The Current State of Paper Recycling - A Global Review

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ABSTRACT:- Wastepaper looks set to become an increasingly important part of the papermaking furnish during the 1990s. Pressure leading to its' increased utilisation rate are numerous and include preservation of forest reserves, reduction of the mounting solid waste problem and tight virgin fibre supplies. Despite the emergence of the environmental forces for the use of wastepaper, economic reasons continue to be important and in many respect, a necessary factor for promoting recycled fibre use in the paper and board industry.

It should be noted that for effective utilisation of wastepaper as sources of secondary fibre, it is necessary to sort and classify the materials into suitable quality grades like Old News Paper (ONP), Old Magazines (OMG), Old corrugated containers (OCC) and Mixed office waste (MOW).

Moreover, from the demand supply study, it was found that sufficient wastepaper is available from US/Europe at a reasonable cost. This justifies the recycled fibre-based new installations.

Furthermore, technical developments in recycled fibre use bring additional economically feasible solutions to increased secondary fibre use. Growth in the demand of deinking grades is one of the key trends in the wastepaper business. Deinking of pulp fibre is essentially a laundering or cleaning process where the ink is considered to be the dirt. In the washing process, dispersants are employed with the detergents to disperse the ink constituents into very fine particles. The removal of the ink dispersion is then accomplished by a multistage washing sequence. In the flotation process, collectors are employed to promote foaming and flocculation of the ink particles. However, in such situations with furnishes having substantial portion of both dispersible and indispersible inks, neither washing nor flotation alone is efficient and it is necessary to consider the hybrid system having both washing and flotation sections. In this system, it is imperative that the added chemicals should have the properties of both dispersants and collectors. Some common names for these products are displectors.

However, deinking process generates large quantities of deinked sludge which have to be disposed of in an economical and environmentally

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sound manner. CPPRI, Babcock & Wilcox are currently studying the use of combustion and composting of the sludge as an efficient and economical means of disposal.

KEYWORDS:- *Wood, Bamboo, Bagasse, Wastepaper, ONP, OMG, OCC, MOW, Washing Deinking, Flotation Deinking, Combined Deinking System.*

INTRODUCTION

Wood and bamboo are the traditional primary fibrous raw materials for production of paper worldwide. Dwindling forestry resources, ecological considerations and rising costs have forced the paper industry world over to seriously consider conservation and to explore prospects for the utilisation of alternative raw material resources. As a result, the utilisation of secondary fibre (e.g. rice straw, bagasse etc.) as well as recycled waste paper is gradually gaining confidence of the industry. Use of rice straw/wheat straw suffers from following constraints which prevent its widespread use in paper making.

* High demand of straw as fodder for cattle feed which is a priority rural need. Straw has also an extensive use as a material for roof thatching in village housing.
* Technological problems with regard to chemical recovery because of high silica content.

Utilisation of bagasse for making newsprint/printing paper is well proven and there are a number of mills in India running successfully and producing quality paper from a predominantly bagasse furnish. However, bagasse based mills tend to be highly capital intensive and cost of bagasse is susceptable to seasonal fluctuation.

Wastepaper looks set to become an increasingly important part of the papermaking furnish during the 1990s. Currently, worldwide wastepaper consumption is about 31% of the total paper and board production. By the end of the decade, the figure could pass 40% (1). Pressures leading to the increased utilisation rate are numerous and include preservation of forest reserves, reduction of the mounting solid waste problem, and tight virgin fibre supplies. Because of the rising cost of market pulp, more mills are buying wastepaper and several waste-based mills are being planned (2).

The present study concerns itself with the review of various techno-economic aspects of paper recycling.

SORTING OF WASTE PAPER

Quality fibre is the key to success. Garden State Paper (GSP) company has seen the quality of its paperstock degenerate in direct proportion to the number of municipalities getting into the recycling business (3). For example, household often consider everything wrapped in the morning paper to be newsprint. As a result, other paper grades are mixed in. as well as contaminants. Thus fibre quality must be downgraded to mixed paper and the price lowered.

For effective utilisation of waste papers as sources of secondary fibre, it is necessary to sort and classify the materials into suitable quality grades. Much of the sorting is done by the collector because this allows him to obtain top price for the waste product. Usually, sorting at the utilising mill is limited to occasional quality control checks to ensure that objectionable materials are excluded. Potentially recyclable paper products are:-Old News Paper (ONP) Old Magazines (OMG), Old corrugated containers (OCC), and Mixed office waste (MOW).

WASTE PAPER SUPPLY AND DEMAND

Worldwide nearly 75 million tons of recycled fibre were consumed by the paper industry in 1988, accounting for almost one-third of the total papermaking fibre needs of the industry. North America and western Europe (as a whole) each consumed 20 million tons of wastepaper in 1988, followed by Japan with a consumption of 12.5 million tons. These three regions accounted for about 70% of the total worldwide use of recycled fibre (4). During the period 1970 to 1988, the demand for recycled fibre grew twice as fast as the demand for virgin pulp on a worldwide basis. This growth amounted to 5% per year for recycled fibre vs. 2.5% per year for virgin fibre. It appears the demand of recycled fibre will continue to grow even more rapidly in the future.

