Review On Technological Advancement In Waste Paper Recycling : A Simple Laboratory Method To Evaluate ONP And Mixed Office Waste By Floatation De-Inking

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ABSTRACT

Technological advancement in recycling of waste paper, the processes and equipment used for deinking operation has been described. An effort has been made to discuss in brief the relative advantages of using recycled paper, effect of process variables, chemistry involved in de-inking chemicals relative to process and types of inks used.

A simple laboratory method for the evaluation of de-inking efficiency of two commercially available surfactants on old news print (ONP) and mixed office waste with old magazines (PAMPS) has been discussed.

Conventional alkaline pulping, floatation and washing followed by oxidative bleach (H_2O_2) and reductive bleach ($NaHSO_3$) sequence were used for the study. The efficiency of de-inking has been evaluated in terms of brightness, de-inking factor, dirt area, number of ink particles and strength index after each stage. While the performance of the surfactant 2 was found to be better in both furnishes than the surfactant 1, but the dirt removal efficiency was lower in PAMPS. The behavior of ink particles also differs. However, the strength properties were not affected by the process. Surfactants improve the cationic demand and drainage time of pulp.

Introduction

A continuous expansion of Indian paper industries has been noticed in last 2 years. Last year the GDP growth was 6% and a growth of 8.5% by 2011 is expected. Total number of pulp and paper industries are 666 nos., out of which 467 mills are recycled fibre based mills. The number of mills in operation is 568 no with an installed capacity of 9.5 million tonnes. Today, the total installed capacity of paper and newsprint production is around 7.5 million tonnes. The per capita demand for paper and paper board is 8.3 kg. requiring production of nearly 9.3 million tonnes of paper and newsprint. In India, more than 30% of our paper and board production capacity is recycled back.

The stringent guidelines for environmental protection, the growing awareness to conserve natural resources and the incentive given by government for increasing the waste paper usage in different paper grades forced the industry to reutilize the waste paper for long term survival. De-inking process has emerged very promising in the above prospective. The chemical pulp which is currently the largest single source of paper making will lose its dominant position to recycle the fibre in coming years.

Raw material prices are expected to increase over the coming years due to the increasing demand from India and china to cope with their developing economics. In spite of numerous small mills shutting down, the industry capacity and production have grown. About 10 lakh tonnes of capacity is added in 2008 and 2009 and with currently under taken expansions, another 15 lakh tonnes is expected to be added by 2012. With demand growing at a faster rate than capacity expansion, imports have been increasing, leading to further expansion opportunities to minimize this deficit. 50% of industry's requirement of waste paper is met through import which is on increasing trend. We have been able to consume only 3-4 million tones out of 13 – 14 million tones of waste paper available in the country. Recovered fibre consumption is going up globally. In India about 850,000-1,000,000 tons of waste paper is being currently recovered annually. The recovery rate works out to about 20% which is much lower in comparison with 65% recovery achieved by many global players. Low recovery is on account of alternate use of paper in wrapping, packing, etc. The utilization rate of recovered fibre is only 47%. Paper mills are heavily dependent on imported waste paper.

The technology advancement has given us opportunity to use waste paper in manufacturing specialty papers too, like writing and printing grades[1,2]. For manufacturing writing and printing grades, efficient de-inking of the waste paper is an essential operation in paper making process. Flotation deinking operation is found to be the most efficient process now a days[3]. The most important factor, which will decide the growth rate of paper industry in the coming years, is the availability of suitable raw materials, economically as well as on sustained basis.

Advantages of Recycling:

- Decreasing availability of conventional raw materials
- Requires 60 % less energy than manufacturing paper from virgin timber.
- It is economical, technologically viable and environmental friendly
- Reduction in both capital and operational cost
- Freedom from complete dependence on market pulp.
- Legislation requires the use of secondary fibre in some products. The use of post consumer waste secondary fibre also has been legislated.
- Price usually favorable in comparison with that of corresponding grades of market pulp. The papers from the deinked pulp can

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impart some important special properties (Increased opacity, Less curling tendency, Less fuzziness, Better formation, Better retention of size and fillers, Softer and less tiny character) to the finished papers compared to paper made from wood pulp.

There are also some limitations like collection, limited availability, variation in fibre composition, unevenness of waste paper quality and operation problems, which need to be addressed to overcome these difficulties.

In India, the end uses of waste paper are much different from other countries. The good quality waste papers used for Kraft, liners for duplex boards and in writing and printing paper. The inferior qualities are mainly used for corrugating medium and fillets in duplex and gray boards. The waste papers available in the market are highly heterogeneous.

In India, there is no organized method for collection, segregation, transportation and reuse of various kinds of waste paper. Therefore, we need following things to develop:
- Collection of waste paper
- Sorting and grading
- Technology to remove contraries
- Suitable de-inking process (machinery and process)
- Quality of products.

Advancement in system of recycling and de-inking technology:

An increase in the use of recycled pulp and higher requirements in pulp quality have led to improvements of de-inking technologies. Progress has been made in various stages of the de-inking process.

Though a major segment of the Indian industry is utilizing the recovered paper for papermaking, yet the industry is facing serious problems in processing due to inconsistent quality.

