Sudan University of Science and Technology
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Potentiality of Waste Paper Recycling for Sustainable Production of Paper in Khartoum State

امكانية إعادة تدوير النفايات الورقية لإنتاج مستدام للورق بولاية الخرطوم

BY

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TABLE OF KEY ABBREVIATION

ONP	Old News Print
MSW	Municipal Solid Waste
GDP	Grand Domestic Production
A4	Printing Paper Package
PPI	Pulp and paper Industry
CD	Conical Disc
T/d	Ton per day
GW	Ground Wood
PGW	Pressurized Ground Wood
SGW	Stone Ground Wood
RMP	Refiner Mechanical Pulp
TMP	Thermo Mechanical
CTMP	Chemi- Thermo Mechanical
TAPPI	Technical Association of Pulp and Paper Industry
ERIC	Effective Residual Ink Concentration
ISO	International Organization for Standardization
FAO	Food and Agriculture Organization
SPSS	Statistical package for social studies

Abstract:

Pulp and paper manufacturing requires large amount of fibrous raw material from wood and other resources. Recovered fiber has become an indispensable raw material for the paper manufacturing industry, accounting about for one-third of the total raw materials because of the favorable price of recovered fibers. The aim of the current study was to investigate the potentiality of waste paper recycling for sustainable production in Khartoum state. To achieve this aim, two sets of questionnaires were prepared; the first set was open closed questionnaire to test awareness about waste collection; sorting, disposal and recycling and the second was designed for the convertors (printing press and packaging manufactures) with extra specific inquires 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 used two different concentrations of sodium hydroxide (3% and 6%). In this study flotation mechanism was used for waste paper old newsprint (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 different charges (1%, 2% and 3%). The analysis of survey revealed that awareness of community play main role in waste management policy. In addition to the present study it could be noticed that the imported amounts of the wrapping papers is 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. In this study the highest yield was obtained when 6% from NaOH 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% from H_2O_2 and Na_2CO_3 were used. The brightness was 53% and 57% respectively. It was also noticed that increasing in concentration of chemicals and disintegration time increased the physical properties of paper (tensile index, burst index and bulk).The present study recommended numbers of actions to be taken in order to improve the performance of the waste paper management system in Khartoum: Establishment of environmental strategies and policies, sorting system and enhancement of private sector participation to increase the overall system efficiency for solid waste, household and packaging factories. The study also recommended using as minimum chemicals as possible in the recycling process.

امكانية اعادة تدوير النفايات الورقية لانتاج مستدام للورق بولاية الخرطوم

المستخلص :

تتطلب صناعة اللب والورق كمية كبيرة من المواد الخام الليفية من الخشب والموارد الأخرى. أصبحت الألياف المعاد تدويرها كمادة خام لا غنى عنها لصناعة الورق، حيث تمثل حوالي ثلث إجمالي المواد الخام نسبة للسعر المناسب لاعادة تدويرها الهدف من هذه الدراسة هو دراسة إمكانية إعادة تدوير النفايات الورقية في الخرطوم لتشجيع صناعات إعادة تدوير، النفايات في السودان. لتحقيق ذلك تم اعداد مجموعتين من الاستبانات المجموعة الاولى كانت عامة لاختبارمستوى الوعي حول جمع النفايات وطرق الفرز والتخلص منها وإعادة التدوير المجموعة الثانية تم تصميمها للمصانع التحويلية للورق مثل(المطابع ومصنوعات التعبئة والتغليف) مع استفسارات محددة تستهدف معلومات حول استهلاك الدرجات الورقية المختلفة من قبل المحولات، ونوع ودرجات الورق المستخدم، وكمية النفايات المتاحة، خلال المسح، تم جمع عينات من ورق النفايات (الطباعة وورق التغليف وورق الصحف القديمة من مصانع التعبئة والتغليف). تم إعادة تدوير نفايات الطباعة والتغليف باستخدام تراكيز مختلفة من هيدروكسيد الصوديوم (3٪ و 6٪). في هذه الدراسة تم استخدام آلية التعويم لورق نفايات الجرايد. لفصل الحبر، تم معالجة اللب بإضافة بيروكسيد الهيدروجين في ثلاث درجات (1٪، 2٪ و 3٪)، واضافة كربونات الصوديوم بدرجات مختلفة (1٪ و 2٪ و 3٪).كشف تحليل المسح أن مستوى الوعي المجتمعي يلعب الدور الرئيسي في سياسة إدارة النفايات بالاضافة الى ذلك خلصت الدراسة الى انه يتواجد بكميات كبيرة من المخلفات الورقية بالموسسات خاصة مصانع التغليف وسهولة جمعها. تم الحصول على أعلى إنتاجية عند استخدام (6٪ من هيدروكسيد الصوديوم 82٪ و 79٪) لتغليف الورق وورق الطباعة على التوالي). في الوقت نفسه تم الحصول على درجة نصاعة أفضل عند استخدام 3٪ من H_2O_2 و Na_2CO_3٪ (53% و57٪ على التوالي). ولوحظ أيضًا أن الزيادة في تركيز المواد الكيميائية ووقت تفكيك الالياف تزيد من الخصائص الفيزيائية للورق (معامل الشد، معامل الانفجار...الخ) وعليه اوصي بإجراءات يمكن اتخاذها لتحسين أداء نظام إدارة النفايات الورقية في الخرطوم مثل وضع استراتيجيات وسياسات بيئية ونظام فرز وتعزيز مشاركة القطاع الخاص لزيادة كفاءة النظام الكلي للنفايات الصلبة في مصانع التعبئة والتغليف المنزلية. استخدام الحد الأدنى من المواد الكيميائية في عملية إعادة التدوير.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

During the era before the introduction of industrialized paper production, the most common fiber furnish was secondary fibers recovered from used textiles. These were rags based on hemp, linen, and cotton. Only after the invention of mechanical wood pulp in 1843 and chemical wood pulp during the second half of the nineteenth century was paper production no longer as reliant on recycled material as in the previous 2000 years (Sixta, 2006).

After wood, the second largest share of pulp produced worldwide is pulp made from recovered paper. Apart from good economic reasons, a major force in this drive to recycling is derived from public pressure to reduce the amount of used paper that is land filled as waste (Asachi, 2010).

The history of papermaking can be traced back to about ad 105, when Ts'ai-Loun Created a sheet of paper using old rags and plant tissues. In its slow travel westwards, the art of papermaking reached Arabia in the middle of the eighth century, from where it entered Europe via Spain in the 11th century. During the 14th century a number of paper mills existed in Europe, particularly in Spain, France, and Germany (Jons *et al* 2017). 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. The operation was continued in a "breaking engine" by adding fresh water until the cloth was separated into single fibers. Until the paper machine was constructed in 1799 by Louis-Nicholas Robert, the final sheet-formation process was carried out manually (Hunter 1978). 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. Mechanical wood pulping was initiated in 1840 by the German Friedrich Gotlob Keller (Lindström *et al* 1988). The wood-pulp grinding machine was first commercialized in Germany in 1852 (Heidenheim) on the basis of an improved technology developed by Voelter and Voith. However, mechanical pulping did not come into extensive use until about 1870 when the process was modified by a steam pretreatment which softens the inter-fiber lignin. Paper made from mechanical wood pulp contains all the components of wood and thus is not suitable for papers in which high brightness, strength, and permanence are required (Sixta, 2006).

