



## Paper Recycling for a Sustainable Future: Global Trends

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**Abstract:** As environmental concerns continue to grow, the need for sustainable practices becomes increasingly critical. One such practice is paper recycling. Because paper waste is the one of critical problem in today world. This review paper examines global trends in paper recycling, exploring the challenges and opportunities in the realm of paper recycling. It also focuses on the specific context of Sri Lanka, highlighting its importance in achieving a sustainable future. This study presents an overview of the current state of paper recycling worldwide, including key factors driving its adoption and success. The paper extensively discusses the topic of recovered papers, including their processes and collection methods. It recognizes the significance of utilizing recovered papers as a valuable resource in the paper recycling industry. It identifies various environmental, economic, and social benefits, disadvantages and challenges associated with paper recycling. Nevertheless, it also highlights the significant potential for growth and improvement in the Sri Lankan paper recycling sector, offering recommendations for enhancing recycling rates. By analyzing global trends and the case of Sri Lanka, this paper underscores the importance of paper recycling as a sustainable solution for the future. It emphasizes the need for collaborative efforts from governments, industries, and individuals to overcome barriers and promote the adoption of paper recycling practices.

**Index Terms:** Paper recycling, Wastepaper, Sustainable waste management, Recovered paper grades, Recovered paper collection, Recovered paper processing, Waste management strategies.

## 1. INTRODUCTION

More paper items are generated as the population rises and internet purchasing becomes more popular. According to a paper.com research, express parcels in China exceeded 50 billion pieces in 2018, and the number of packaging boxes was over 14.3 billion. According to "Paper Industry Association White Paper" data, the equivalent paper consumption is approximately 1 million tons, accounting for approximately 2.3% of corrugated and boxboard paper output. In Malaysia, it is projected that 2.3 million tons of recycled materials are released to garbage sites each year, with an RM900 million value. According to FAO (Food and Agriculture Organization of the United Nations) recovered paper figures for 2017, 235,816 tons of recovered paper were collected globally, whereas 211,144 tons of paper were reused. However, paper recovery rates in Malaysia remain low, at around 40%. Only 100,000 tons of newsprint are recovered from the trash stream out of around 250,000 tons produced each year. A substantial proportion has yet to be recycled [1].

Recycling is the process of collecting and converting waste items into new raw resources. It is critical in both the waste management hierarchy and the sustainability of waste management. Indeed, recycling aids in the conservation of natural resources, the creation of value, the reduction of carbon footprint and environmental pollution, and the improvement of health. The chemical and physical characterization of various types of waste materials, the development of technological processes, the formulation of the appropriate legislative and administrative framework, and consumer involvement and education are all required for concrete recycling implementation [2].

The traditional method of producing paper from pulp derived from raw wood is unprofitable and unsustainable. The UN environment program proposes many solutions and goals to help ensure sustainability on earth, including the 12th goal – Sustainable consumption and production. It aims to detach economic growth from environmental damage, boost resource efficiency, support the shift to low-carbon and green economies, and promote sustainable lifestyles. Recycling paper is one of the ways to fulfill this goal. For more than 30 years, recycled paper has been sold in the market. It is one of the best solutions to lessen environmental issues and waste generation. Recycling decreases the need for new raw materials and prevents the loss of potentially useful resources. The Delft University of Technology has done extensive study on the circular economy and packaging. The 4R technique, which stands for "recycle, reuse, renew, and rethink," was developed by the university. In this sense, recycling refers to the use of waste packaging materials to generate new packaging. As the global demand for packaging board has grown, a substantial amount of secondary cellulose raw materials has been created; these materials account for 25-40% of municipal solid waste (MSW) that is disposed of in landfills or burned. These disposal methods are not environmentally friendly due to the creation of toxic gases and polluting leachate. By recycling these fiber sources and employing them as raw materials for new sustainable goods, forest resources can be maintained while other environmental repercussions are reduced.

Paper recycling is a top issue for many countries throughout the world. China, for example, has established a market-driven paper recycling system. In the United States and Japan, more than a million tons of recovered paper are recycled. Most countries also have their own recycling policies or regulations. For example, Japan has a strict rule called the Containers and Packaging Recycling rule to regulate trash in their country.

The government of Malaysia established the Solid Waste Management and Public Cleansing Corporation Act (SWCorp) to support and ensure the successful execution of the National Solid Waste Management Policy. As a result, making efficient use of wastepaper may not only reduce the amount of MSW, but also assist conserve and protect the environment.

Furthermore, current waste management practices are shifting away from garbage disposal and toward recycling, reusing, and recovering. According to Bajpai, replacing one ton of virgin fiber with one ton of recycled paper results in a 100% reduction in wood use, a 33% reduction in wastewater, a 27% reduction in energy consumption, a 28% reduction in air particle emissions, and a 54% reduction in solid waste. This data set demonstrates the significance of wastepaper recycling. As a result, recycling wastepaper is becoming increasingly popular as a resource-saving and environmentally responsible alternative to pulp and paper production.

