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Potentiality of Waste Paper Recycling for Sustainable production of Paper in Sudan

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Abstract

To assess the potentiality of waste paper recycling for sustainable paper production in Sudan, two sets of questionnaires were prepared; the first set was public to test their awareness about solid waste collection; sorting, disposal and recycling. The second was designed for the convertors (printing press and packaging manufactures) with extra specific inquiries targeting information about consumption of different paper grades by the convertors such as, type and grades of paper used, amount of waste. During the survey, waste paper (printing, wrapping paper and old newsprint) samples were collected from the packaging and press houses. Printing and wrapping waste was recycled using two different concentrations of sodium hydroxide (3% and 6%).In this study flotation mechanism was used for waste paper from old newsprints (ONP) for the detachment of the ink. The pulp was treated with two sets of chemicals: in the first set hydrogen peroxide was added in three different charges (1%, 2% and 3%). In the second set Sodium carbonate was added in three deferent charges (1%, 2% and 3%).The analysis of survey data revealed that awareness of community plays the main role in waste management policy. With regards to pulping properties the highest pulp yield was obtained when 6% NaOH charge was used. The yields obtained were 82% and 79% for wrapping paper and printing paper respectively. At the same time for ONP the better brightness was obtained when 3% H_2O_2 and $Na_2CO_3$was used. The brightness was 53 and 57 respectively. It was also noticed that increasing the

concentration of chemicals and disintegration time increased the physical properties of paper (tensile index, burst index and bulk). Recommendations of actions to be taken in order to improve the performance of the waste paper management system in Khartoum for increasing the amount of waste paper available for paper industry from household solid waste through sorting were suggested. The study also recommended using as minimum chemicals as possible in the recycling process.

Key Words: Recycling – Waste paper - Papermaking

Introduction

For centuries, paper had been made from linen, hemp and cotton rags. After cleaning, sorting and cutting, these were boiled with potash or soda ash to remove the remaining dirt and color. Throughout the 18th century the papermaking process remained essentially unchanged, with linen and cotton rags furnishing the basic fiber source. However, the increasing demand for paper during the first half of the 19th century could no longer be satisfied by the waste from the textile industry. Thus, it was evident that a process for utilizing a more abundant material was needed. Consequently, major efforts were undertaken to find alternative supplies for making pulp. As a result, both mechanical and chemical methods were developed for the efficient production of paper from wood. The clear deficiencies compared to paper made from cotton rags made it necessary to strengthen the development of chemical wood pulping processes, focusing on the removal of accessorial wood components such as lignin and extractives. The first chemical pulping process was the soda process, so-named because it uses caustic soda as the cooking agent.

Major raw materials used by paper industry are wood, annual plants, industrial waste such as bagasse, in addition to the waste paper and agricultural residues like wheat straw, rice straw, jute sticks, hemp, kenaf, grasses, sea weed etc. Apart from this, paper industry consumes large amount of chemicals like caustic soda, sodium sulphide, sodium carbonate, chlorine, hypochlorite, mineral acid; coal, talcum powder. Normally, fiber resources for pulp and paper are obtained from trees or agricultural crops. Forest resources have important value in producing a range of different wood resources for pulp and paper-based industries (Holik, 2006).

Wood resources are divided into two types which are softwoods (such as spruce, pine, fir, larch and hemlock) and hardwoods (such as eucalyptus and birch). 90-92% of fibers used for pulp and paper production globally come from wood resources (Jimenez, *et. al*, 2009; Sridach, 2010) These wood resources are used in many

kinds of paper grades due to its smooth surface area and strong strength (Dawitz, 2004). Nonwoodfibers, also referred to as ‘‘alternate fibers’’, are nonwood cellulosic plant materials from which papermaking fibers can be extracted. The most widely used nonwood for papermaking are straws, sugar cane bagasse, bamboo, kenaf, hemp, jute, sisal, abaca, cotton linters, and reeds. Most nonwood plants are annual plants that develop full fiber potential in one growing season.

For effective use of recovered paper it is necessary to collect, sort and classify the materials into suitable quality grades. Therefore, after collection recovered paper should be brought to the collection yards where it is sorted. Detrimental substances as e.g. plastics, laminated papers etc. are removed before baling. The sorted recovered paper is usually compacted by baling machines. Industrial recovered paper from large generators is usually delivered to and processed in recovered paper yards integrated in the paper mill (Ogunwusi, 2013).

This investigation aimed at exploring the potentiality of waste paper recycling for sustainable paper production in Sudan. This could be achieved through:

- specifying the main sources, quantities and qualities of waste paper available for paper industry
- investigating the suitable pulping conditions for the different types of waste paper.
- determining the suitable deinking method for old newsprints.
- evaluating the quality of paper produced from the different combinations.