U.S. and Canadian wastepaper consumption has risen at a steady pace since the late 1980s, but export markets have steadily declined due to new trend overseas. This has driven some wastepaper prices worldwide to their lowest levels in many years, and the downslide probably is not over yet (5).

European market curbed its consumption for the U.S. wastepaper primarily due to recycling legislation in Europe, specially Germany's Green Dot Programme. Subsidized wastepaper from Germany is flooding not only the European market but also as far away as the Far east. Department of commerce export statistics far 1987 show that the Far east was the biggest buyer of U.S. exports of wastepaper (2). Considering the present situation, steady supply of wastepaper from U.S. is quite bright. Table-1 presents the recovery, consumption, import

Table-1.

Wastepaper recovery, consumption, import & export by some leading countries

('000 Tonnes)

Country	1986	1987	1988	1989	1990	1992	1993
U.S.A.							
Recovery	20029	21693	23177	24563	26242	30479	32450
Consumption	16271	17329	17745	18344	19769	24765	24234
Imports	91	115	146	157	112	136	125
Exports	3401	4012	5117	5722	5901	5850	5342
Germany	(*)	(*)	(*)	(*)	(*)		
Recovery	4560	4746	5452	5845	6334	7912	8564
Consumption	4084	4315	4965	5202	5771	6742	6995
Imports	479	596	699	727	799	712	555
Exports	949	1014	1165	1273	1399	1885	2124
Netherlands							
Recovery	1177	1411	1528	1491	1567	1728	1740
Consumption	1228	1477	640	1687	1820	1998	2017
Imports	461	538	685	788	861	1255	1260
Exports	372	459	584	588	635	985	983
Belgium							
Recovery	523	612	705	691	684	746	640
Consumption	236	260	262	255	265	286	273
Imports	79	73	105	102	103	140	145
Exports	366	425	548	541	523	600	512
United Kingdom							
Recovery	2355	2603	2781	2977	3092	3246	3224
Consumption	2147	2310	2417	2578	2847	3086	3125
Imports	40	55	60	80	159	158	52
Exports	248	348	424	479	404	318	151
France							
Recovery	2342	2550	2712	2878	3039	3117	3217
Consumption	2289	2460	2812	3086	3295	3527	3778
Imports	423	411	646	718	775	996	1001
Exports	476	512	546	510	520	586	440
Canada							
Recovery	1077	NA	NA	1339	1310	1881	2116
Consumption	1595	1695	1811	1851	1789	2905	3612
Imports	634	729	550	540	497	1026	1488
Exports	233	261	170	314	260	231	232
Japan							
Recovery	10511	11209	11957	13091	13860	14466	14386
Consumption	10730	11591	12539	13487	14603	14924	14841
Imports	352	616	588	438	634	444	417
Exports	127	59	6	51	22	36	46

Source: Pulp & Paper International
Note: Star (*) marks figures relate to Federal Republic of Germany.

and export figures for waste paper from 1986 to 1993 with respect to USA, Germany, U.K., France, Holland, Belgium, Japan and Canada (2). Recovery and consumption for various grades are discussed in the following paragraphs.

Most of the increase in utilisation rate in the U.S. occurred in two grades-ONP and OCC. The ONP growth has been spurred by recent legislation in some 25 states mandating that newspaper publishers use newsprint containing various levels (upto 90%) of recycled fibre. Additionally, several new federal laws provide incentives for the manufacture of recycled newspaper. Recovery of ONP are expected to exceed 50% in 1995 (6). As rates increase beyond 50%, fiber supply tightens and eventually reaches a plateau. OCC recovery rates in 1990 went above 50% and should continue rising through 1995. This grade will soon be at or near the ceiling of practical recovery (65-70%) and some temporary spot shortages could begin occurring in the near future (6). The reason for such extensive recovery and reuse of OCC is that it is easily collected and sorted.

Utilisation of MOW actually declined significantly during the 20-years period (1970-1990), from a utilisation rate of about 22% to near 11% (6). This decline was due primarily to sorting and deinking difficulties. However, currently its utilisation rate has improved very rapidly. This represent a major potential fibre source for recycled fine papers, once significant processing hurdles are overcome.

Alongwith ONP, collection of OMG have risen in line with the startup of newsprint flotation deinking systems, which require a mix of ONP and OMG, typically in a ratio of around 70 : 30 (5).

DEINKING TECHNOLOGY

Growth in the demand of deinking grades will be one of the key trends in the wastepaper business. In 1988, some 11 million tons or approximately 14% of the recycled fibre used, are deinking grades. Approximately half of this is used for newsprint, with another quarter going to tissue products. Thus the great bulk of wastepaper-64 million tons or close to 85% of the total is used without deinking, mainly in packaging grades. By 2001, the deinking grades are expected to have increased to about 31 million tons or 24% of the total consumption (130 million tons) of the recycled fibre (4). This is inevitably going to result in the construction of more and bigger deinking plants.

Deinking of pulp fibre is essentially a laundering to cleaning process where the ink is considered to be the dirt. Chemicals, along with heat and mechanical energy, are used to dislodge the ink particles from the fibres and disperse them in the aqueous medium. The ink particles are then separated from the stock, either by washing or flotation or by using a modern hybrid process that combines the two elements.

