneration.
- Explosion pulping of bagasse using soda at 200°C and 13.8 MPa. N_2 -pressure and explosive discharge through multiple bar nozzles reduces alkali consumption by 30–40%, improves drainage and reduces pollution load²².
- Vapour phase pulping of bagasse, with presoaking with alkali, cooked after removal of alkali at 160°C gives 5% more yield than convention liquid phase cooking. The volume of liquid effluents is reduced by half and had a COD of 992 kg/t against COD of 1964 Kg/t in conventional liquid phase pulping²³.
- Use of peroxide, oxygen, nitrogen peroxide and ClO_2 in place of Chlorine in bleaching^{20,24} use of multistage counter current washing can reduce pollution loads.

- Use of green liquor sulphite process with high available alkali for agri-residue will give BL with less silica and help in recovery²⁶.
 - Use of combination of counter current washing with recycling and purification by an adsorption resin can reduce pollution load significantly. Similarly modifications in conventional multistage bleaching sequence for recycling the effluents by UF/RO technology will reduce pollution load²⁶.
- Changes in bleaching sequences can reduce pollution.

9.2 Chemical Recovery :

- Small mills not using chemical recovery can plan Ferrite recovery process (27, 28). Here BL of 30% conc is burnt with Ferric oxide at 850°C. This gives recovery of chemicals and regeneration of ferric oxide besides reducing pollution load significantly.
- Wet cracking of BL (10% solids) of agricultural residue at 360°C and high pressure (200 atm) in absence of oxygen results in carbohydrate conversion to char powder, organics becoming a gas (mixture of CH_4 , C_2H_6 , H_2 and CO_2) with possibilities of SO_2 recovery. The process is claimed to be economic and help control pollution²⁹.
- Desilication process for BL will help in increasing causticization efficiency and Lime mud reburning, thereby reducing pollution³⁰.
- Black liquor oxidation, changes in evaporator configuration (use of venturi evaporator), wet air oxidation, fluid bed combustion, thin film evaporation, oil flash evaporation^{32,32} will help in energy conservation and pollution control.
- Use of UF/RO Technology for Bl regeneration will significantly help energy conservation and reduce pollution³³.
- Possibilities of using BL oxidation to reduce pollution loads and evaporator steam use show promise.

9.3 Treatment methods :

Anaerobic treatment methods will receive greater attention over aerobic treatment methods for reduction of COD due to the generation of methane

gas on one hand and reduced sludge volume on the other^{34, 35, 36}. Many commercial alternatives are available. The system is cheaper than aerobic system and is more flexible.

- Application of SO₂ to reduce bleach plant effluent will receive attention³⁷. SO₂ Treatment significantly reduced toxicity of C_D EHED, and C_D EDED bleach effluents.
- Use of active carbon beds to remove chlorinated organics adhering to fibres and particles alongwith flocculation, settlement and filtration reduces pollution load²⁰.
- Use of closed cycle bleach plant effluents will reduce pollution load^{21, 38}.
- Wet air oxidation of Soda recovery effluents control deposits³⁹.
- In stream aeration of waste waters⁴⁰, recycling and individual processing of selected effluents⁴ reduces pollution load.
- Removal of colour by use of dolomite, coal ash^{41, 48} use of fungus (Ligninolytic cultures of white rot fungus—Phanerochaete chrysosporium)^{42, 43} for bleach plant effluents could be quite successful. Fungal treatment can reduce energy requirements for secondary refining of TMP⁴³.
- Use of Ca-hypochlorite, Changing CEHH to HCEH or HCEHH bleaching sequence reduced colour by 76% and Pollution load by 40–50%⁴⁴.
- Fluidized bed incineration and heat recovery of primary clarifier sludge is possible. Further cleaning of flue gases by multicleaners will reduce the particulates⁴⁵.
- Use of hydrogen peroxide (7 to 10 mg/l) can reduce the sulphides from pulp mill effluents to 3–7 mg/l besides reducing odour and sludge volumes⁴⁶.
- Effective use of kraft mill effluents after treatment for irrigation is possible⁴⁷.
- Possibilities of generating protiens, look promising³.
- Reduetion of dust in bagasse handling and boiler operations will receive attention.