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Materials and Methods

Material

The waste paper used in this study comprised:

a) Printing paper: collected as post consumer waste (trimings) from commercial printing facilities (copy paper).
b) wrapping paper: collected as post consumer waste from SamierGassim Packaging Factory (Khartoum north) using Kraft and fluting paper.
c) Old newsprints (ONP): was collected from commercial printing facilities such as press houses and some governmental institutions.

Chemicals used in this study were Sodium hydroxide, sodium carbonate and hydrogen peroxide.

Methods:

Questionnaires

Two sets of questionnaires were prepared from literature review, the first set was targeting the public and the second was a structured survey targeting the convertors (printing presses and packaging manufactures). The public questionnaire was prepared in accordance with the objective of the research to test the awareness of the targeted group about waste collection; sorting, disposal and recycling. This questionnaire was divided into three major parts: general information about the target group, their awareness and waste recycling practice. In this study sample, a hundred questionnaires were distributed to citizens in different areas of the three capital towns (Khartoum, Omdurman and Khartoum North).

The second survey which was structured questionnaires targeting converting establishments was designed to collect basic information about convertors facilities; information of consumption of different paper grades by the convertors such as, type and grades of paper used, amount of waste, … etc; and waste paper collection and utilization. Both questionnaires were analyzed by (spss) system and evaluated.

Collection and sorting of samples:

Waste paper samples were collected directly from the packaging facilities, press houses and from their trash containers, after that sample were sorted manually to Kraft paper, Kraft liner, corrugated media, newsprint and printing paper.

Pulping:

In this study waste paper (printing and wrapping paper) was cut into small pieces and soaked in warm water liquor with a ratio of 1:5 (paper : water) at 60^{o}C with two deferent concentrations of Sodium hydroxide (3% and 6%) for 2 hours. During this treatment pulp was stirred 3-4 times. In this stage initial pH was 9. This waste paper feed stock was pulped and defibrated in a turbo pulper for two different times 5 and 8 minutes then screened by standard method.

Deinking process (flotation):

The pulp slurry with 6% consistency was produced in a disintegrator operating for approximately 5 min. The pulp was treated with two sets of chemicals: in the first set hydrogen peroxide was added in three different charges (1%, 2% and 3%). In the second set Sodium carbonate was added in three deferent charges (1%, 2% and 3%). All the reagents used were proportional to the weight of the dry newsprints. The pH in this stage was adjusted to about 9.5–10.

The pulp was homogenized for 1hour. To produce the right consistency for flotation, the pulp was diluted with tap water in a 1:2 ratio. The purpose was to release the fibers and facilitate the detachment of the ink from the paper.

Handsheets formation:

Handsheets for physical tests were prepared according to (TAPPI -220-sp- 81) with a British standard machine and condition to (TAAPI- 402-sp-98). The obtained sheets were air-dried using plastic rings and tested for their physical and mechanical properties in accordance to standard procedures.

Evaluation and testing of handsheets:

The sheets produced from pulps were conditioned for 24 hours before testing for tensile strength according to (TAAPI- 404- cm-92), burst strength according to (TAAPI- 403- om-97), bulk density and brightness according to (TAAPI- 425- om-81) using a minimum of six best sheets from each test.

Results and Discussion

Personal attributes of the target group:

Table 1 shows personal information and education level of the target group. It could be notice that most of the sample population is well educated with 69% university graduates, 14% postgraduates, 13% secondary and 4% primary.56% of the group were females, 58% were jobless and 73% were between 20 and 35 years of age,

Table 1. Personal information of targeted group.

Sex				**Jobs**				**Age**		**Education**	
M		FM		Yes		No		20<	11	primary	4
No	freq	No	freq	No	freq	No	freq	20-25	42	Secondary	13
44	44%	56	56%	42	42%	58	58%	26-35	31	university	69
								36-50	13	postgrade	14
								50>	3		

Table 2shows the frequencies of storage group participation in waste handling. 61% of the population sample collects waste and 84% accept to pay fees against that reflecting good attitude and enough support of the waste management policy. Nevertheless, 88% of them believe that there is a need to change the existing system of solid waste management. In Turkey opinion polls indicate that more than 80% of the population is

ready and willing to participate in separate collection programmers (Metin, *et. al*, 2003).

Table 2.frequencies of participation and awareness of target group in waste handling.