The key chemicals used for stock deinking are surfactants. These chemicals are usually chemically modified mineral oils, where hydrophilic groups have been added to the molecular structures to make them partly soluble. Surfactants affect the surface tension of liquids and solids. Three specific types of surfactants are important in deinking applications (7).

detergents - to remove ink from the fibre.
dispersants - to keep the ink particles dispersed and prevent redeposition onto the fibres,
foaming agents - to reduce the surface tension of water and promote foam formation.

Other chemicals (caustic soda, sodium silicate, sodium carbonate etc.) are also used to enhance the action of the surfactants. Details of such deinking processing aids are given in Table-2.

Table-2

Deinking Processing Aids (8)

Deinking Chemical	Structure Formula	Function	Dosage (% of Fibre)
Sodium Hydroxide	$NaOH$	Fibre swelling-ink breakup, saponification ink dispersion	3.0-5.0
Sodium Silicate	Na_2SiO_3 (hydrated)	Wetting, peptization, ink dispersion, alkalinity and buffering, peroxide stabilisation	2.0-6.0
Sodium Carbonate	Na_2CO_3	Alkalinity, buffering, water softening	2.0-5.0

Deinking Chemical	Structure Formula	Function	Dosage (% of Fibre)
Sodium or Potassium Phosphates	$(NaPO_3)n$. n=15 Hexameta-phosphate $Na_5P_3O_{10}$ Tripoly-Phosphate Tetrasodium Pyrophosphate	Metal ion sequestrant. Ink dispersion. Alkalinity, buffering, detergency, peptization	0.2-1.0
Nonionic Surfactants	$CH_3(CH_2)n$ CH_2-O $(CH_2CH_2O)_x$ H Ethoxylated linear alcohol. Ethoxylated alkyl phenols	Ink removal. Ink dispersion. Wetting, emulsification, solubilizing	0.2-2.0
Solvents	C_1-C_{14} aliphatic saturated hydrocarbons	Ink softening solvation	0.5-2.0
Hydrophilic polymers	CH_2 CHCOOH (Na)n Polyacrylate	Ink dispersion Antiredeposition	0.1-0.5
Fatty acid	$CH_3(CH_2)_{16}$ COOH stearic acid	Ink Flotation aid	0.5-3.0

It is important to note that the addition of chemicals suitable for the washing/ flotation process is variable depending on the furnish quality and quantity.

Deinking by Washing

In the washing process. dispersants are employed with the detergents to disperse the ink constituents into very fine particles. The removal of the ink dispersion is then accomplished by a multistage washing sequence. Both the cleaning and dispersion operations are carried out in the pulper. The function of this pulper is to transform the wastepaper into an aqueous fibrous slurry and at the same time separate the ink from the fibres through the process of emulsification. The ink pigments and oil vehicular components end up as colloidal particles which then can readily be removed by washing. The time required in pulping is dependent on the rate of defibering and not on the chemical reaction which occurs rather quickly. Pulping can be done either batchwise or continuously. with batch operation preferred because of better control and greater uniformity. although requiring double the pulper units for a given throughput.

The separation of ink in the washing process corresponds to a stock-thickening process, whether accomplished by conventional washing equipment or screens. It is convenient to classify devices by discharge consistency.

1. *Low consistency washers-* up to 8% discharge consistency (e.g. sidehill screens and gravity deckers).
2. *Intermediate Consistency washers-* 8-15% discharge consistency (e.g. inclined screw extractors and vacuum filters)
3. *High Consistency Washers-* Above 15% discharge consistency (e.g. screw presses).

A comparison of theoretical ink removal efficiencies and dilution water requirements for commonly used washers is compiled in Table-3.

Table-3

Theoretical ink removal by typical washing devices (11)

Washers	Consistency (% B.D.)		Dilution Factor	Dilution Water required (Gal/BDT)	Theoretical ink removal %		
	Inlet	Discharge			1st Stage	2nd Stage	3rd Stage
Sidehill Screen	0.8	3.0	124	29.735	74.0	93.2	98.2
Gravity Decker	0.8	5.0	124	29.735	84.7	97.7	99.6
Inclined Screw Extractor	3.0	10.0	32.3	7.750	72.1	92.2	97.8
Screw Press	4.0	28.0	24	5.750	89.3	98.9	99.9

Most commercial washing systems are based on counter current water flow to minimise consumption. With countercurrent design. wash water flow is opposite in direction to pulp flow. As illustrated in the simple three-stage system (Fig. 1). fresh or recovered clean water is added for dilution before the last stage of washing, effluent from the second