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. A year later, the first commercial soda mill using poplar as raw material was built on the Schuylkill River near Philadelphia under the direction of Burgess, who served as manager of the mill for almost 40 years (Harris 1993). Because this process consumed relatively large quantities of soda, papermakers devised methods for recovering soda from the spent cooking liquor through evaporation and combustion of the waste liquor and recausticizing of the sodium carbonate formed. To compensate for the losses, sodium carbonate had to be added to the caustic zink unit. Eleven million tonnes of waste paper are produced yearly by the European pulp and paper industry, of which 70% originates from the production of deinked recycled paper (Abdel-Shafya and Mansour, 2018).

Due to the large volumes of waste generated, the high moisture content of the waste and the changing waste composition as a result of process conditions, recovery methods are usually expensive and their environmental impact is still uncertain. For this reason, it is necessary to continue research on different applications of wastes, while taking into account the environmental and economic factors of these waste treatments (Monte, et al, 2009).

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 is brought to the collection yards where it is sorted. Detrimental substances as e.g. plastics, laminated papers etc. are removed before balling as well as possible. 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).

Conventionally for low and middle income countries such as Sudan which is commonly referred to as a developing country any solid waste is known to be Municipal Solid Waste (MSW). Awareness of separation is partially there, but the urge to apply it is ignored, for economical reasons and may be under estimating the problem (Coffey *et al*, 2010: Ray and Rahman, 2016).

In many countries the implementation of a MSW management system depends on several important factors such as the country's statutes, environmental requirements, strategies in environmental management, energy policy, economic and technological feasibility and capabilities, and education and environmental awareness of citizens. (Zhu, et al., 2009: Joshi and Ahmed, 2016)

Since solid waste collection is not well organized, acceptable grades of waste paper are available only at specific facilities that are packaging and press houses. The lack of detailed information about the types and amount of waste paper and paper products necessitates continuous survey.

1.2 Objectives

Overall objective

To investigate the possibility of waste paper recycling for sustainable production in Khartoum state.

Specific objectives

- To specify the main sources, quantities, and qualities of waste paper available for paper industry
- To investigate the suitable pulping conditions for the different types of waste paper.
- To determine the suitable deinking method of old newsprint.
- To evaluate the quality of paper produced by the different combinations.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

The history of paper is also the history of human culture and civilization. Paper was the most important Carrier of information in the past. It was only with increasing paper production, that the transfer of knowledge, education and information to a larger portion of society became possible. Today paper has changed from a rare artisan material to a commodity product, with a high practical value in communication, in educational, artistic, hygienic, sanitary and technical applications (Sixta, 2006).

Paper is a major product of the forestry industry, and is used widely in our society. Paper products are used not only in their obvious applications in the publishing industry and for writing on, but also in a variety of specialty papers, cardboards, brown papers etc. In addition, various chemicals are produced as a byproduct of the pulp and paper industry (Holik, 2006).

The knowledge of paper manufacturing spread westward, along with the silk and trade routes, reaching India is round 605 AD. Pulp and paper production has increased globally and will continue to increase in the near future and is one of the largest manufacturing sectors in the world. Per capita consumption of paper is sometimes yardstick for measurement of industrialization (Karenlampi, 1992)

Pulp and paper industry is one of the oldest industries in India; there are about 500 Kraft mills and many thousands of other types of pulp and paper mills in the world. India has the fastest growing pulp and paper market in the world with growth rate of 10% over one year in per capita consumption, which is expected to grow in future. The Indian paper industry is among the top 15 global players today, with an output of more than six millions tones annually with an estimated turnover of Rs 150,000 millions. Projected demand of 13 million tons by 2020. (Sundra and Marimuthu, 2012)

2.2 Pulp and paper demand and supply

The raw materials technology and markets play a crucial role in the geographical location of pulp and paper industry. Today, when the bulk of investments in the industry are made in China with fast growing demand for paper products, markets have become ever more important. (Kurosawa and Hashino, 2012)

Economic development in Asia has triggered growing demand and thus a shift of global demand. While Europe is a net importer of pulp, the net export of paper has, however, steadily grown over the last decade. With declining demand, the sector anticipated and some companies actively explore opportunities in higher value papers, such as coated fine papers for magazines and advertisement, which are, however, also under pressure from digitalization. Further prospects for the pulp and paper sector are expected from the bioeconomy; for example food-packaging and pulp-based fabric (Roth, et al 2016).

Newsprint is mainly used for the publication of newspapers. Demand for this grade is closely correlated to the performance of gross domestic product. High GDP growth means rising personal incomes, which in turn, make newspapers more affordable. Other factors, such as advertising expenditures, literacy rates, pagination of newspapers and the development of electronic media, also affect demand for newsprint. (He and Barr, 2004).

Printing and writing papers are mainly used for publication of magazines, catalogues and books (textbooks, notebooks and exercise-books). Demand growth for this grade is highly correlated to overall economic activities, especially the performance of advertising, commercial printing and educational printing and writing. China’s consumption of printing and writing paper grew by 9.1 %, or 540,000 tonnes per year in 1990- 2003, exceeding 10 million tonnes for the first time in 2002. Several factors have contributed to strong demand growth for this grade, including increasing levels of economic activity, a relatively low per capita consumption base, and a relatively high rate of literacy and educational demand (Zang 2008).

Containerboard, including linerboard and corrugated medium, is mainly used to make fiber boxes to pack a variety of durable and nondurable goods. Demand for this grade is highly correlated with the performance of economic activities, such as industrial production and consumer spending. China’s successful reforms have led to rapid economic growth, especially in the segments of merchandise exports and consumer spending, which in turn, have resulted in strong demand growth for containerboard (He and Barr, 2004).

There is no pulp mills in Sudan, the last mill was in Aroma east of Sudan and was shut down in 1960s. There are six packaging factories in

Khartoum which import the paper from Saudi Arabia, Sweden, Singapore, etc. There is high need for paper in Sudan as the price of Newspapers increase every year due to lack of paper. The A4 pile for writing and printing purpose (400 pieces) cost about 3 US Dollars, this deficiency of paper products is well known in Sudan in quantity and quality (khider 2013).

2.3. Raw Material

Paper industry consumes a wide variety of cellulosic raw materials cellulosic derived from forest, agricultural residues and waste paper; non-cellulosic coal, chlorine, lime, sodium hydroxide, sodium sulphide, fuel oil, talcum powder etc.

2.3.1 Types of fibrous raw materials

Major raw materials used by paper industry are wood, annual plants, industrial waste as fresh bagasse, in addition to the waste paper and agricultural residues like wheat straw, rice straw, jute sticks, hemp, kenaf, grasses, sea weed… etc (Ashori, 2006). Apart from this, paper industry consumes large amount of chemicals like caustic soda, sodium sulphide, sodium carbonate, chlorine, hypochlorite, mineral acid; coal, talcum powder etc (Sundra and Marimuthu., 2012). Generally, the pulp and paper industries obtain cellulose from hardwood or softwood. The total capacity of pulp and paper production from wood resources is more than one million tons/year. However, this amount is higher in Malaysia due to the increasing pulp production and consumption in paper-based products. In the net paper consumption in Malaysia is approximately three million metric tons. (Goyal., 2010)

The demand of paper consumption was increased in 2009 when the average of paper consumption was about 151 kg/capita and this value is expected to reach to 200 kg/capita by the year 2015 (Katrin., 2010).