The major factor is improper and unorganized collection and distribution system still prevailing in the country. Due to lack of an Indian grading system, at source grading / sorting is not practiced and most of the paper is recovered in mixed form. This results in high percentage of prohibitive material and out throws which adversely affect the quality of recovered paper stock.

Collection of waste paper :

In India, the waste paper is recovered by collection from household, shops, printing houses and converters, rag pickers and municipality waste. There is no integrated collection system [4]. It is still disorganised in India. It is carried out by individual wheeler and system of sorting is unsophisticated. Various ways to improve are:
- Increase Paper industriy's participation in collection and sorting of domestic waste.
- Import mixed waste paper of low cost and sort it here to avail at lower cost.
- Separation of long and short fibres by fractionation at mill.
- Compaining in schools.
- Source separated materials from offices directly by private service.
- The manufacturing industry requires to receive the materials be baled.

Sorting and grading :

There is no facility for sorting, proper grading system and baling of waste paper except for imported waste raw materials. Sorting of mixed waste paper by grade is to be done for different application to enhance the value of fibre can be done manually or by image processing technique. The primary objective and challenge is to obtain the raw materials of highest purity. Properly sorted waste paper will increase the quality of produced paper and save processing chemicals and energy. In recycling, waste papers are to be segregated into various grades as they are subjected to different recycling processes. A grade refers to the quality of a paper or pulp. The basis of grade is weight, color, usage, raw material, surface treatment, finish or a combination of these factors.

There are 20 varieties of waste papers graded in IX groups based on fibre quality and type. Out of which group-I (white wood free, unprinted) & II(white wood free printed) were placed at top to produce quality writing and printing papers. Sorting will make acceptable level of non-homogenity to get product specific desirable paper.

To improve sorting system we have to follow:
- Sorting at source as followed in Japan
- Sorting of imported waste in India and to be baled before sending to mills
- Organised sector of collection for its implementation
- Legislation should be implemented for its exploitation.

Technology to remove contraries

Normally, the equipment used in Secondary fiber processing is of the same type found in other pulp and paper mills processing virgin fiber. Some equipments are specifically modified for the use of secondary fiber, or use different mesh wire and screens.

Secondary fiber processing requires a multiplicity of cleaning and screening equipments, in different sequences, combinations and sizes, as per specific needs. The screening equipments work on the principle of size and shape for removal of contraries. Combinations of screens with different sizes of slots and holes are often used as standard equipments in all the secondary fiber based mills [2]. The mesh size of screen to be used for better efficiency ranges at different systems are : Washing (1 - 10 microns), Floatation (10 - 150 micron), Cleaning (100 - 1000 microns) and Screening (1000 micron and above).

All the three types of centri-cleaners i.e. forward, reverse and high density are normally used in the secondary fiber processing, in different stages, which work on the principle of difference in specific gravity of the constituent fiber, debris and contaminants for separation / cleaning. Each mill has its own configuration of different process equipments depending on the raw material used and to make desired products.

Suitable deinking process (machinery and process)

Machinery:

Pulping **:**

Medium consistency pulpers and drums are the currently used in pulping technology. The former is favoured due to better ink detachment and the latter due to less breaking up of contaminants. Large Drum pulpers [5], batch Helico pulpers [6] are used. Large drum pulper are used for high daily production capacity (600 T/d), but Helico pulpers are used for smaller production.

Screening and cleaning**:** Machinery suppliers have made a large contribution to the improvement of contaminant removal with the development of contoured fine slotted screens (down to 0.15 mm and even 0.10 mm). The last development of this new generation of screens also uses intermediate dilution of the pulp along the screen which gives a higher efficiency for a lower energy

consumption as well as low fibre losses [7].

Floatation**:**
The design of floatation cells has completely changed since the beginning of deinking. Suppliers now propose high efficiency cells, with a reduced reject rate. The last developments proposed on the market recently are more on injector designs, reduction of floatation losses through counter current washing of the froth [8]. The quality of de-inked pulp has been improved by technology improvement, in de-inking chemical and equipment even for low quality waste paper significant improvement received in pulping, screening, cleaning, light weight contaminant removal, floatation and post de-inking fibre treatment.

Process **:**
Two-stage floatation processes were firstly developed for improving the removal of stickies before or after de-inking. Examples are an acidic loop implemented after a conventional alkaline deinking stage in order to precipitate and remove sticky material by fine screening and cleaning, a process including a first cleaning [9] and screening stage at low temperature, without chemicals in order to remove non-ink contraries before they are broken down into small particles, and a second alkaline stage to release and remove ink [10]. Dispersion and bleaching were very favorable effect on residual ink detachment and implemented between two de-inked loops.
For production of high quality market pulp from office recovered papers some mills are running with 3 loops, 3 floatation stages, 3 thickening/washing stages, 2 dispersing stages, 3 bleaching stages (4 if peroxide in the pulper is considered as bleaching), multiple cleaning and screening stages. However, the trend is to try to reduce the process operating units.