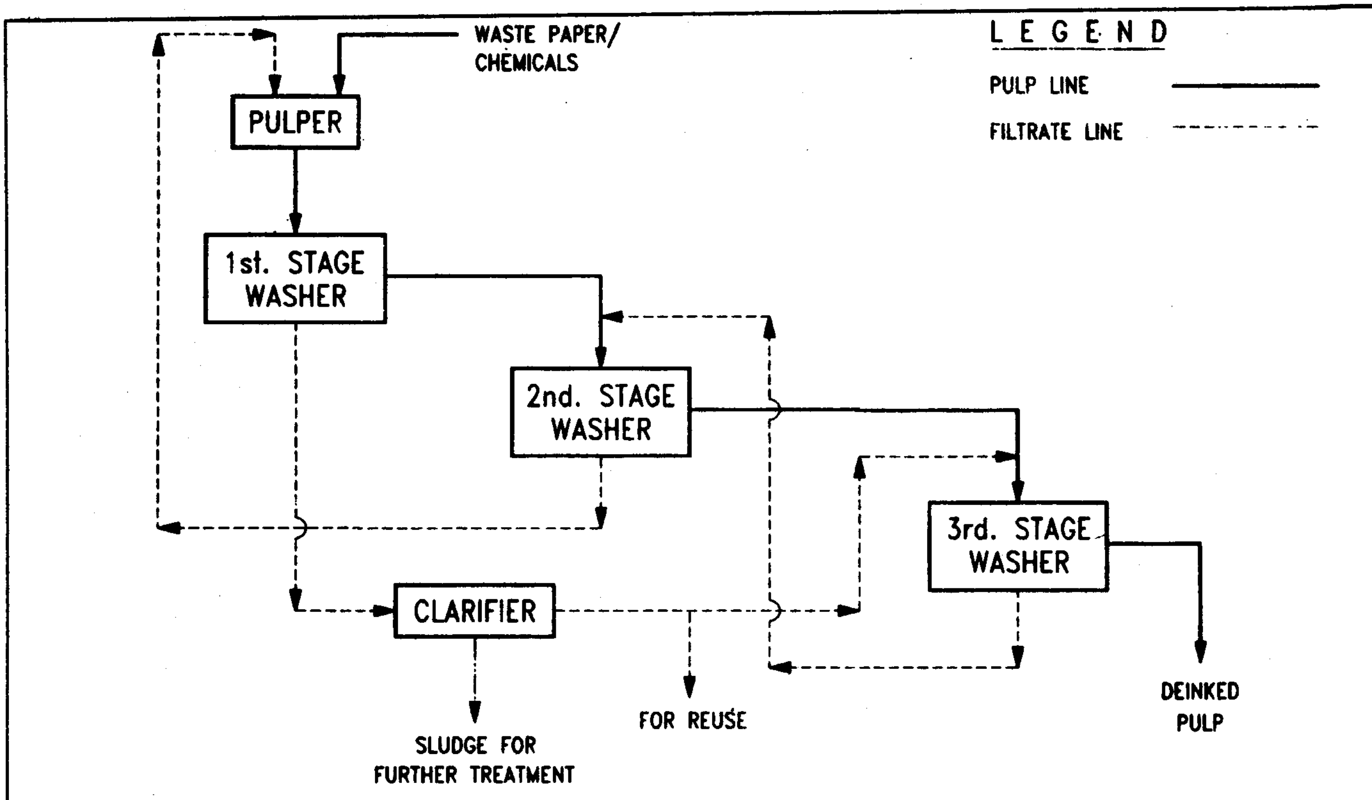

Fig.-1 : THREE-STAGE COUNTER-CURRENT WASHING (10)