2.3.2 Wood as raw material in pulp and paper industry

Normally, fiber resources for pulp and paper are obtained from trees or agricultural crops and residues. Forest resources have important value in producing a range of different wood resources for pulp and paper-based industries. 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; these wood resources are used in many kinds of paper grades due to its smooth surface area and strong strength (Holik, 2006).

2.3.3 Non wood raw material

Nonwood fibers, 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 non wood plants are annual plants that develop full fiber potential in one growing season. There is a wide variety of nonwood plant fibers that can be used for papermaking. Nonwood such as bagasse, wheat and rice straws, bamboo, and kenaf are being used in the manufacture of pulp and paper all over the world. Kenaf (Hibiscus cannabinus), for example, is being explored as a useful raw material for papermaking in developing and developed countries. Total kenaf production in 1999-2000 was 0.51 million tons, among which production from China accounted for 44%, India for 39%, Thailand for 12%, and the remainder coming from Indonesia, Vietnam and elsewhere (Ashori, 2006).

Nowadays, many other countries are looking for non-wood plants fiber resources as alternative fibers in pulp and paper-based industries. This is due to the depletion and rising prices of wood resources and readily available non-wood fiber resources in these countries (Chandra 1998)

Nonwood is a critical fiber resource in regions with inadequate forest resources, and will continue to play an increasingly important role in these regions. Environmental pressures, restrictions on forest uses and significant increases in wood and recycled fiber costs are also forcing many paper companies in the traditionally forest-rich countries to take a renewed look at nonwood fibers. Nonwoods are abundantly available in many countries and are the major source of fiber for papermaking in some developing countries, particularly China and India. Approximately 2.5 billion tones of nonwood raw materials are available each year worldwide; however, most of this raw material is currently untapped for pulp and papermaking (Ashori, 2006). The United States is also looking for non-wood fibers to be resources of pulp and paper-based as alternative fiber in this industry to replace the virgin fiber resources. At the same time, Europe has a shortage of short fiber hardwood pulp and is thus an importer of this kind of pulp (Trumi 2009). They found out that some of the non-wood fibers have the properties to replace these fibers. Hence, the use of non-wood fiber for pulp and paper-making is thus also expected to grow in Europe (Chandra and Rustgi (1998).

The total of non-wood plants (8 - 10%) pulping capacity worldwide is increasing faster than the wood pulping capacity.Indeed, China and India are the lead countries that use of non-wood fibers in pulp and paper production rather than other countries in the world (Mabee and Pande, 1997).

2.3.4 Waste paper as raw material

In recent years, recovered paper that is repulped and made into new paper has become an important complement to virgin fiber for many papermakers throughout the world. Increasingly, paper is made from a combination of virgin fiber and secondary fiber or from secondary fiber alone. (Flynn and Bob, 2008)

Because of the pulp and paper industry are now facing a shortage of raw materials, the energy crisis, environment pollution, the three big problems, waste paper become important papermaking raw material, using waste paper in recent years papermaking industry has become one of the hottest topics. Waste paper is to promote the use of paper making industry sustainable development important factors. In recent years the waste paper recycling continues to increase, in 2010, the world has reached140 million tons of waste paper dosage, the total is 43.8%. And these recycling waste paper deinking for 15% of white paper (newsprint paper, Printing paper to write on and toilet paper, etc), and in the waste paper deinking technology regeneration process is particularly important. (Trumic et al., 2007)

Utilization rates for different countries should not be compared without further comment. It is important to know the structure of the production program of the different national paper industries in the main product categories of packaging papers and board, graphic papers, household and hygiene papers as well as specialty papers because the utilization rates for these product segments differ significantly (Sixta, 2006).

2.3.4.1 Waste paper grades

Waste paper, a significant portion of the solid waste stream, is bought and sold on the basis of grade, and prices vary accordingly. Grades of paper range from low grades, such as newspaper and corrugated, to highgrades, such as printing, writing, and computer paper. Mixing different grades lowers the quality by reducing the value in remanufacturing. Paper grades are generally defined as specified by the Paper Stock Institute of America which lists specific guidelines that define different grades of paper based on type and preparation. In general, the source of the secondary fiber will dictate the paper grade into which it can be processed (Rogoff, 2014). There different criteria for grading waste paper.

2.3.4.2 Waste paper sorting:

The primary challenge in the recycling of paper is to obtain raw material with the highest purity. Highly sorted paper stream will facilitate high quality end product, and save processing chemicals and energy. Automated paper sorting systems offer significant advantages over human inspection from fatigue, throughput, speed and accuracy point of view. From 1932 to 2008, different mechanical and optical paper sorting methods have been developed to fill up the demand of paper sorting. (Rahman *et al,* 2014) Still many countries including Malaysia, waste papers are sorted into different grades using manual sorting system. (Rahman, *et al* 2009)

2.3.4.3 Waste paper Recycling:

Waste paper recycling is one of the most well-established recycling schemes applied to waste materials today. Recycled paper is an integral part of paper and pulp production. In addition to recycled paper being an important raw material for the paper industry. it has also been demonstrated in several studies that paper recycling may offer significant environmental benefits in a lifecycle perspective. (Laurijssen et al., 2010)

Thus, paper recycling may be regarded as beneficial from both a resource and environmental perspectives and should be promoted as much as possible. (Villanueva and Wenzel, 2007).

2.4 Pulping Processes

The pulp and paper industry (PPI) produces pulp, paper, paper board and other cellulose-based products. The main steps of the process are pulping, papermaking and paper finishing. Pulping can be based on mechanical, semi-chemical or fully chemical methods. Wood used to make pulp contains three main components: cellulose (desired for papermaking), lignin and hemicelluloses (Ogunwusi, 2013).

2.4.1 Chemical pulping:

Wood chemical pulping processes, it is known that the pulping and bleaching performance is highly dependent on the abundance, structure and reactivity of lignin, cellulose and hemicelluloses. In particular, lignin content and its composition are important parameters in pulp production for the delignification rates, chemical consumption and pulp yield (Zhou, *et al* 2017).

Since the fibers in wood and plants are glued together with lignin, the chemical way to produce pulp is to remove most of the lignin and thereby release the fibers. The delignification of wood is achieved by degrading the lignin molecules and introducing of charged groups, keep the lignin fragments in solution and eventually remove them by washing. No pulping chemicals are entirely selective towards lignin; also the carbohydrates of the wood are to varying extent lost. Approximately half of the wood material is dissolved in chemical pulping. No chemical pulping method is able to remove all lignin in the pulping stage, at least not without severe damage to the carbohydrates. The delignification is therefore terminated with some lignin remaining in the pulp. The amount of lignin left in the pulp is estimated by determining the kappa number of the pulp. (Monica, 2009).

2.4.1.1 Soda process

Soda pulping, invented in England by Burgess and Watts in 1851, uses sodium hydroxide as the cooking chemical. Finding little enthusiasm in England for this new process, Burgess brought the method to the U.S. in 1854 and the first mill was started in 1866. Many of the early soda mills converted to the Kraft process once it was discovered. The soda process still has limited use for easily pulped materials like straws and some hardwoods, but is not a major process. Anthraquinone may be used as a pulping additive to decrease carbohydrate degradation. A recent development is the use of oxygen in soda pulping. While oxygen bleaching is not very specific to delignification compared to other bleaching methods, it is fairly specific to delignification relative to other pulping methods (Biermann, 1996).