10. Conclusion :

Bagasse is going to be key material for paper making. The processing technology is in for far reaching changes. Pollution abatement and control is going to be an important area requiring attention. There is a need for systematic monitoring of bagasse based paper industry for getting first hand reliable information on pollutants, their characteristics and their effects on environment. The monitoring of gaseous, liquid and solid effluents must proceed as a regular strategy to develop alternatives to achieve minimum acceptable standards. This will require development of new cost effective technologies to reduce pollution.

REFERENCES

1. Koncel, J. K. —Paper Trade Journal, Vol. 169, No. 2, PP 43–45, December (1985).
2. Judt, M. F. —Proceedings of the International Seminar on “Bagasse Newsprint”, Madras, PP 48–50, April (1986).
3. Moreno, R.A. —“Bagasse Paper Making Environmental Aspects -Actual State and needed advances” Paper Presented in UNEP Workshop on Environmental aspects in Non-wood fibre Pulp and Paper Manufacture” —Hangzhou (China) Nov. 24–28, (1986).
4. Salabar, J. & Maza, F—TAPPI CA Report No. 40, P 89 (1971).
5. Snarez, R.C, Gonzalez, E.B, & Alaba, H.D. — UNEP Industry and Environment, Vol. 6, No. 1, PP 9–10, Jan/Feb/March (1983).
6. “Environmental Management in Pulp and Paper Industry” —Vol. 1, UNEP —Industry & Environment Manual Series, No. 1, (1981).
7. Proceedings of the “International Seminar on Bagasse Newsprint”, Madras (India), April 6, (1986).
8. Venkataraman, T.S. & Torza, S—TAPPI Proceedings, 1986 Pulping Conference, Vol. 1, PP 23–34 Ontario, October 26–30, (1986).