Participation and awareness of community in:	**Yes**	**No**
Collection of solid waste	61	38
Feed back and Communication	56	42
Paying fees	84	15
Place of disposal	25	74
Collaboration in waste disposal	89	11
If there any need to change the existed system	88	9

Table3 shows methods of storage and disposal of waste used by repondents. It revealed that 51% of them do not store their waste, 19% were found to use store rooms, followed by waste basket (16%) and trash bags (12%). The analysis also showed that 46% of the target group take their waste to the waste containers while 18% burn it .In comparison Bor (South Sudan) and Zanlingy burn 34.7% and 56% of their waste respectively (Elsarraf, et. al, 2017). Most of the people think that the waste containers are far from their houses (45%), followed by those who consider the waste containers are source for bad odors (26%) while 18% think that waste containers are very small, which could be an indicator of the challenges facing waste management in Sudan.

Table 3 Methods of storage and disposal of waste.

Storage at home		**Mean of disposal**		**Waste containers**	
Don't store	51	Burn	18	far from house	45
Trash bags	12	Put it on street	7	Very small	18
Waste basket	16	Put it in waste containers	46	Source for bad odors	26
Store room	19	Uncertain	28	No problem	11
Uncertain	3				

Tables 4 shown knowledge about sorting and recycling of solid waste. The survey has showed that 53% of the

population sample are aware of waste recycling process, and 53% aware of sorting methods and most of them (80%) believe that sorting is important.

Table 4 knowledge about sorting and recycling of solid waste.

Awareness of:	**Frequencies**	
	yes	No
Recycling process	53	45
Importance of sorting	80	19
sorting methods	53	46

Table5 shows the contents of households sorted solid waste and reuses. The respondents found that 45% of sorted materials were organic matter followed by metals (26%) and paper (8%). This was in line with a study conducted by (Ali, 2009) who found that Khartoum state has a high rate of waste generation with a high percentage of organic materials approximate to 50%. It is expected to have higher organic matter in low-income countries like Sudan (Garang, 2017). Similar trend was reported from City of Bor South Sudan where solid waste materials generated include plastic (41%), organic waste (29%), paper (15%), wood (6.3%) and metals (0.5%).

The current investigation showed that, 30% of Khartoum state's wastes are recyclable materials that should not be disposed to landfills. Concerns about sorting organic matter may be attributed to the fact that these can generate bad odor when kept for long time in spite of the irregularity of the collection service. Meanwhile, some materials (metal, plastics and paper) could be sorted to be sold later. Also the survey revealed that 53% know how to sort their waste, 16% of them sell part of their waste, while 24% give their waste to others. The survey also revealed that 64% believe that safety of environment is their driving force for waste sorting, 24% favor sorting as a comfortable collection method, while 8% look at sorted waste as income generating practice.

Table5 Frequencies of contents solid waste and uses**.**

Content of solid waste				**Uses of sorted material**			
Organic	Metals	Paper	Others	Sell it	Special uses	Gives to anthers	I don't no
45	26	8	19	16	8	24	**7**

The second questionnaire targeted the printers and convertors community participation in supplying waste

paper. The studied samples were from printing, cardboard and packaging establishments represented by 53%, 33.33% and 13.33% respectively. According to table6 it could be noticed that the imported amounts of the wrapping papers is very high compared to the different types of the printing papers (not to mention office copy and printing papers). The available waste from these facilities could easily be collected and the different types provide a wide range of products.

Table 6 Approximate consumption of different paper grades by the converters.

Paper types	**Quantity (ton/year)**
Kraft	1376-9600
test- liner	1367- 2400
fluting	1200-12000
60and70 g	2-126
Art	1.5-30
Postal	3-45
Carbon	0.9-1

Pulp and Paper Evaluation:

Table7 shows the effect of sodium hydroxide concentration on pulp and paper properties. Increase in sodium hydroxide concentration enhanced pulp properties and increased yield percentage to 82% when use 6% sodium hydroxide with wrapping paper, compared to 75% and 70% for 3% Na OH and without NaOh, respectively. NaOH stimulates the interaction and dissolution of paper into fibers and dissolves additives at the ends of the paper industry (Ma, *et. al,* 2011). In wrapping and printing paper the addition of sodium hydroxide caused additional delignification of reject which has decreased their amount. The new delignifiedfibers were added to the yield which is the cause of its increase, also it was found that tensile index of handsheets was in the range of 55.7 to 64.5mN*m^2/g, burst index ranged from1.8 to 2.7 kPam²/g , while bulk density ranged from 4.12 to 4.39 g/cm³. It could be noticed that increasing sodium hydroxide concentration had enhanced the physical properties of the paper produced. Slight difference was reported in paper properties when the concentration is increased from 3 to 6%. This finding is similar to what was found for handsheets produced from mixed recycled pulp in different ratio (Alam,*et. al,* 2016). This could be attributed to the fact that sodium hydroxide will cause swelling of the fibers and hence improve fiber-fiber bonding.