2.4.1.2 Kraft process

In 1879, Dahl, a German chemist, used sodium sulfate as a makeup chemical for soda pulping to regenerate NaOH; actually Na_2S was formed and, unexpectedly, gave much faster delignification and stronger pulps, since shorter cooking times are used resulting in less carbohydrate degradation. This led to the kraft (or sulfate) process, which is now the dominant process. Although related work on the process had been done earlier, Dahl discovered the kraft chemical recovery process, which is perhaps more important than the kraft cooking process (Sundholm, 1999). The first kraft mill went into operation in 1890 in Sweden because the German papermaking industry did not accept this new process. The process developed and grew quickly from 1915 to 1930, especially in the southern U.S. where the resinous pine species did not pulp well by the sulfite process with calcium base. Kraft pulping is a full chemical pulping method using sodium hydroxide and sodium sulfide at pH above 12, at 160-180°C (320- 356°F), corresponding to about 800 kpa (120 psi) steam pressure, for 0.5-3 hours to dissolve much of the lignin of wood fibers(Chandra, 1998). The active chemicals in the Kraft liquor are Na2S and NaOH. Other chemicals in Kraft liquors are important because they are involved in the recovery process; these include Na_2CO_3 and Na_2S0_4. Still other chemicals such as NaCl are important as contaminants that may build up in the system. The amounts of chemicals are reported on Na_2O basis in North America. Various combinations of these chemicals are given special Names because these combinations can predict how the liquor will behave better than considering the amount of chemicals themselves. Pulping chemicals are reported as concentrations in liquor or as a charge on dry wood (Kurosawa and Hashino, 2012).

2.4.1.3 Sulfite process

The sulfite pulping process is a full chemical pulping process, using mixtures of sulfirous acid and/or its alkali salts (Na^{+1}, NHs^{+1}, Mg^{+2}, K^{+1} or Ca^{+2}) to solubilize lignin through the formation of sulfonate functionalities and cleavage of lignin bonds. By 1900 It had become the most important pulping process, but was surpassed by Kraft pulping in the 1940s. It now accounts for less than 10% of pulp production. Woods with high pitch contents or certain extractives (such as the flavones dihydroquercitin in Douglas-fir) are not easily pulped at the lower pH's. Once the dominant pulping process, now less than 10% of pulp is produced by the sulfite method in this country, partly due to environmental considerations. Some advantages of sulfite pulping are bright, easily bleached pulps, relatively easily refined pulps, pulp that forms a less porous sheet that holds more water than Kraft pulps (for use in grease-resistant papers), and pulps with higher yield than Kraft (Biermann,1996)

2.4.1.4 Other chemical processes

Extended delignification chemical pulping and bleaching of chemical pulps are both delignification reactions. Of course, bleaching reactions are much more specific for lignin removal than pulping, but are much more expensive. Improvements in pulping that allow cooking to lower lignin contents and new processes before conventional bleaching are referred to as extended delignification. A variety of pretreatment processes (many of which are experimental) applied to pulp lower the amount of bleaching chemicals required, leading to lower levels of chlorinated organic materials. Organosolv pulping is largely an experimental pulping procedure using organic solvents such as methanol, ethanol, acetic acid, acetone…etc. to remove lignin. It has the advantages of having no sulfur emissions and a simple chemical recovery process which would allow relatively small mills to be constructed. Klason was the first to try to remove lignin from wood by dissolving it in acidified alcohol solutions in solutions of 5% HCl in ethanol in 1893. Cooking dry spruce chips for 6-10 hours led to dissolution of 28-32% of the wood. The alcohol cellulose process of Repap enterprises using 50% ethanol and 50% water at 195 °C for approximately 1 hour has been demonstrated at 15 t/d (Biermann, 1996).

In chemical pulping, the fibers are less likely to be damaged than in other pulping processes. Chemical pulping is more expensive than mechanical pulping but it has better strength and brightness properties. (Sixta, 2006).

2.4.2 Mechanical pulp

Pulp consists of wood fibers or other lignocelluloses materials that have been broken down into discrete fibers during pulping. These liberated fibers obtained after pulping can be dispersed in water and reformed into a web to produce a paper sheet. In many papermaking operations, a combination of chemical and mechanical pulps is used to obtain the desired paper characteristics. Mechanical pulping offers different advantages in the production of pulp and paper (Sundholm, 1999).

Wood fibers are disintegrated using mechanical actions such as grinding and refining, where heat is generated to soften the lignin for easier fiber separation. Since the lignin is only softened, it is retained in the pulp and, therefore, high yields of 90 to 95% can be obtained (Biermann, 1996). However, the presence of lignin can restrict fiber swelling during pulping and less collapsible fibers are, therefore, produced. It is likely that these lignin-rich fibers form weak paper, because of less inter-fiber bonds that are formed due to the small contact areas and limited hydrogen-bonding. Mechanical actions such as grinding and refining can also damage fibers and contribute further to reduction in strength (Chandra, 1998). The strength properties of mechanical pulp can be improved by either a chemical pre-treatment, mixing chemical and mechanical pulped fibers, or by additional refining steps (Monica, 2009).

Wood and agro-residues are exposed to grinding or shredding to free the cellulose fibers. This process produces high pulp yield i.e. of the order of 90-95%. Lignin is retained with pulp in this process. Pulp produced in this process is normally used for newsprint production.

There are different types of mechanical pulping processes as briefly listed below;

2.4.2.1Groundwood pulp (GW)

Grinding was reported to have been used for mechanical pulping to manufacture ground wood pulp (GW), as early as 1844 . Friedrich Keller was the first to press wood logs against a rotating stone together with water, to get pulp for paper production. The process works by the same principles today and when logs are pressed against the rotating grindstone with hot water, the fibers are torn out from its middle lamella matrix. This can be done either at atmospheric or pressurized conditions. Pressurized ground wood pulp (PGW) gives a pulp of higher strength than atmospheric ground wood (Sundholm., 1999).

2.4.2.2 Refiner wood pulp

In this process logs are cut down into wood chips that are then defibrated to mechanical pulp by means of disc refiners. Depending on the type of chips pre-treatment or chip post-treatment, several processes can be carried out.

In refiner different process:

• Stone ground wood (SGW) is produced by the mechanical defibration of round wood logs by a grinding stone.

• Refiner mechanical pulp (RMP) is obtained by mechanical deliberation of woodchips in a refiner and is carried out without pre-treatment. Deliberation takes place under atmospheric pressure. The wood chips are deliberated at temperatures of about 100 °C, mostly in two stages with consistencies of 20 to 30% in the second stage.

• In the refiner process with thermal pre-treatment (TMP), wood chips are treated with steam at 110 °C to 130 °C for 2 to 5 min before they are deliberated under high pressure.

• In the refiner process with chemical pre-treatment (CTMP/CMP), wood chips are impregnated with chemicals before they are mechanically deliberated in the refiner under high pressure of about 3 bar or at atmospheric pressure, mainly in two stages. (Sixta, 2006)

2.4.3. Hybrid pulping processes

Semi chemical pulping is a mechanical pulping process which involves pretreatment with chemical solution to reduce the energy requirements during processing and uses a combination of chemical and mechanical (i.e., grinding) energy to extract pulp fibers. Wood chips first are partially softened in a digester with chemicals. Once chips are softened, mechanical methods complete the pulping process (Chandra 1998).