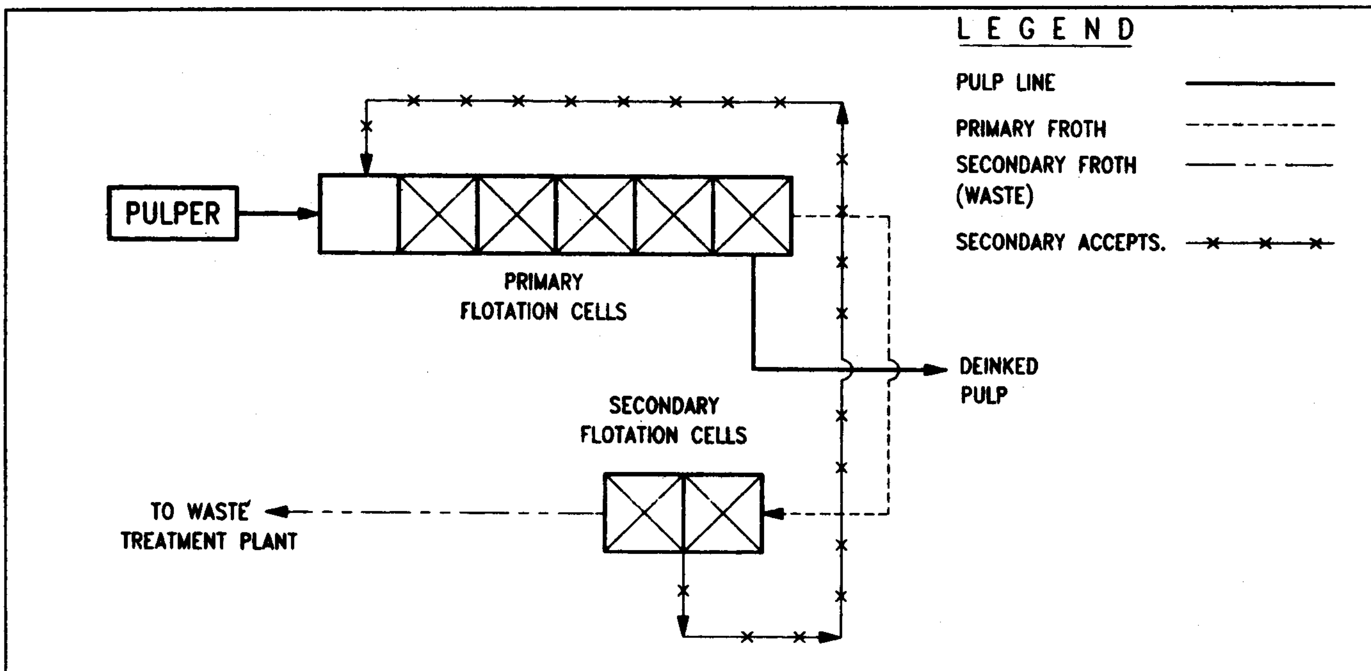

Fig.- 2 : FLOTATION DEINKING SYSTEM

washer is used for pulper make-up and effluent from the first washer, the inkiest, is discharged or clarified (9).

As the ink (which are smaller than 30 microns) is dispersed into a colloidal suspension, particles can be considered soluble and will be removed in proportion to water removed, Theoretical ink removal by a system can be calculated for counter current flow using.

$$r = 1 - \frac{1}{(y/x)^n + (y/x)^{n-1} + \ldots\ldots + y/x+1} \qquad (1)$$

It is shown in Appendix-I that in a three-stage system having gravity deckers each with 0.8% inlet consistency and 5.0% outlet consistency, theoretical ink removal efficiency is 99.6%.

Deinking by Flotation

In the flotation process, the cleaning stage is carried out in the pulper. Chemicals are then added to promote foaming and flocculation of the ink particles. The stock is finally aerated in a series of flotation cells, causing the light flocs of ink particles to rise to the surface where they are skimmed off.

It is achieved by influencing the wettability with water of the particles to be separated. The water repellency of the surface of the particles to be separated is achieved by the addition of special heteropolar chemicals called collectors, which deposit on the surface of the particles. At the same time, the treated particles can deposit on air bubbles that are introduced into the suspension, stabilized by frothers acting on the gasliquid boundary. (12).

The entire flotation machine consists of a number of series connected cells through which the suspension passes in a steady flow (Fig. 2). The cells are connected in two groups. The primary stage cleans the basic material, while the secondary stage is used for reclaiming fibre from the froth coming from the primary stage. Only the accepts from the primary stage are passed on for further processing: the secondary - stage accepts are returned to the basic materials ahead of the primary stage to reduce the loss of valuable fibres. The secondary stage froth goes to waste.

A schematic diagram of a flotation cell is shown in fig. 3.

Washing Vs Flotation-A Comparison

Washing is a viable deinking alternative only with furnishes having dispersible inks or when substantial ash removal from a filled or coated furnish is desired (13). Flotation is most effective in removing larger, nondispersible ink particles, often visible to the naked eye.

It is significant to note that fibre loss from a flotation cell tends to be longer, more valuable fibre, as it is more apt to float to the top. Fibre loss from a washer is primarily fines and debris (most passes through a 200-mesh screen). In this respect, even if fibre loss were higher from a washer, it would not necessarily disadvantageous in terms of pulp quality and process operation.