9. Rangamannar, G., Venkataraman, T.S., Harrison, J.R. & Defoe, R.J. —TAPPI Proceedings, 1986 Pulping Conference, Ontario, Vol. 1, PP 35-42 October 26-30 (1986).
10. RAO, M.V.G., Rao, N. R. M., Satyanarayan, T. V. V. Sarkar, P. K. & Dorairajan — TAPPI Proceedings, 1986 Pulping Conference, Ontario, Vol. 1, PP 121-128 October 26-30 (1986).
11. Blidberg, G.—“Environmental Considerations for non-wood pulping” —Paper presented in UNEP Seminar on environmental aspects in non-wood fibre pulp and paper manufacture”, Hangzhou (CHINA), Nov. 24-28, (1986).
12. “Comprehensive Document for Small pulp and paper industry”—Report by NEERI, Nagpur, May (1985).
13. “The SSVL Environmental Care Project Technical Summary”—Stockholm, (1974).
14. Setty, T.K.R., Subramanya, S.B. & Rajaram, B.K. IPPTA—Convention Issue, PP 115-125 (1983).
15. “Pollution Abatement and Control Technology (PACT) Publication for Pulp and Paper Industry” UNEP Industry and Environment Information transfer series—(1985).
16. Salloum, J. D. & Betts—International Seminar on “Management of Environmental problems in Pulp and Paper Industry”—DPC, Delhi, PP 66-70 Feb. (1982).
17. Kbeinert, T.N.—Annual TAPPI Conference, Miami Beach, Jan. (1974).
18. Singh, S.V., & Sharma, Y.K.—International Seminar on “Management of Environmental Problems in Pulp and Paper Industry” DPC, Delhi, PP 230-235 February (1982).
19. Johansson, A. —“Environmental Aspects of Non-wood fiber pulp and paper manufacture.” UNEP Workshop, Hangzhou (China) Nov. (1986).
20. Mc Allister, J.—Pulp & Paper JI., Vol. 39, No. 3, PP 24-34 March (1986).
21. Kramer, J.D. —TAPPI, Vol. 64, No. 10, PP-7, October (1981).
22. Marners, H., Yurittu, J.P., & Menz, D.J.—TAPPI Vol. 64, No. 7, PP 93-96, July, (1981).
23. “Vapour Phase Pulping of Agricultural Residues” —Research report No. 15, CPPRI, (India) August (1985).
24. Ruhaenen, M. & Duggal, H.S., —TAPPI, Vol. 65, No. 9, PP 107-111, September (1982).
25. Sapkal, V. S. & Basu, S.—IPPTA Convention Issue, PP 123-127, March (1984).
26. Chen Ren. Yue—“The Main pollution abatement measure of non-wood fibre pulp mills-Chemical Recovery” —UNEP Workshop, Hangzhou, China, November (1986).
27. Chaudhuri, P.B.—International Seminar on “Management of Environmental problems in pulp and paper industry”, DPC, PP 293-298, February (1982).
28. “Development of a suitable chemical recovery process for small mills—studies on ferrite [DARS] recovery process” —Research Report no. 16, CPPRI, September [1985].
29. Tan Lang—PPI, Vol. 28, No. 6, PP 58-59, June [1986].
30. Veeramani, H. & Prabhu, P.S. —IPPTA Convention issue, PP 151-154 [1983].
31. Andrews, R. R., Roscoe, R. S —TAPPI, Vol. 64, No. 12, PP 49-51, Dec. [1981].
32. Clay, D.T, Karnofski, M.A., —TAPPI, Vol. 64, No. 12, PP 45-48, Dec. [1981].
33. Basu, S., & Irrana, K. —IPPTA convention issue, PP 163-166, [1983].
34. Harvey, L.M., & Rubiano, J.C.—Paper Trade JI., Vol. 167, No. 6, PP 28-30, March 30, (1983).
35. —, Pulp and Paper Trade JI., Vol. 39, No. 3, PP 36-38, March (1986).
36. Priest, C.J.—TAPPI, Vol. 64, No. 11, PP 55-60, Nov. (1981).
37. Donnimi, G.P., Mosher, S.C. & Scroggins, R.P. — Pulp & Paper Canada, Vol. 86, No. 12, T 410-413 (PP 190-193), December (1985).

38. Geller, A., & Gottsching, L.—TAPPI, Vol. 65, No. 9, PP 97-101, Sept. (1982).
39. Bennett, A.J., Gillett, J.D., & Wunder, H.—APPITA, Vol. 35, No. 5, PP 383-394 March (1982).
40. Eder, L.J., Cunningham, W.J., & Ratliff, F. T.—TAPPI, Vol. 65, No. 11, PP 85-88, November (1982).
41. Srivastava, R.K., Mathur, K.C.—Indian Pulp & Paper, Vol. 40, No. 1, PP 5-6, June-July (1985).
42. Sudman G., Kirk, T.K. & Chang, H.—TAPPI, Vol. 64, No. 9, PP-145-148, September (1981).
43. Barker, S.S., Kirk, T K., & Chang. H., —TAPPI, Vol. 65, No. 10, PP 111-113, October (1982).
44. Bhargava, G G., Dwivedi, R.P., Jangalgi, N. R. & Kaul, S.S.—IPPTA, Vol. 18, No. 3, PP 58-59, September (1981).
45. Keki, R. M.—TAPPI, Vol. 64, No. 9, PP 149, September (1981).
46. Tendulkar, S.R., & Datta, S.K.,—IPPTA, Vol. 18, No. 3, PP 56-57, September (1981).
47. Rangan, S.G., & Rao, A. R. K.— Workshop on "Pollution Control in Paper Industry"— FICCI, New Delhi, December (1985).
48. Parthasarthy, V.R. Chandra S., Saxena, U.L., & Chowdhary, L. N. — International Seminar on "Management of Environmental Problems in Pulp and Paper Industry" — DPC, PP 139-159, February (1982).
49. Rao, N.J.—"Environmental aspects in processing bagasse for pulp and Paper manufacture" — UNEP Workshop Hangzhou, (China), November (1986).