2.4.3.1 Thermo mechanical pulp (TMP)

In thermo mechanical pulping wood chips are prepared with Steam and washed wood are fed into a pressurized, narrow space between two metal discs with grooved patterns. Either one disc rotates while the other remains stationary or both plates rotate. A conical disc (CD) refiner has both a plane zone and a conical zone to prolong the retention time of the fiber compared to a single disc refiner with just a flat zone. Double disc refiners are more energy efficient to the same degree of fiber treatment than the conical disc refiners that are more difficult to steer to the right fiber properties .the double disc refiner fibers have also been found to have a higher degree of external fibrillation and fiber flexibility (Reyier, 2008).

2.4.3.2 Chemi- thermo mechanical pulp (CTMP)

The CTMP process is similar to the TMP process, but before refining, the heated wood chips are exposed to chemicals to makes the rupture of the fiber occur in the primary wall/middle lamella interface, rather than in the S1/S2!wall as in the thermo mechanical pulp (Biermann, 1996).

2.5 Paper properties

The properties of the paper substrate are important partly because the substrate is visible between the printed areas, and partly because the substrate defines the background reflectance for the toner layer. Paper parameters can be grouped into three main categories: structure and composition, optical and appearance, electrical and thermal (Chen, 2009). Physical and mechanical properties of paper play an important role in its runability and printability, while optical properties play a factor in determining the quality of a print (Dawitz, 2004). Moreover, optical properties, mechanical properties, permeability to liquids, and so on, directly affect the quality of the images and the production process (Yang, 2003).

2.5.1 Physical properties of paper

The machine direction of paper is parallel to the direction of travel during the manufacture of the paper; cross direction is perpendicular to machine direction. Paper properties such as tensile, fold, and compression vary significantly between these directions (Sixta 2006)

2.5.1.1 Basis weight(grammage)

The weight of paper per ream, normally expressed on an air-dry basis (about 6-10% moisture, with 9% the standard) is known as the basis weight. For example, a printing paper is reported at weight/cm^2 ream and newsprint is 49 gsm (g/m^3 is the TAPPI Standard unit).

2.5.1.2 Tensile strength

Tensile strength is measured on paper strips 20 cm (7.9 in.) long by 15-25 mm (0.6-1.0 in.) with the ultimate force is reported in lb/in., kg/m, or N/m. The tensile strength should be measured separately in the machine and cross machine directions of paper. (Biermann, 1996)

2.5.1.3 Burst strength

The burst strength, which is also called the Mullen or pop strength, measures the amount of hydrostatic pressure (which increases at a specified rate) required to rupture a piece of paper. The paper is ruptured by a small, circular (30.5 mm, 1.20 in. diameter), rubber diaphragm pushed against the paper by glycerin. The maximum pressure before rupture is measured in psi or kPa. The burst test is highly correlated to the tensile strength. TAPPI Standard T403 describes the test for paper, T 807 for paperboard and linerboard, and T 810 for corrugated and solid fiberboard. The burst may also be reported in units of force divided by basis weight to give the burst index, burst factor, or burst ratio. (Sixta 2006)

2.5.2 Optical properties of paper

The quality of a flotation deinked paper is judged by its optical properties. Two parameters are often used; brightness and effective residual ink concentration. These are used to create a benchmark of measurement, on processed paper.

2.5.2.1 Brightness

The brightness of a paper is defined as the reflectivity blue light of the effective wavelength 457nm with a distribution from 400-500nm. The reflection is measured on a scale from 0 - 100% ISO. Notable is that this measurement only takes into account the blue region, ignoring the yellow and red portions of the spectrum and that the brightness measuring method was developed to monitor the bleaching process of paper (Castro, *et al* 2002).

2.5.2.2 Effective Residual Ink Concentration (ERIC)

The brightness is not an effective way to monitor the deinking process. A comparison of recycled newsprint and virgin newsprint gives the same reflectance in brightness but in the infrared region the two can vary greatly (Castro, *et al* 1999).

The purpose of the deinking process is to separate a system of hydrophobic material (ink) from hydrophilic material (fiber) by using the differences in their chemical properties. The chemistry of the system needs to be formulated so that the surfaces of the ink particles are highly hydrophobic-unstable surfaces. This gives ink agglomeration and strong adhesion to air bubbles for the flotation process (Beneventi *et al* 2001).

2.5.2.3 Opacity

This is a measure of the amount of light transmitted through paper. When no light is transmitted, the opacity is 100 %. The measuring principle is based on comparison of reflectance for a single paper sheet over a black background compared to an opaque stack of paper samples. As opacity increases with increased absorption and scattering of light, the following parameters are of prime importance for opacity: basis weight, filler content in base paper, degree of calendaring, type and treatment of pulp, as well as coat weight and coating color components, especially the type of Coating of Paper and Board pigment used (fine pigments increase scattering). Opacity is measured in accordance with TAPPI Test Method T 425 (Holik, 2006).

2.6 Deinking Process

Deinking is an important step in recycling of waste paper which it is process for detaching and removing printing inks from recycled fibers to improve optical properties of recovered printed papers. Deinking process is more complex, it is a physical and chemical change process. Deinking the entire process can be divided into three steps relief separation fiber, make the ink from fiber deinking from and emerge the ink particles in thick liquid material removed (Ma, *et al* 2011).

Ink washing involves ink removal by washing it from the fiber using sodium hydroxide, sodium silicate, and hydrogen peroxide with a suitable dispersant in the pulper. Often the dispersant is stearic acid and micelle formation occurs in the classic mechanism by which soap is able to make grease and oils water "soluble". The emulsion is washed from the pulp, and the ink is removed from the wash water by flocculation so the wash water may be reused. Hard water should not be used during ink washing since this will precipitate the soap and the complex will not be water soluble. The clarified water is then reused to wash more pulp. This general method has been used since the nineteenth century. It is suitable for traditional inks with vegetable oil vehicles that are readily saponifiable and dispersible (Sxita 2006).

Flotation is a process that separates materials based on the property of wet ability. The process is carried out in ink flotation cells (several cells may be used in series) using sodium hydroxide, sodium silicate, and hydrogen peroxide with a collector system consisting of a surfactant.

With ink flotation, large ink particle sizes are desired (at least 5 /im, but 10-50 ixmis ideal) so the ink can agglomerate and be skimmed from the slurry. Ink flotation can be divided into three phases: Collision of ink particles with air bubbles, attachment of ink particles to air bubbles, and separation of the ink particle-air bubble complex from the pulp. In previous study the use of the flotation technique resulted in good brightness and pulp recovery in the removal of ink from pulp produced from discarded newspaper study (Costa, 2005).