A washing system offers better process con-

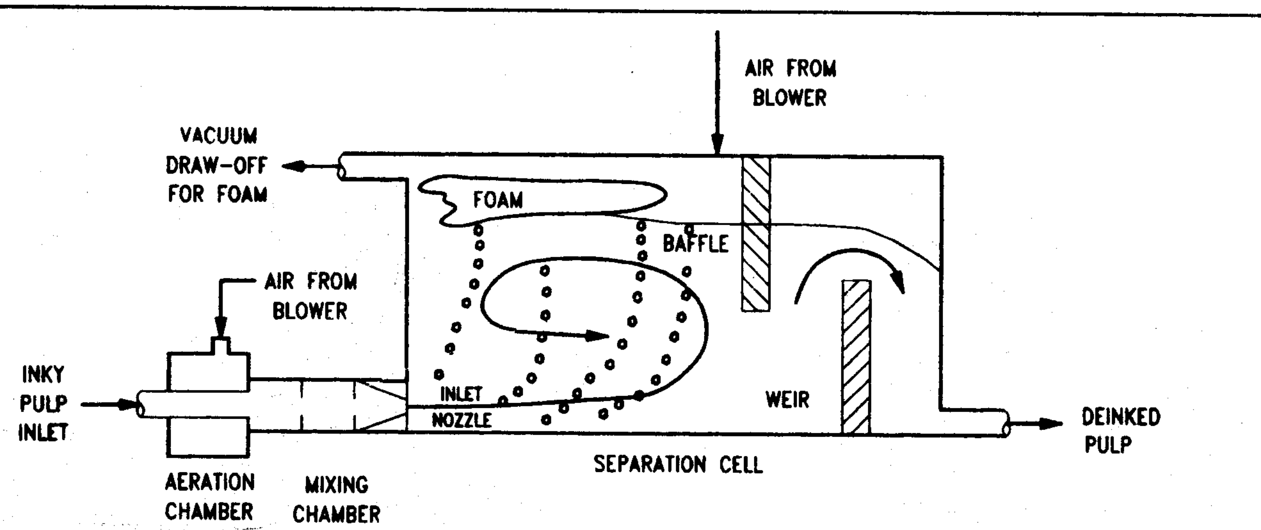

Fig.- 3 : DEINKING FLOTATION CELL

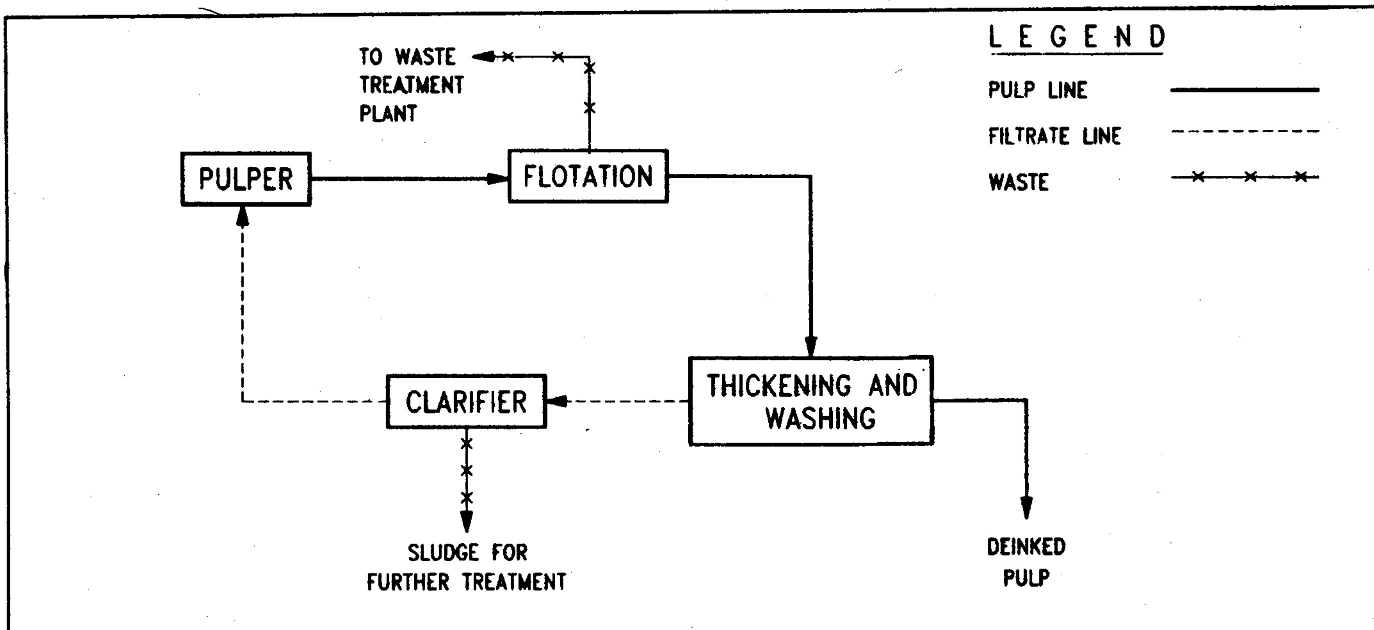

Fig.-4 : BASIC SCHEMATIC DIAGRAM OF A COMBINATION DEINKING SYSTEM WITH FLOTATION FOLLOWED BY WASHING.

trol and stability, after acceptable chemical removal and dispersion in the pulper, ink removal from pulp is mechanical and predictable. With a flotation system after similar chemical removal in the pulper, removal from the pulp depends on further chemical action. Interferences with this chemical environment can result in upsets or quality fluctuations. It also concluded that chemical and capital costs were lower with washing (14). Quality of wash deinked pulp is higher than flotation deinked pulp in terms of brightness, freeness, ash removal, tensile strength, tear strength, burst strength, except opacity.

However, in such situations with furnishes having substantial portion of both dispersible and indispersible inks, neither washing nor flotation alone is efficient, and it is necessary to consider "combination" system having both washing and flotation sections. Combination systems provide new possibilities with very non-homogeneous furnishes or ink types to ensure effective deinking.

Combined Deinking-System

For maximum operating flexibility and improved quality of the deinking stock, a system utilizing both washing and flotation can be used as illustrated in Fig. 4. In the hybrid systems, it is imperative that the added chemicals should have the properties of both dispersants and collectors. Some common names for these products are "dispersant-collectors" "displectors" (15). They are usually proprietary formulations of alkoxylated fatty acid derivatives. Hence, they share some of the physical properties of both dispersants and fatty acid collectors. General chemical structure of different classes of deinking chemicals can be seen in Table-IV.

Table-4.