Quality of products

The main causes of defects due to quality of deinked pulps are related to inks and adhesives used for printing, presence of more contaminants in imported waste papers, lower fiber strength and require process adjustments to reduce machine run interruptions.
To overcome all the above to produce a high grade writing and printing paper, the quality standard of waste papers should increase by :

- Classification and types of waste paper used.
- Using papers by grade and reusing high value papers
- Moisture content: should be limited to 10%.
- Out throw: should be free from non-cellulosic contaminants.
- Free from mechanical fibres, unbleached fibres, wet strength paper, carbon paper.
- Free from laser ink printing paper.
- By adopting fibre fractionation or blending with virgin fibre.
- Chemical additives often are required to compensate for reduced fiber strength
- Some other quality parameters along with the steps to be taken for improvement are given below:

Difficulties	Cause	Steps to be Taken
Low brightness	Longer pulping time, low floatation efficiency, presence of water-based ink.	Optimised pulping time, pseudo neutral deinking.
Smeared pulp	Attachment of binder and ink film to the fibres, offset heat set prints	Increasing floatation efficiency with surfactants.
Coloured pulp	Presence of dyes, retrogravure prints, water based inkjet inks	Efficient bleaching (oxidative and reductive).
Specks and dirt	Presence of tonners, laser prints, UV cured inks, digital prints	Increasing removal efficiency in pulping stage.

2.Process involved to remove different types of inks from paper :

Ink type	Raw material	Process to use / Improve
Water based inks	Flexographic print	Efficient washing and screening
Oil based inks	Offset and letter press print	Dispersion, bleaching
Vegetable oil based inks	Offset, offset heat set	Flaotation with surfactant, dispersion, froth floatation module
Aqueous dye based inks	Inkjet prints	Bleaching (oxidative and reductive)

The present work is under taken to find out a easy, suitable method of evaluation of surfactants by flotation process in laboratory which is mostly used for deinking of waste paper. The equipment used is available in all pulp and paper testing laboratories. The de inking study was done to find out the efficiency of chemicals for removing the ink from old news print and office waste.

EXPERIMENTAL

Paper recovered from two sources has been taken for the present study.

1. Old newsprint paper: Indian express (daily newspaper of 6 months old).
2. PAMPS (Office waste paper, old magazines and printed materials:: 50:50).

Surfactants: Sample S1 and S2 available commercially were used. 1% Solutions of these chemicals was prepared and the required amount of 0.2% w/w on OD paper was used.

The collected papers were cut into ½ inch square size. 1 kg of papers were soaked at 8% consistency for 30 minutes and then disintegrated by taking 100gm in each batch for 15 minutes in laboratory disintegrator (Global Engg. Corp.). The freeness was measured and one set of hand sheets were prepared and the brightness, dirt count area, no. of ink particles and strength properties were tested. Hand sheets were also prepared from unprinted portions of the waste paper. The detail experimental conditions for carrying out the evaluation (pulping, floatation, washing and bleaching) a given in Table 1.

Quantities of chemicals were charged as a percentage on the OD paper feed to pulper. The pulping of the disintegrated samples were carried out in laboratory disintegrator at 4% consistency and pH was maintained at 9.0 by adding 1.2 ml of 10% NaOH solution used at temperature of 45 ^{0}C, retention time 12 min., H_2O_2 dose (0.1% on OD raw material), sodium silicate (2%) and EDTA (0.2%).

TABLE 1: PULPING CONDITIONS

Particulars	Unit	Result
Consistency	%	4.0
pH	-	9.0
Temperature	^{0}C	45
Time	min.	12
H_2O_2 on OD raw material	%	0.1
Na_2SiO_3	%	2.0
EDTA	%	0.2
Flotation :		
Consistency	%	0.32
Temperature	^{0}C	40
Time	min.	6
Air flow	kg/cm^2	4.0
Washing :		
Mesh screen size	µm	50
Bleaching :		
Oxidative bleach		
Consistency	%	10
Temperature	^{0}C	80
Time	min.	60
pH	-	9.4
H_2O_2 dose	%	3.0
NaOH	%	1.5
Reductive bleach		
Consistency	%	3.5
Temperature	^{0}C	60
Time	min.	60
pH	0	6.8
$NaHSO_3$ dose	%	1.0

The obtained slurry was diluted to 0.32% consistency, 8 lt. slurry was taken to carry out the floatation test. For floatation test, a laboratory semi automatic hand sheet former manufactured by Fibre tech Instruments, Roorkee (Model FBI 7) was used (Fig-1). The detailed specification and procedure of the equipment is given below:

(Fig -1 : Laboratory semi automatic hand sheet former Model FBI 7, Fibre tech Instruments, Roorkee).

Semi-automatic sheet former has the selection of functions in automatic and manual mode. It is equipped with central cabinet for automatic regulation of filling water, air agitation, drainage. Water is fed to sheet former in solenoid valve which shut off automatically after reached to correct level. It consists of stock container vertical cylinder, filling chamber, wire part, pneumatically operated couch plate, suction chamber and water reservoir with recirculation pump. Agitation to the stock can be started in manual mode. It has three pressure gauges to show the inlet pressure to the sheet former, air pressure during the agitation with a precious air regulator to maintain the airflow as per pulp suspension required. A proximity sensor fitted on the top of the container to maintain the height of the suspension and also prevent the splash over edge of water when the air agitation is operating. The inlet air pressure is maintained at 4.0 kg/cm^2. The agitation air pressure can be changed as per requirement.