2.7 Chemical Deinking

There are many chemicals use in deinking process such as Sodium hydroxide, Hydrogen peroxide, Sodium silicate, Fatty acid, Non-ionic surfactants and Enzymes

Sodium hydroxide (NaOH or lye) is used to adjust the pH towards the alkaline region of pH 9-10, the swelling of the fiber caused by the lye can help the mechanical release of the stiffer ink from the surface of the fiber. (Ma *et al* 2011) .The alkaline environment also saponifies the fatty acids and hydrolyses the ink resins.The NaOH causes an ionization of the carboxylic groups of the cellulose fibers and saponification of some ink bindes and acid resins in the wood. The release of the ink is due to ionization of fibers and the ink´s surface groups, generation of electrostatic repulsive forces, and mechanical stress at the ink/fiber interface after swelling and release of fatty acid soaps (Zhao, *et al* 2004).

Hydrogen peroxide (H_2O_2) is added to the process to prevent the yellowing of the paper that occurs with the addition of sodium hydroxide. The hydrogen peroxide forms a per hydroxyl anion (HOO^-) in water which attacks the groups causing yellowing in the lignin called chromophores. The hydrogen peroxide can also break the chemical cross-linkage that is formed between alkyl binders of the ink when stored and dried (Theander and Pugh, 2004).

Sodium silicate is used to stabilize the hydrogen peroxide. By inactivating the metal ions in the process causing breakdown of hydrogen peroxide, and by maintaining a stable pH an optimization of the effect of the hydrogen peroxide. There are also other minor effects of the sodium silicate such as improved dispersion of ink, due to attachment to colloidal particles (Lakouraj and Movagharnejad, 2005).

Fatty acid mixtures are commonly used in in flotation as dispersants and (in their saponified form) as collectors. These mixtures are often of commercial grade and primarily contain C 14-18 carbon chains, which consists mainly of stearic, oleic, palmitic and linoleic acids. The blends are sensitive to change in properties, directly influencing foaming, selectivity, and carryover of chemicals to the paper machine. (Theander and Pugh, 2004)

Non-ionic surfactants are used today in flotation mainly as dispersion agents. There are many surfactants that have been produced especially for the flotation deinking process and are used in the concentration range of 0,001-0, 01 % on dry fiber bases. The surfactants used in flotation deinking are non-ionic due to their low sensitivity towards the hardness of the water. Ionic surfactants do not improve the result of the flotation and can lead to high yield losses in the flotation stage. (Kumara, 2015).

In Abd El-Khalek (2012) study (Performance of different surfactants in deinking flotation process) found that a two-step deinking process involving pulping and flotation steps and utilizing different types of surfactants was studied for laser printed papers. Deinking performance of each surfactant was used without further use of a chemical additive except pH regulator. The brightness of feed pulp was 44%. The higher brightness of pulping step of 62% was achievable with 3%alcohols as nonionic surfactants compared to anionic and cationic surfactants. The higher brightness of flotation product was achievable at pulp pH 7, 11 and 12 for nonionic, anionic and cationic surfactants, respectively (Abd El-Khalek., 2012).

Another study (Lakouraj, 2005) has shown that the enzymatic treatment can improve ink removal efficiency. Optimization of the enzymatic treatment time and enzyme concentration allowed elimination of the toner particles and significantly improved the cleanliness of recycled non-impact printed waste papers. Enzymatic treatment time equal to 90 min and enzyme pulp ratio equal to 0.2 cc/g introduced as optimum conditions for deinking process (Lakouraj, 2005).

Also, Kumar (2015) in his study found that the studies conducted on enzymatic and chemical deinking have shown that the enzymatic deinking with the isolated cellulose based enzyme showed the encouraging results in respect of pulp yield and quality of effluent with significant improvement in optical and strength properties. Further studies are in progress to upscale the enzyme production on large scale to demonstrate the process in an identified newsprint mill in order to promote the enzymatic deinking in Indian paper industry as a clean and green technology initiative (Kumara, 2015).

In addition to some studies that focus in used chemical, different condition and mechanism for deinking process. Because it’s simple and available method in the same time low cost , Shall (2005) in his study found a simple and effective deinking process involving pulping and flotation was developed. The process depends on adding reagents in the pulping stage that lead to formation of fine bubbles at ink fiber water interface. the result of preliminary test showed that brightness of more than 55% could be obtained from mixed stock containing 30%. The process has several feathers such as, few chemical such as hydrogen peroxide and alkaline reagent (e.g ammonium hydroxide, sodium bicarbonate and sodium carbonate) are used and high yield of good quality (brightness) product(Shall, 2005).

From practical and economic view point, this process may prove to be more economical due to low reagents consumption. Operating at room temperature, increased plant capacity by floating higher solid content pulp and possibility of water recycling further testing at large scale is recommended to qualify the potential of this process. (Abd El-Khalek, 2012).

Today, in the paper industry, flotation deinking is the dominating process worldwide for the removal of printing inks from recovered paper. Most studies focusing in this process and experimental studies have been conducted to evaluate different operating conditions, including temperature of liquid phase, concentration of solid in flotation, etc. The efficiency of the process is evaluated in terms of brightness and filthiness. Process of deinking flotation today is a dominant process in the world of paper industry that is used for ink removal from old paper, (Shall 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

The waste paper used in this study comprised:

a) Printing paper: free (5) kg collected as post consumer waste (trimings) from commercial printing facility (copy paper) from Medicine Academic in Khartoum.

b) Wrapping paper: free (5) kg collected as post consumer waste from Samier Gassim Packaging Factory (Khartoum north) paper using Kraft and fluting.
c) Old newsprints (ONP): free (5) kg was collected from commercial printing facility such as press houses and some governmental institutions.

Chemicals used in this study were Sodium hydroxide, sodium carbonate and hydrogen peroxide which were purchased from Alwalieden Company, Sudan.

3.2 Methods

To achieve the objectives of this research the data was obtained in two ways:

3.2.1Questionnaire

Two sets of questionnaires were prepared from literature review, the first set was targeting the public (households) and the second the convertors (printing press 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 society, awareness and waste recycling practice. In this study sample, hundred questions were distributed to citizen in different areas of the three Capital City (Khartoum, Omdurman and Khartoum north)

The second survey was structured questionnaires targeting 15 from converting establishments (5 from cardboard and 10 from packaging and printing) 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 of the questionnaires were analyzed by (spss) system and evaluated.

3.2.2 Collection and sorting of samples

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

3.2.3 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 (dry weight of paper to water) at 60^{o}C with two different concentrations of Sodium hydroxide (3% and 6%) soaked for 2 hours, during treatment pulp was stirred 3-4 times. In this stage initial pH was 9. This waste paper feed stock was pulped and defiberated in a turbo pulper for two deferent times 5 and 8 minutes then screened.

3.2.4 Dinking process (flotation)

The pulp slurry with 6% consistency from old newsprints was produced in a disintegrator operating for approximately 5 min. The pulp was reacted with two sets of experiments: 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 different charges (1%, 2% and 3%). All the reagents used were proportional to the weight of the dry newspaper. The pH in this stage was adjusted to about 9.5–10.

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

3.2.5 Handsheets formation

Hand sheets for physical tests were prepared in according to TAPPI T205 standard with a British standard machine. The obtained sheets were air-dried using plastic rings.