General Chemical Structure of Several Classes of Deinking Chemicals

Type	Formula	Chemical Nomenclature
Surfactant/ dispersant	$CH_3 (CH_2)_n (C_6H_4) (OCH_2 CH_2)_m$ - OH	Alkylphenol ethoxylate
	$CH_3 (CH_2)n\text{-}(OCH_2 CH_2)_m$-OH ethoxylate	Linear alcohol
Collector	$CH_3 (CH_2)_n C(O) O^-/Na^+$	Fatty acid soap
Displector	$CH_3 (CH_2)_n$-C(O)-$(OCH_2 CH_2)_m$ -OH	Fatty acid Ethoxylate

Deflaking

Fibre separation is seldom completed in the pulper particularly if aged paper is present or the ONP have been exposed to light or heat.Thus the deinking process always contains units called deflakers which are refiner-type machines either conical or planular but operated with a gap between the rotor and stator sufficient to breakdown the residual paper flakes without refining the fibres. Since, metal and other hard contaminant objects can damage the surface elements in the deflaker, which are bars or some-times peg-like protrusions, the deflakers are preceded by units known as high density cleaners which are capable of separating heavy contaminants from fibrous slurries at consistencies of 4 to 5%.

Screening, Cleaning and Bleaching

Removal of contaminants, particularly stickies, is a key element for the success of any recycling system. Separation is achieved either with screen plates or by centrifugal force.

Screening is generally divided into two systems for coarse and fine separation, each system generally will have reject stages to recover fibre and minimise losses. Coarse screens have baskets with circular perforations 1.2-1.5 mm diameter whereas fine screens have slots 0.2-0.25 mm wide.

The separation of heavy-fraction contaminants through the conical end of the cleaners at low consistency (0.5-1.0%) is the most successful and universally used in all paper mills. Since light-fraction contaminants go out the wide end of the centrifugal cleaner, so called reverse cleaner systems were developed with accepts discharged at the conical end. The best approach so far for light-fraction centrifugal separation is use of cylindrical designs where heavy and light fractions discharge at the same end of the cleaner with light in the center.

The bleaching of deinked pulps follows the same procedures as other mechanical pulps, using either sodium hydrosulphite at low consistency (3-4%) or hydrogen peroxide at high consistency (20-25%) as described in TAPPI monograph.

Use of peroxide provides the capability of achieving much higher brightness levels (60-80 ISO) not possible with hydrosulphite but at a higher cost.

Steam is added in hydrosulphite bleaching to achieve a temperature level of 50 - 55°c. Since metallic ions such as iron and manganese can have negative effects on brightness of mechanical pulps, these are readily chelated with agents such as ethylenediaminetetraacetic acid (EDTA) and the metallic ions can be more prevalent with recycled than virgin pulps. Towers are designed for about one hour retention and generally upflow with zone agitation just at the bottom and the top so the mass moves in a plug-like manner. Addition of sodium hydrosulphite is generally in the range of 5-10 kg/ton of pulp.

peroxide bleaching is done at higher consistencies of 20-25%, so the pulp must first be thickened with belt presses which avoids knurling and twisting of the fibres. Chemicals are then added with special mixing device. Typically three different chemicals are used, hydrogen peroxide in the amounts of 1-5% depending on the final brightness desired, 1-2% caustic soda to achieve a pH level of 10.5-11.0 and 3-5% sodium silicate which largely prevents reversion due to iron. Steam is also added to the mixer to obtain minimum temperature of 50° c. and the stock is steeped in a down-flow tower for atleast one hour. It is then important to dilute the pulp back to low consistency (3%) and add a reducing agent such as sulphur dioxide or sodium hydrosulphite to remove any residual peroxide and minimise brightness reversion.

Another reductive bleachidng agent showing promise is thioureadioxide. According to published work, one tissue mill in Austria is using thioureadioxide under production condition (16).

UPGRADING OF RECYCLED PULPS USING ENZYMATIC TREATMENT

Recycled fibres, have lower freeness and strength than virgin fibres, and low pulp freeness limits the speed at which the paper machine can operate. A substantial gain in freeness would enable the use of lower - grade recycled fibres while increasing paper production.

In a joint effort of a European research consortium, the impact of enzyme treatments on dewatering properties, fibre-length distribution, and strength properties was investigated. It was found that the action of endoglucanases was necessary to improve the drainage of reclaimed paper (17).

In another work, experimental designs investigating the effects of enzymes and polymer dosages on the freeness of pulp were conducted. To increase freeness, it is important that enzyme dose, reaction time, temperature, pH and agitation rate be optimised. Under optimal conditions, enzyme dose varies from 2-3 kg/ton of dry pulp, while pH ranges from 5-7. Reaction should be carried out at 40-50^0 C for 120 min (18). Continuous mixing during the enzyme treatment is essential for significant freeness gain.

PROBLEM WITH MOW

Toner "Inks" are widely used in office photocopiers and laser printers, and their use appears to be increasing as newer high-speed copiers and high-resolution printers come on the market. Toners are composed principally of a thermoplastic polymer, either styrene-butadiene copolymer, acrylic polymer or polyester with added carbon black or a colored pigment and sometime iron oxide (magnetite) to render the toner magnetic. The original toner particles are typically about 20 microns in size for most machines.or 10 microns or less for high-resolution printers. During the copying process, the toner particles are laid down electrostatically on a paper sheet to form the desired characters. The paper sheet and toner are then subjected to elevated temperature and moderate pressure. Since the toner is a thermoplastic, the particles fuse under the influence of heat and pressure to form a continuous toner is a thermoplastic, the particles fuse under the influence of heat and pressure to form a continuous toner mass. The heat and pressure also act to strongly adhere the fused toner character to the paper sheet. The extreme tenacity with which the fused toner characters adhere to the paper substrate is obviously a desirable quality for the final copied sheet to possess.