Table 7 Effect of sodium hydroxide concentration on pulp and paper properties:

Sample type	**NaOH %**	**Physical properties**			
		Screened Yield	**Tensile index ($mN*m^2/g$)**	**Burst index($kpa*m^2/g$)**	**Bulk (g/cm^3)**
Printing paper	0	74	55.7	1.8	4.12
	3	76	63.2	2.3	4.19
	6	79	64.5	2.7	4.39
Wrapping paper	0	70	40.5	1.8	4.03
	3	75	51.5	1.9	4.07
	6	82	61.4	2.1	4.16

Table8 show effect of time of disintegration on pulp and paper properties. Although increased disintegration caused cutting of weak fiber of recycled fibers, it increased the pulp yield specifically in printing paper. In addition the results showed that increasing time of disintegration increased pulp yield and improved the physical properties of the paper produced from the printing waste paper in terms of tensile strength, burst index and bulk density where it reaches 64.9, 2.6 and 5.64 respectively. The same effect was noticed in wrapping paper which reaches 56.8, 2.2 and 5.79 respectively.

Table 8 Effect of time of disintegration on pulp and paper properties.

Sample type	**Time (min)**	**Physical properties**			
		Screened Yield	**Tensile index ($mN*m^2/g$)**	**Burst index(kpa $*m^2/g$)**	**Bulk density (g/cm^3)**
Printing paper	0	61%	53.9	2.2	3.63
	5	67%	57.2	2.4	3.92
	8	74%	64.9	2.6	5.64
Wrapping paper	0	76%	23.6	1	4.22
	5	84%	51.1	1.9	5.21
	8	86%	56.8	2.2	5.79

Table 9 show the effect of hydrogen peroxide percentage on paper properties. Only brightness increased regularly with increasing hydrogen peroxide, while other properties did not show any trend. This can be attributed to the increasing of ink salvation power, in addition to the other effects of H_2O_2 in the promotion of the fiber dispersion, saponification and change in other ink ingredients such as glue material, starch and the nature of the carrier and so on which agree with the findings of (Alam,*et. al,* 2016).The brightness of newsprint paper was enhanced by the increasing sodium carbonate more than that of H_2O_2.Similar results were reported for the effect of Sodium Percarbonate and Perborate (Pesman, *et. al*, 2014). The physical properties, however did not show any trend (increase or decrease) with increase of H_2O_2. The table also shows that paper made from newsprints waste paper gave lower strength properties than those made from printing

paper and wrapping paper.

Table 9 Effect of hydrogen peroxide percentage on properties of sheets made from newsprints

H_2O_2 %	Tensile index ($mN*m^2/g$)	Burst index ($kpa*m^2/g$)	Bulk density (g/cm^3)	Brightness %
0	28	1	6.25	41
1	38.5	1.1	5.51	48
2	31	1.3	6.98	52
3	33.9	1	5.96	53

Table 10 shows the effect tof sodium carbonate percentage on physical properties of paper made from newsprints waste paper. While brightness of feed pulp was 41%,a brightness of53% and 57% were obtained as result of using 2% and 3%, of Na_2CO_3respectively. Tensile and burst were increased gradually and then decreased at 3% of sodium carbonate. This table also shows that the strength properties made from newsprints waste paper are lower than those made from printing paper and wrapping paper, while bulk density was higher.

Table 10 Effect of sodium carbonate concentration on properties of handsheet made from newsprint waste paper.

Na2CO3%	Tensile index ($mN*m^2/g$)	Burst index ($kpa*m^2/g$)	Bulk density (g/cm^3)	Brightness %
0	28.0	1	6.25	41
1	33.5	1.3	6.33	48
2	34.6	1.3	6.31	53
3	31.7	1	6.35	57

Conclusions and recommendations

Conclusions

- The paper industry cannot rely on the existing solid waste management system practiced by the public in Sudan for supplying raw material because of the absence of sorting.
- It is possible, however, to produce certain grades of paper depending only on recycling of waste paper obtained from packaging and printing houses.
- The sorting practice for solid waste includes organic matter and recyclable materials like metals, paper and plastics.

- All pulp and paper properties studies increased with increased NaOH concentration in the pulping process.
- Increase in both H2O2 and Na2CO3 percentages in pulp made from newsprints waste caused an increase in brightness but with no significant effect on other properties.
- Paper produced from printing and wrapping waste paper had higher strength properties but with less bulk density than that produced from old newsprints.

Recommendation

- The future work will cover investigating the effect of blending recycled paper pulp with other types of virgin pulps from wood or non-wood fibers at different ratios for producing better quality paper.

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