3.2.6 Evaluation and testing of handsheets

The sheets produced from pulps were conditioned 24 hours before testing. The moisture contents, thickness and specific volume, tensile strength, burst strength, tear strength and brightness were determined for a minimum of six best sheets from each pulp in accordance with the TAPPI standards and methods shown in table (3.1)

Table 3.1 the evolution of handsheets according to the TAPPI standards

Test	Standard

Handmade sheet formation	TAPPI-220m-sp-01
Conditioning	TAPPI-402-sp-98
Thickness and specific volume	TAPPI 411 om-83
Brightness	TAPPI 425 om-81
Tensile strength	TAPPI 404 om-82
Bursting strength	TAPPI 403 os-76
Moisture contents	TAPPI 412 om-83

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1Characteristic of the Target Group

Table 4.1 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 females, 58% were jobless and 73% were between 20 and 35 years of age,

Table 4.1 structure of personal information of targeted group.

Sex%		Jobs%		Age %					Education			
M	F	Yes	No	20<	20-25	26-35	36-50	50>	Primary	Secondary	university	Postgraduate
44	56	42	58	11	42	31	13	3	4	13	69	14

M= Male, F= Female

Table 4.2 shows 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 4.2 frequencies of participation of target group waste handling**.**

Awareness of community	Yes%	No%	Not responded%
Collection of solid waste	61	38	1
Feed back and Communication	56	42	2
Paying fees	84	15	1
Place of disposal	25	74	1
Collaboration in waste disposal	89	11	0
If there any need to change the existed system	88	9	3

Table 4.3 shows methods of storage and disposal of waste. It revealed that 19% of storage areas were found to be stored in rooms, followed by waste basket (16%) and trash bags (12%) whereas 51% don't store the collected waste. Compared to developing countries such as Sudan and Southern Sudan (Garang 2017: Adam et. al 2016), the analysis has shown that 46% of the target group take their waste to the waste containers while 18% burn .while in Bor and Zanlingy 34.7% and 56% respectively burn their waste. 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 4.3 methods of storage and disposal of waste.

Storage at home%		Mean of disposal%		Waste containers%	
Don't store	50	Burn	18	far from house	45
Trash bags	12	Put it on street	8	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 4.4 shows knowledge about sorting and recycling of solid waste. The survey has shown that 53% from the population sample are aware of waste recycling process, and 53% perform some kind of sorting and most of them (80%) believe that sorting is important.

Table 4.4 knowledge about sorting and recycling of solid waste.

Awareness	**Frequencies%**		
	Yes	No	No responded
Recycling process	53	45	2
Importance of sorting	80	19	1
Are you sorting solid waste	53	46	1

Table 4.5 shows the contents of households sorted solid waste and reuses. 45% of sorted materials were organic matter followed by metal (26%) and paper (10%), in line with a study conducted by (Elsarraf *et al* 2017) 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 (Ali, 2009). Similar trend was reported from City of Bor South Sudan (Garang 2017) where solid waste materials generated include plastic (41%), organic waste (29%), paper (15%), wood (6.3%) and metal (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 among the 53% who sort their waste, 16 of them sell while 22% give their waste to others. The survey also reveals that 64% believe that safety 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.

Table 4.5 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	10	19	16	8	22	**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% and 1 4 % respectively. Table 4.6 shows the source of paper, sorting and disposal of waste paper among the convertors society. While all of the cardboard converters import their base paper, the printers import some and buy some locally. It could be noticed that automatic presses were employed only in cardboard facilities; the others collect their waste manually. Most of the collected waste either sold to others or stored in designated area.

Although in some cases the waste was just discarded, the price for the waste paper can reach up to US$ 55 for the wrapping paper.

Furthermore, some of the collected waste was exported especially to Saudi Arabia.

Table 4.6. Source of paper, collection, sorting and disposal of waste paper and recycling in different facilities:

	Facility type		
	Cardboard and printing	**Packaging and Printing**	**Printing**
Paper source			
Direct import	5	9	1
Indirect import	0	9	1
Collection method			
Manually by workers	1	8	1
Automatic presses	4	0	0
Waste storage			
With other wastes	0	2	0
In designated places	2	3	1
Sold to others	3	3	1
Value of the waste			
Free	0	2	0
(0.1-10) US$ / tone /year	0	4	2
(10-40) US$ / tone /year	3	2	0
(41-55) US$ / tone /year	2	0	0

According to table 4.7 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 4.7 Approximate consumption of different paper grades by the converters in Khartoum State.

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

4.2 Pulp and Paper Evaluation

Table 4.8 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% from 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 delignification fibers 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 64.5 $mN*m^2/g$, burst index is ranged from1.8 to 2.7 $kPam^2/g$ and bulk is ranged from 4.12 to 4.39 cm^2/g^3. 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 4.8 Effect of sodium hydroxide concentration on pulp and paper properties:

Sample type	**NaOH concentration %**	**Physical properties**			
		Screened Yield	**Tensile index (mN*m^2/g)**	**Burst index (kpa*m^2/g)**	**Bulk (g/cm^2)**
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

Table 4.9 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 4.9 show 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 4.10 shows 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 H2O2 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 (Ma *et al* 2011). The brightness of newsprint paper was enhanced with the increasing of sodium carbonate concentration more than that of H_2O_2. Similar results were reported for the effect of Sodium Pecarbonate and Pecarborate (Pesman *et al*., 2014).The physical properties, however did not show any trend (increase or decrease) with increase of H_2O_2 concentration. The table also shows that paper made from newsprint waste paper gave lower strength properties than those made from printing paper and wrapping paper.

Table 4.10 Effect of hydrogen peroxide on sheets properties made from newsprint paper.

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 4.11 shows the effect of sodium carbonate concentration on physical properties of paper made from newsprint waste paper. While brightness of feed pulp was 41%, a brightness of 53% and 57% were obtained as result of using 2% and 3%, of Na_2CO_3 respectively. 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 4.11 Effect of sodium carbonate concentration on properties of handsheet made from newsprint waste paper.

Na_2CO_3%	Tensile index	Burst index ($kpa*m^2/g$)	Bulk density	Brightness %

	(mN*m²/g)		(g/cm³)	
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

CHAPTER FIVE

CONCLUTIONS AND RECOMMENDATIONS

5.3Conclusion

- 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 scarcity 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.
- Increased in both H_2O_2 and Na_2CO_3 concentration in pulp made from newsprints waste caused an increased 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 newsprint.

5.2 Recommendations:

- It is highly recommended to change the existing solid waste management system to a system based on sorting of the solid waste during collection and storage.
- There is need to increase public awareness concerning appropriate waste collection, sorting, storage and disposal.

- State and federal regulations and incentives should be considered to encourage and be prepared for paper and other recycling industries.
- Paper recycling industry should depend on printing and wrapping waste paper and avoids using old newsprints waste for better quality paper.

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بسم الله الرحمن الرحيم

استبيان رقم (1)

المعلومات العامة :

1. **النوع؟**

أ. ذكر ( ) ب. أنثى ( )

2. **الفئة العمرية؟**

أ. > 20 ( ) ب. 20-25 ( ) ج. 26-35 ( ) د. 36-50 ( ) ه. < 50 ( ).

3. **مكان السكن؟**

....

4. **المستوى التعليمى؟**

....

5. **هل يوجد وظيفة؟**

نعم ( ). لا ( ).

درجة الوعي :

6. **من يتولى النفايات الخاصة بك ؟**

....

7. اين تقوم بتخرين النفايات الصلبة داخل المنزل؟

....

....

8. كيف تتخلص من النفايات الصلبة الخاصة بك؟

أ. حرقها ( )

ب. تركها فى الشارع ( ).