The floatation was carried out at 40 ^{0}C at air flow rate of 4 kg/cm^2 for 6 min. Foam was collected and yield loss and sludge generation was calculated. Yield loss was also calculated from the effluent generated after washing from 150 mesh screen. The drainage time was noted. The retained slurry was diluted and 60 gsm hand sheets were prepared. Washing was done in a centrifuse with mesh size of 50 mm screen. Bleaching was performed in two stages with oxidative bleach using H_2O_2 (3%) and reductive bleach with (1%) sodium hydrosulfite. The above procedure was done under 3 sets of conditions, i.e. without addition and with 0.2 % of surfactant each of S1 & S2 in pulping.

Hand sheets of 60 gsm were prepared after each stage of pulping, floatation, bleaching and tested for brightness, de-inking factor, dirt area, no. of ink particles and strength index properties. The results a presented in Table 2 (ONP) and Table - 3 (PAMPS). The ISO brightness is measured by Technydyne brightness tester on both sides of the sheets, is reported as an average. The dirt area and strength properties were tested using the standard TAPPI procedures. The efficiency of a de-inking operation i.e de-inking factor (the ratio of amount of ink removed, to the amount of ink present before de-inking) were calculated. The cationic charge demand of the drained water was tested. The results a presented in Table-4.

TABLE - 2: DEINKING BEHAVIOUR OF OLD NEWS PRINT PAPER A: WITHOUT SURFACTANT

Sl. No.	Particulars	Unit	Initial	After pulping	After floatation	After washing	After H_2O_2 stage	After $NaHSO_3$ stage
1.	Brightness - Unprinted Brightness -Printed	%ISO	51.0 44.5	47.0 40.8	50.5 44.0	49.6 45.5	52.5 48.5	54.5 53.7
2.	Deinking factor	%	-	-	33.0	53.4	65.8	94.2
3.	Dirt count	mm^2/m^2	564	555	100	89	43	35
4.	No. of ink particles	$no./m^2$	5750	5761	1450	1113	1250	1200
5.	Strength index	-	947	1015	1063	1026	1151	954

B: WITH SURFACTANTS

Sl. No.	Particulars	Unit	After floatation		After washing		After H_2O_2 stage		After $NaHSO_3$ stage	
			S1	S2	S1	S2	S1	S2	S1	S2
1.	Brightness	%ISO	45.6	45.4	46.4	46.0	49.5	49.3	53.8	54.5
2.	Deinking factor	%	49.5	47.4	63.6	59.1	74.4	72.6	94.9	100
3.	Dirt count	mm^2/m^2	53.5	50.0	44	39	31	24	22	19
4.	No. of ink particles	$no./m^2$	850	900	550	488	720	700	650	650
5.	Strength index	-	935	1041	983	1050	1091	1032	1032	922