However, this very quality becomes a serious detriment if these copied sheets are subsequently to be recycled (19). For the toner contaminant particles found in MOW, flotation is believed to represent the best separation process, although there are many problems to overcome. Solution to these and many more problems are currently sought, but if real progress is to be made the deinker will have to call other interested parties to his aid. The scope of co-operation between ink producer, paper printer, paper mill and chemical supplier is enormous. Careful formulation of inks to produce a recyclable paper with an acceptable print quality is not an impossible task with existing technology (20).

DISPOSAL OF DEINKED SLUDGE

While helping to take some of the burden of solid waste from the municipalities, recycling in the paper industry creates new waste problem. It generates large quantities of deinked sludge, which have to be disposed of in an economical and environmentally sound manner. CPPRI, and Babcock & Wilcox are currently studying the use of combustion and composting of the sludge as an efficient and economical means of disposal (5).

ENVIRONMENTAL BENEFITS

Environmental benefits compared with aspects of other various virgin pulping methods are as follows (21):

- Forest resources are preserved.
- Municipal landfill life is extended.
- Energy use decreases, reducing operating costs and boiler-generated air emissions.
- Odor emission decreases. Deinking process give off less odor than most chemical pulping processes.
- Chemical use decreases in some cases. Significant chemical savings are possible when deinked pulp is substituted for kraft pulp.
- Effluent BOD_5 loading decreases in some cases.
- Effluent flows are usually lower.

ECONOMICS OF RECYCLING

Despite the emergence of environmental forces for the use of wastepaper, economic reasons continue to be important, and in many respects, a necessary ingredient for promoting recycled fibre use in the paper and board industry. Furthermore, technical developments in recycled fibre use bring additional economically feasible solutions to increased secondary fibre use. The per tonne production cost of ONP/ OMG Deinked pulp for newsprint is approximately Rs. 14000/- which compares favourably with the purchased CTMP and other available alternatives like Mechanical bagasse pulp. For other grades specially printing-writing papers, the picture is mixed for both capital costs and production costs.

CONCLUSIONS

Despite the emergence of environmental forces for the use of waste paper, economic reasons also justify the use of recycled fibre. However, the disposal of deinked sludge calls for more scientific attention. It is also observed that combined deinking system having both washing and flotation sections is the newest development in the deinking technology. From the study of demand-supply gap, it can be concluded that prospect of raw material supply from US/ Europe at a reasonable cost is sufficient to justify new installations in India.

Nomenclature

F = mass of BD fibre fed to washers.

n = number of washing stages.

r = removal of ink particles, %

x = mass of water remaining in thickened stock

$$= \text{mass of BD fibre}\left(1 - \frac{1}{\text{discharge consy.}}\right)$$

y = mass of water removed during washing.

$$= \text{mass of BD fibre}\left(\frac{1}{\text{inlet.consy.}} - \frac{1}{\text{discharge consy.}}\right)$$

Z = mass of ink particles in the colloidal suspension.

APPENDIX-I

SAMPLE CALCULATION FOR INK REMOVAL EFFICIENCY OF COUNTERCURRENT WASHING SEQUENCE

Input Data

Inlet consistency = 0.8%
Discharge consistency = 5.0%

In a three stage system having gravity deckers, each stage is conforming to above data.

$$y = F\left(\frac{1}{0.8} - \frac{1}{5.0}\right) = 1.05\ F$$

$$x = F\left(1 - \frac{1}{5.0}\right) = 0.8\ F$$

i.e. $y/x = 1.3125$

Using equation (1), the following figures can be arrived:

Quantity of ink particles at the outlet of 1st stage washer 0.1588Z.

Quantity of ink particles at the outlet of 2nd. stage washer 0.0252Z.

Quantity of ink particles in the deinked pulp $4.005\times10^{-3}Z$.

Hence, the theoretical ink removal efficiency $(1-4.005\times10^{-3}) \times 100 = 99.6\%$.

APPENDIX-II

THE PER-TON SALES COST OF ONP/OMG DEINKED PULP VIS-A-VIS PURCHASED CTMP

Sl. No.	Description	Unit	Rates (Rs.)	Specific consumption (Unit Tonne of pulp) Deinked	CTMP (Purchased)	Cost (Rs. Tonne) Deinked	CTMP (Purchased)
A.	Cost of Production						
1.	Raw Material						
	a. ONP	Tonnes	7500	0.875	--	6550	--
b.	OMG/MOW	Tonnes	8550	0.375	--	3200	--
c.	CTMP	Tonnes	17500	--	1.0	--	17500
	Subtotal					9750	17500
2.	Chemicals	--	--	--	--	1600	--
3.	Utilities (Coal Power Water)	--	--	--	--	1500	200
4.	Stores, Consumables, Labour etc.	--	--	--	--	1000	150
	Cost of Production (1 Thru'4)	--	--	--	--	13850	17850
B.	Cost of Capital (Incl: Interest, Depriciation etc.) @ 15% on total plant cost	--	--	--	--	1500	150
	Total Per-Ton Sales Cost (A+B)	--	--	--	--	15350	18000

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