ج. رميها في المصارف ( ).

د. وضعها فى حاوية النفايات ( ).

هـ. أحضارها لموقع ألقاء النفيات ( ).

ز. لاعرف ( ).

9.هل يتم جمع النفايات الصلبة من الحى؟

أ. نعم ( ).

ب. لا ( ).

10. كيف تجمع النفايات من الحى السكنى؟

أ. عربات النفايات من الشارع الفرعى ( ).

ب. عربات النفايات من الشارع الرئيسى ( ).

ت. من حاوية نفايات ( ).

ث. من منطقة تجمع مفتوحة ( ).

ج. من منطقة تجمع مسورة ( ).

ح. اخرى

ماهى؟...

....

11. في حالة حدوث مشكلة في نقل النفايات أو جمعها، هل هنالك جهة يتم اللجوء إليها؟

أ. لا ( ).

ب. نعم ( ). **ما هي هذه الجهة؟**

....

....

12.هل تدفع رسوم خدمات النفايات؟

أ. نعم ( ) .

ب. لا ( ) .

13. ما رأيك فى حاويات النفيات فى منطقتكم إن وجدت؟

أ. بعيدة جداً عن المنزل ( ).

ب. صغيرة جداً لأحتواء جميع النفايات الصلبة ( ).

ج. مصدر للنفايات المبعثرة و الروائح الكريهة ( ).

د. لا يوجد مشكلة ( ).

14. ماهى المشلكة التى يمكن ان تحدث فى حالة عدم جمع النفايات من داخل الحى؟

أ. صحة المواطن ( ).

ب. تلوث الحى السكنى ( ).

ت. بعثرة القمامة ( ).

ث. المظهر العام ( ).

ج. لا يوجد مشكلة ( ).

15. هل تعرف اين تؤخذ النفايات التى تم جمعها من منطقتكم؟

أ. نعم ( ).

ب. لا ( ).

16. هل انت راضى عن نظام جمع النفايات الصلبة؟

أ. غير راضى على الاطلاق ( ).

ب. غير راضى ( ).

ج. غير مهتم ( ).

د. راضى ( ).

هـ. راضى جداً ( ).

17. اذا كنت غير راضى عن نظام جمع النفايات ؟ ما هو السبب برأيك؟

أ. الخدمة غير متوفرة و دائماً ( ).

ب. عدد المرات غير كافى ( ).

ج. الاهمال فى جمع النفايات مع ترك بعضها ( ).

د. النفايات لا تجمع مباشرة من المنازل "مكان الجمع بعيد" ( ).

هـ. لا يوجد فرز وتدوير للنفايات.

و. اخرى؟ حدد ؟

....

....

....

18. هل تعتقد أن هناك حاجة لتغيير النظام القائم؟

أ. لا ( ).

ب. نعم ( ).

19. هل انت على استعداد للمشاركة فى التخلص الآمن من النفايات فى الحى؟

أ. نعم ( )

ب. لا ( )

20. كيف يمكنك ان تساهم فى التخلص من النفايات ؟

أ. اخذ النفايات الخاصة بك لنقطة التجمع التى يحددها الحى او المحلية ( ) .

ب. فرز النفايات ( ).

ج. تنظيف المبعثرات حول موقع التخلص من النفايات ( ).

فرز النفايات :

21. ماهى احسن الطرق للتخلص من النفايات بعد جمعها ؟

أ. الحرق ( ).

ب. فرز المفيد منها ( ),

ج.نقلها خارج المدينة ( ).

د. لا أعرف.

22. هل تعرف عن اعادة التدوير(إستخدام النفايات بعد المعالجة)؟

أ. نعم ( ).

ب. لا ( ).

23. هل هناك اهمية لفرز النفايات قبل جمعها ؟

أ. نعم ( ).

ب. لا ( ).

24.هل تقوم بفرز ؟

أ. نعم ( ).

ب. لا ( ).

25.اذا كانت الاجابة بنعم ؟ ماذا تفرز ؟

أ. عضوى (بواقى الطعام ....) ( ).

ب. ورق ( ) .

ج. حديد ( ) .

د. اخرى ( )

....

....

....

....

26. ماذا تفعل بالمفروز من النفايات الخاصة بك؟

أ. يتم فرزهم و بيعهم ( ).

ب. يتم فرزهم للاستعمال الخاص ( ).

ج. فرزها و إعطاها للاخرين للاستخدام مرة اخرى( ).

د. لا اعلم ( )

27. ماهى العوائق التى تحول دون فرز النفايات ؟

أ. لايوجد مرافق كافية محلياً (صناديق خاصة ، حاويات ، مراكز لبيع القابل لاعادة التدوير ، الجمع المنتظم للقابل للتدوير) ( ).

ب. لا وقت ( ).

ت. ليست اولوية ( ).

ث. لاتوجد مساحة تخزين( ).

ج. لا يوجد معلومات ( ).

ح. لا يوجد حافز ( ).

28. ماهى المحفزات لتتمكن من المشاركة فى فرز النفايات؟

أ. طريقة جمع مريحة (   ).

ب. مقابل مادى (   ).

ج. المحافظة على بيئة آمنة (   ).

د. تجنب العقوبات (   )

بسم الله الرحمن الرحيم

استبيان رقم (2)

1. **نوع المنشأة:**

أ . كرتون وتغليف ( )　　　　ب. طباعة وتغليف ( )

ج . طباعة ونشر( )　　　　د. طباعة ( )

2.**نوع الورق المستخدم:**

أ. تغليف : كرافت ( )　　تست لاينر ( )　　فلوتينق ( )

ب. طباعة : أذكر أنواع الأوزان المستخدمة

رقم	النوع	الوزن (جم/متر2)

3. **مصدر الورق:**

أ. مستورد مباشرة ( )　　　　ب. مستورد محلي ( )

4. **معدلات الاستهلاك من كل نوع:**

رقم	النوع	الكمية بالطن للعام الواحد

5. **ماهي تقديراتكم للتكاليف (يشمل القصاصات)؟ بالكيلو/فترة زمنية؟**

………………………………………………………

6. ما هي كيفية جمع الورق التالف والقصاصات؟

………………………………………………………

………………………………………………………

7. ما هي استخدامات الورق التالف والقصاصات؟

أ. بواسطة المنشأة ( )   ب. بواسطة منشأة أخرى ( )   ج. لايستخدم ( )

8. في حالة استخدامه، ما هي أوجه الإستخدام؟

………………………………………………………

………………………………………………………

9. أين يتم التخلص من الورق التالف والقصاصات؟

أ. مع النفايات الأخرى ( ) ب. في أماكن مخصصة ( )

ج. يباع لجهات أخرى ( )

10. كم هي القيمة التي تتحصلون عليها من بيع الورق التالف والقصاصات؟

………………………………………………………

11. هل يشكل الورق التالف والقصاصات أي خطورة على المنشأة؟

أ. نعم ( )   ب. لا ( )

12. في حالة الاجابة نعم ما هي هذه الخطورة؟

……………………………………………………………………

……………………………………………………………………

13. في حالة وجود جهة مستفيدة من الورق التالف والقصاصات:
ما هو السعر المتوقع من جانبكم (بالكيلو)؟

……………………………………………………………………

14. نوع التعامل ؟

أ. طويل الامد ( ) ب. مع من يدفع اكثر ( )