Fig.- 2: Improvement in Properties of Old News print pulp after Different Stages

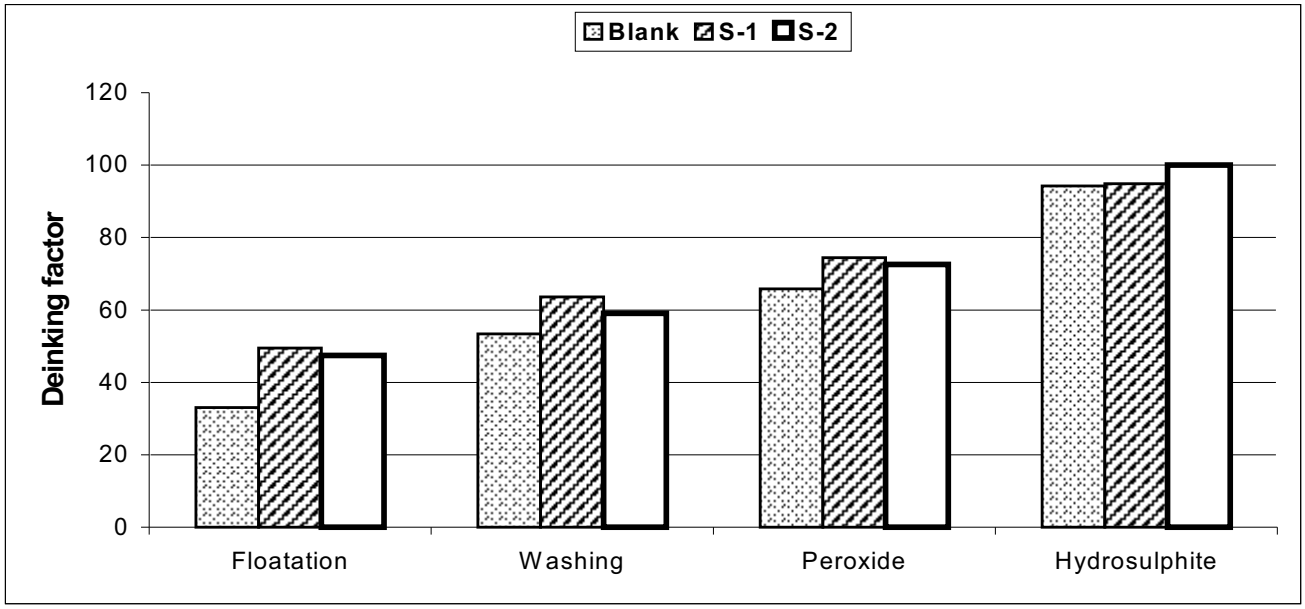

Fig. 2A: Deinking factor

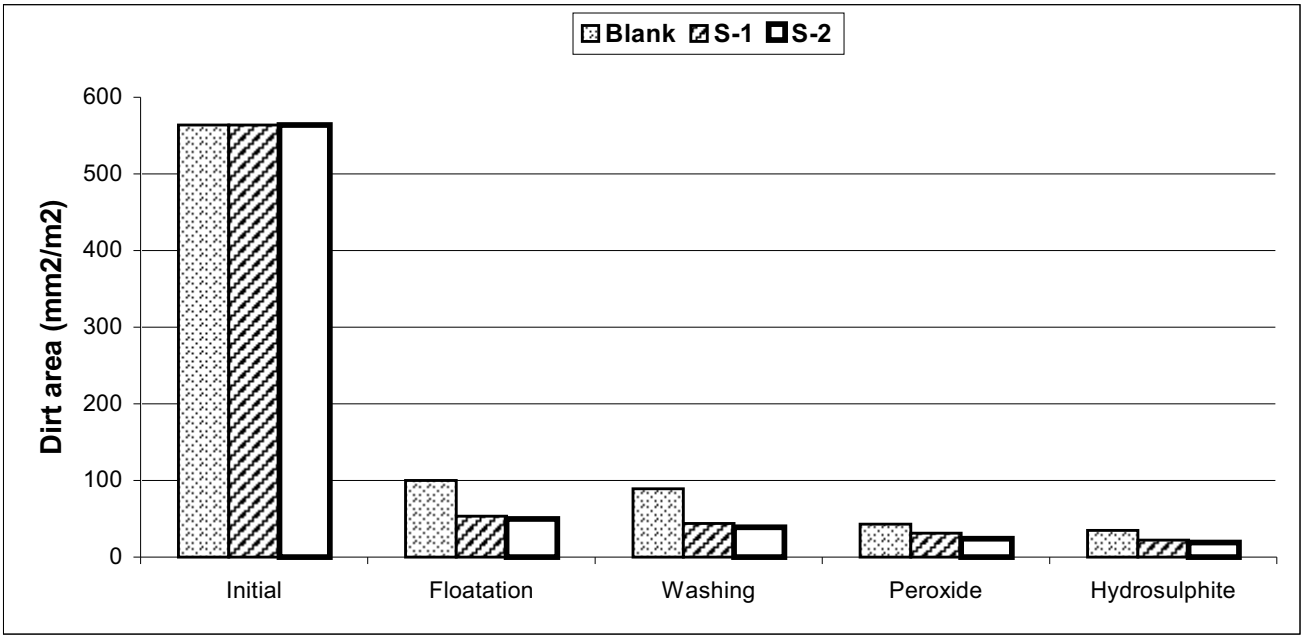

Fig. 2B: Dirt area

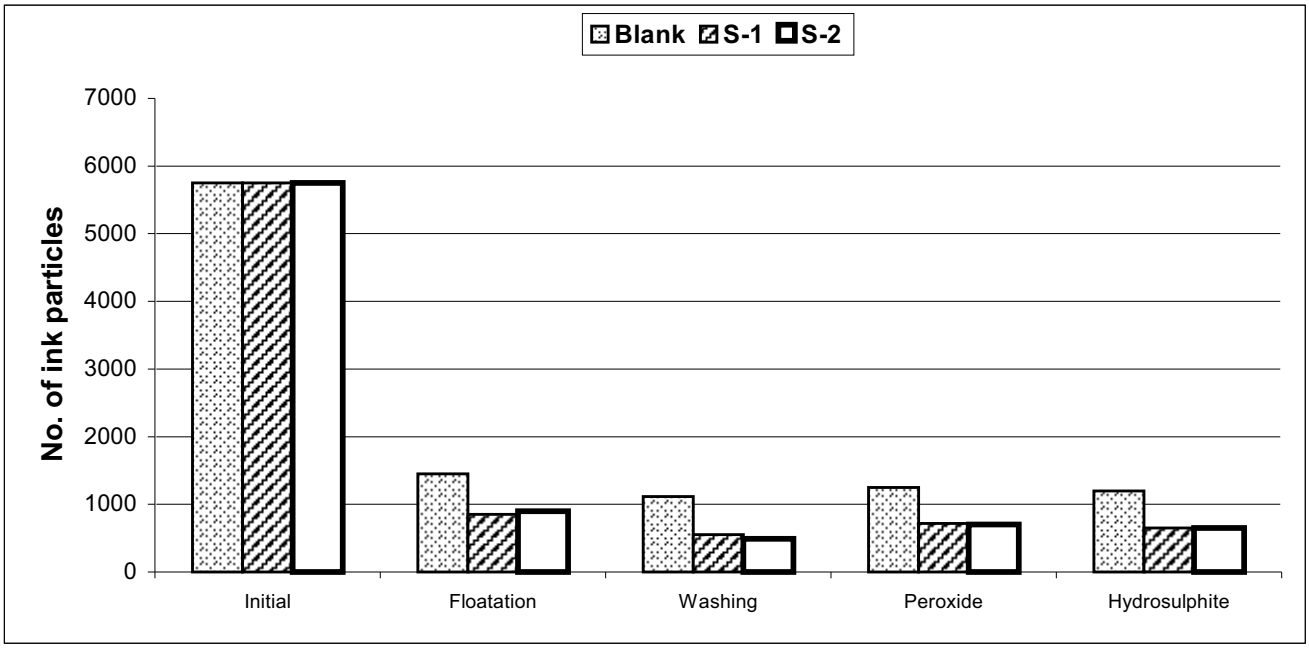

Fig. 2C: No. of ink particles

TABLE - 3: DEINKING BEHAVIOUR OF PAMPS A: WITHOUT SURFACTANT

Sl. No.	Particulars	Unit	Initial	After Pulping	After floatation	After washing	After H_2O_2 stage	After $NaHSO_3$ stage
1.	Brightness - Unprinted Brightness - Printed	%ISO	89.2 55.7	84.1 50.0	86.9 54.9	85.3 56.9	85.7 68.4	85.4 72.1
2.	Deinking factor	%	-	-	13.3	19.5	51.5	62.4
3.	Dirt count	mm^2/m^2	1070	1069	858	836	791	320
4.	No. of ink particles	$no./m^2$	85250	85136	55500	53600	4100	577
5.	Strength index	-	967	976	975	1036	990	925

B: WITH SURFACTANT S

Sl. No.	Particulars	Unit	After floatation		After washing		After H_2O_2 stage		After $NaHSO_3$ stage	
			S1	S2	S1	S2	S1	S2	S1	S2
1.	Brightness	%ISO	57.0	57.8	62.2	62.9	70.4	71.0	73.4	73.7
2.	Deinking factor	%	19.0	21.1	34.6	36.5	57.1	58.8	66.1	66.9
3.	Dirt count	mm^2/m^2	582	596	512	506	326	317	294	284
4.	No. of ink particles	$no./m^2$	51850	51350	38140	38370	3606	3888	400	417
5.	Strength index	-	1039	1064	1035	1060	995	1028	1005	1044

Fig. - 3: Improvement in Properties of PAMPS pulp after Different Stages

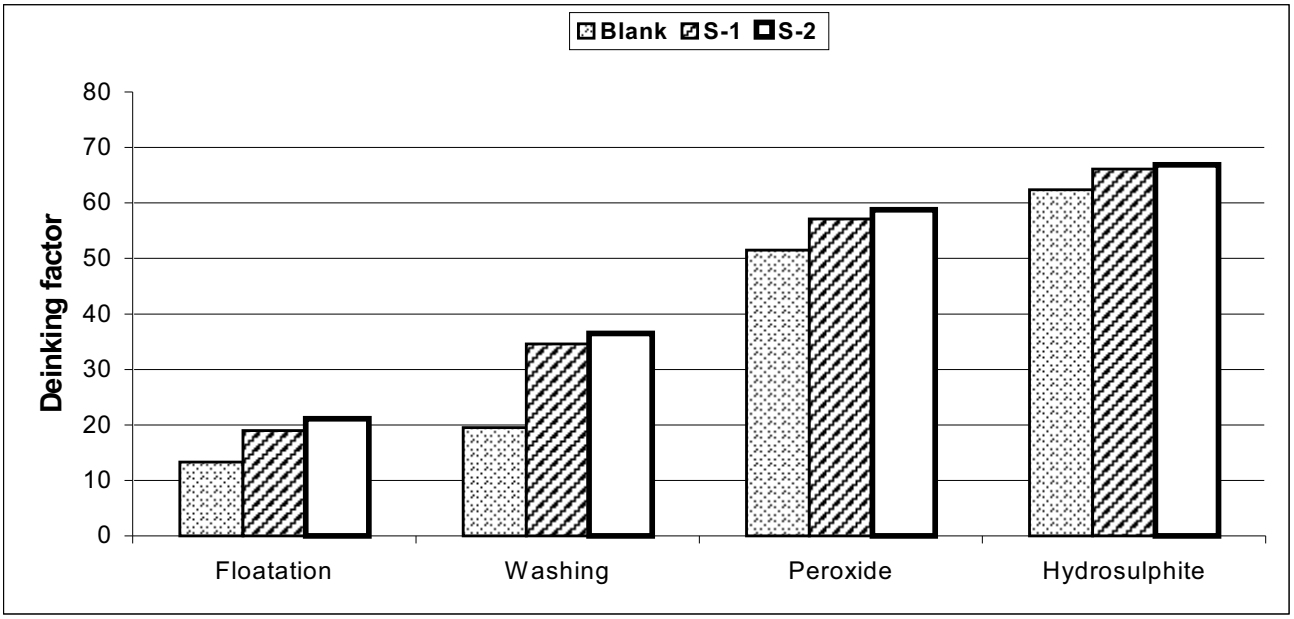

Fig. 3A: Deinking factor

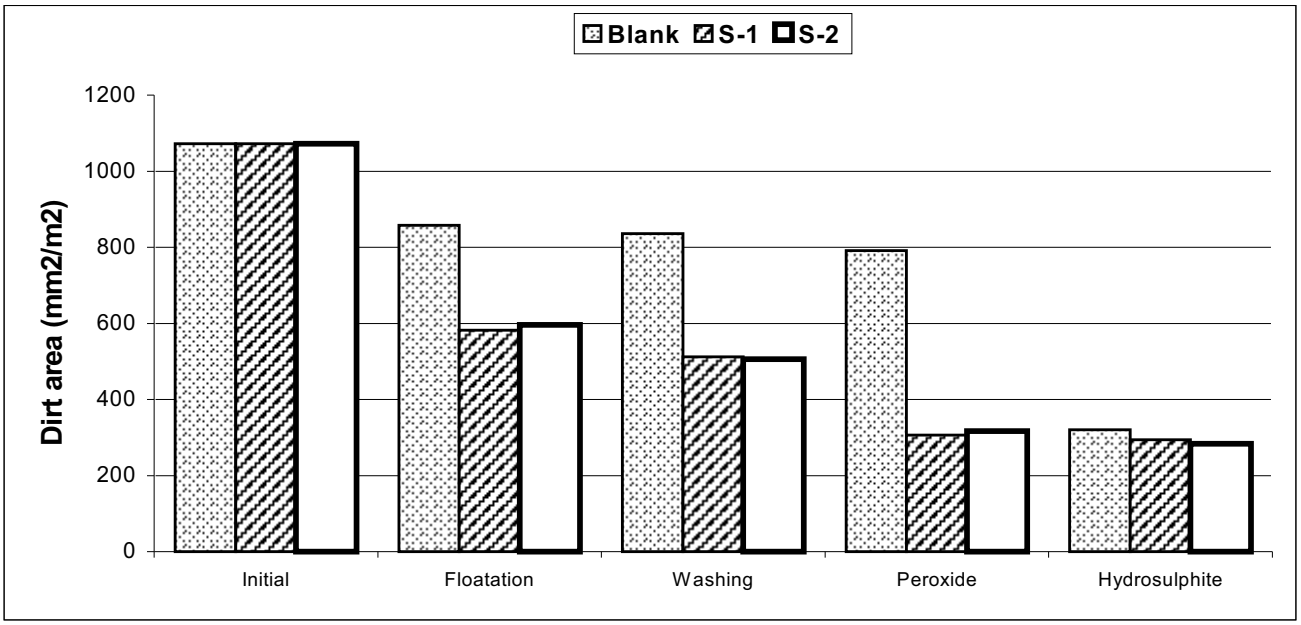

Fig. 3B: Dirt area

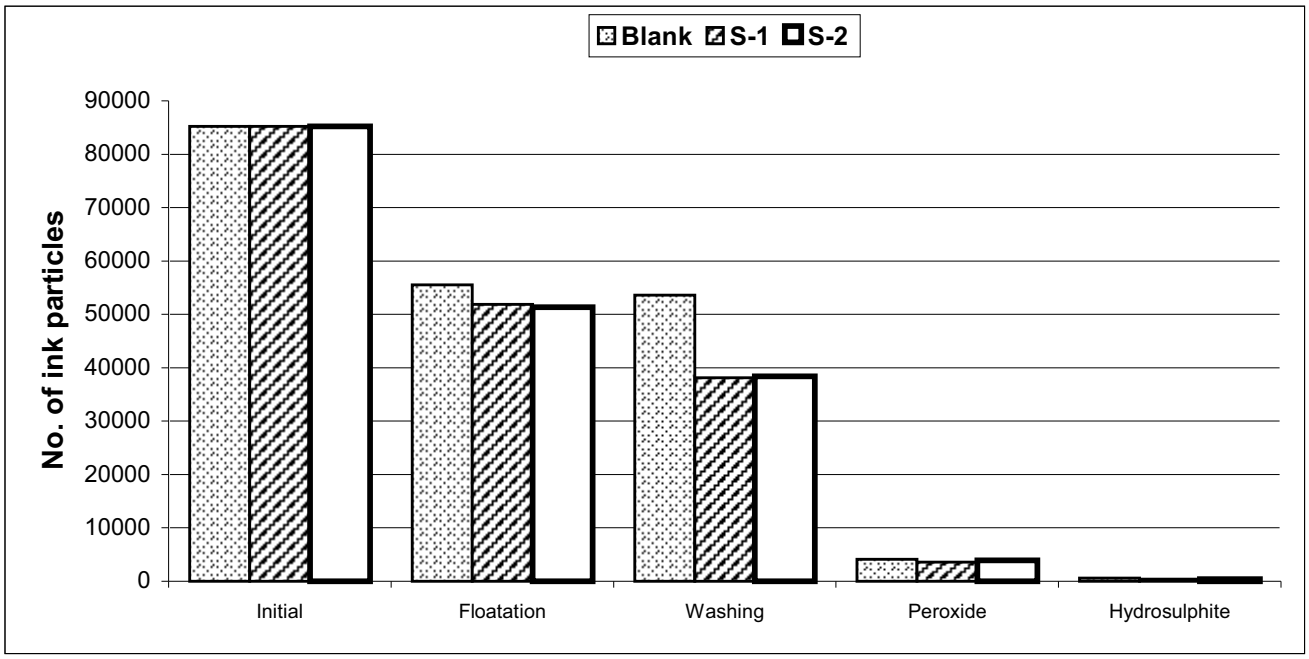

Fig. 3C: No. of ink particles

TABLE 4: OTHER PROPERTIES AFTER FLOATATION

Sl. No.	Particulars	Unit	Old Newsprint			PAMPS		
			Blank	S-1	S-2	Blank	S-1	S-2
1.	Sludge generation (as such % on OD material)	%	1.26	2.18	1.58	0.16	0.14	0.14
2.	Yield loss due to floatation	%	1.17	1.96	1.47	0.08	0.08	0.07
3.	Drainage time	Sec.	625	300	430	485	385	422
4.	Drain water pH		7.9	8.1	8.2	7.8	8.1	8.2
5.	Cationic demand	mv	-5.22	-4.71	-3.07	-4.2	-3.97	-4.04
6.	Total solids	gpl	0.21	0.21	0.21	0.43	0.6	0.5
7.	Yield loss in water	%	6.56	6.56	6.56	13.4	18.75	15.67
8.	Total yield loss after floatation	%	7.73	8.54	8.03	13.48	18.83	15.67
9.	Pulp freeness	^{0}SR	47.5	49.0	51.0	39.5	41.0	40.5

Results And Discussion

Deinking of ONP:

The results of floatation deinking performed in the laboratory by simple method using semi-automatic hand sheet former are presented in Table - 2(A & B). The efficiency of surfactants was studied by comparing the de-inkability factor (Df), dirt area reduction and no. of ink particles reduction (Fig. 2) at different stages. Results show that the final target brightness (standard for newsprint i.e. 50% ISO) was achieved without surfactants. However, the cleanliness in terms of dirt area and no. of ink particles was not good. This was achieved by using the surfactants (S1 and S2). The Df was also increased with surfactants. The Df was more significant for surfactants at floatation stage i.e. 49.5 and 47.4% respectively for S1 and S2 than blank without surfactant (33.0%). The Df of 94.9 100% could be achieved after bleaching using the surfactants. The effectiveness of S2 was comparatively better than S1. The consistent values of strength index indicating the pulp quality was not affected by the present process condition of deinking. The results in Table-4 show that, the S1 and S2 process produced more sludge, increased fines in effluent, low drainage time and increases cationic charge demand of the drain water compared to blank.

Deinking of Mixed Office Waste (PAMPS): The deinking behavior for this furnish (Table-3 A & B) was completely different due to the fine ink particles generated after pulping (Fig. 3). More no. of fine ink particles were generated (85250 no./m^2) after disintegration. The Df as well as ink particles reduction were much low after floatation (13.3% and 55500 no./m^2)

and after washing (19.5% and 53600 no./m^2) without surfactants. By using surfactants S1 and S2 and after peroxide stage the dirt area was significantly reduced (94.4 - 95.7%) and no. of ink particles reduced (95.4 - 95.8%) thereby increasing the Df to (57.1 - 58.8%). The final pulp contains only 400 417 no./m^2 of ink particles and the Df increased to 66.1 66.9% using surfactants. The final brightness of 73.4 73.7% ISO could be achieved. The strength index values were also retained. The results in Table-4 show that, the S1 and S2 process produced marginally higher sludge after flotation stage, very high increase in fines in effluent, low drainage time and increases cationic charge demand of the drain water compared to blank.

The above results indicate the following:

1. S1 and S2 can effectively utilized as deinking agent for old newsprint sample for recycling. S2 was found to be marginally better than S1.
2.. S2 is comparatively works better than S1 for the deinking using conventional pulping and floatation process for PAMPS.
3. Both the surfactants are less effective to remove the ink particles from office waste than old newsprint. However, the ink particles were dispersed by the treatment.

Conclusion

In India, for production of high quality writing and printing paper from recycling office recovered papers, the waste paper quality is to be improved by proper collection, sorting and grading system and upgrading the machinery and process with recent technologies.

The developments in chemistry, design of efficient devices and combination of various technologies and the conception of new processes have led to the improvement of inks and contaminant removal efficiency. High grades of deinked pulps can be produced now-a-days. Higher requirements in pulp quality, use of deinked pulp in new grades of printing papers, adaptation of processes to new inks and contaminants call for new innovations.

The de-inking study to evaluate the chemicals by floatation process can be done by using laboratory disintegrator and semi automatic sheet former. The efficiency of the chemicals can also be determined.

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