However, recycling recovered paper can have a negative impact on paper quality. For example, recycled papers have a worse quality than paper made from virgin pulps because the fibers are shorter and have less tensile strength. Paper fibers cannot be recycled indefinitely because they are destroyed throughout the handling and recycling process. It is possible to recycle up to seven times. Every year, the paper industry employs 19 million tons of recycled paper to manufacture containerboard; nevertheless, mechanical

qualities deteriorate with each fiber reprocessing cycle due to fiber's resistance to swelling when rewet after drying. Papers manufactured from recycled fibers change color and may turn yellow over time. The user perceives some downsides in the quality of recycled paper, such as its opacity (which impacts strikethrough or see-through on double-sided printing), mechanical qualities, and printer longevity. Print quality improvements would encourage more people to use recycled paper. The bulk of paper properties influence how effectively paper prints electrophotographically. Increases in basis weight, brightness, caliper, density, hardwood fiber content (%), fluorescence, gloss, opacity, and porosity improve print quality, but increases in Parker Print-Surf (PPS) roughness have the reverse effect.

Electrophotography is a dynamic technology used in copiers, fax machines, and digital printers. It is an imaging technology that prints a digital file as an output using a photoreceptor, light source, electrostatic principles, and toner. Despite significant technological developments throughout the years, the core technique of electrophotography has remained mostly unchanged. The color gamut of electrophotographic digital printing is controlled by a variety of elements, including the printer, toner, and, in particular, the qualities of the paper (such as whiteness, roughness, and gloss), all of which have an impact on the final color gamut and reproduction quality [3].

Due to resource waste, notably paper, Sri Lanka has faced numerous social, environmental, and economic difficulties. Recycling waste papers can be regarded as a profitable business in wastepaper management to assure resource recovery. The largest state-owned printing firm in Sri Lanka generates 600 tons of paper trash every year, the most majority of which is discarded. A cost-benefit analysis was performed to determine the financial feasibility of plant installation using a currency conversion rate of 1 US\$ = 200 LKR. We estimated the Cost-Benefit Ratio (CBR), Net Present Value (NPV), and Internal Rate of Return (IRR). This study assumed that recycled waste papers are only used to make file covers with a market price of 3.95 LKR, that the price of the file covers as well as the cost of electricity, water, maintenance, and labor are constant throughout the year, and that the proposed paper recycling process runs for 16 hours. per day/20 days per month, machines run in two shifts with four skilled professionals and six unskilled laborers in each shift, production in the first year of the project is half of its maximum production capacity, and the entire recycling process is manual.

The minimum land area required to establish the paper recycling facility is estimated to be 10 perches from the printing premises. Data for this study were gathered from a well-known paper recycling equipment manufacturer as well as through interviews with four paper recycling industry professionals. The planned paper recycling plant at the current printing firm has a CBR of 1.09, an NPV of 11,230,770.65 LKR at a 10% discount rate, and an IRR of 32%. The calculated CBR, NPV, and IRR values supported the financial feasibility of the proposed paper recycling operation on the State Printer's grounds. Because paper recycling consumes a significant amount of water, building a recycling water plant, efficient work schedule management, and diversifying recovered paper goods can all assist to lower project costs [4].

## 2. FACTORS AFFECT TO PAPER RECYCLING

Paper recycling is an example of sustainable production in the context of policies established and solutions sought in this field in a climate change economy. This brings up the current issue of determining and influencing the process, as well as our research interest. The study identified and systematized the following groups of factors: environmental; operational and economic; legal and regulatory. The effect they have on wastepaper (WP) recycling has been recognized in order to facilitate and improve the quality of the goods obtained.

The possible limits of employing WP for recycling are connected to the availability of sources from which used paper products may be recovered, which can be increased by improving their location and collection. The development of WP demand and supply, as well as the reflection of worldwide trends on raw materials, have an impact on WP delivery and prices, as well as the costs of alternative waste processes.

It is critical to have a conscious attitude and develop public culture on recycling issues, as well as to clarify environmental policy terms. This will have an impact on the quality of the recycled paper used, which is a crucial determinant of the completed product's quality. As a consequence of our review, we believe that the factors that influence the paper recycling process can be systematized, as indicated in the Table 01.

TABLE 01. FACTORS INFLUENCING THE RECYCLING PROCESS OF WASTEPAPER [5].

Factors for the paper recycling process		
Environmental friendliness of production	Operational and economic	Legal and regulatory
environmental awareness	recycling costs	definition and classification of paper for recycling
the effectiveness of waste management systems	capacity of recycling plants (factories)	prohibitions and licensing requirements
resource (green) economy policies	price of primary raw materials	waste legislation
eco-design of paper and cardboard products	alternatives to waste management	quotas for trade
availability of sources and raw materials for recovery	market conditions for recyclable materials	defining "best practices" for waste management
climate change reporting	quality of paper for recycling	voluntary agreements

The environmental friendliness of production is critical in the recycling of wastepaper (WP). Paper recovery is influenced positively by recycling awareness, particularly in European nations with low collection rates. Well-informed people are more likely to recycle and be satisfied with their actions. State institutions play an important role in public awareness initiatives. Recycling behavior is consistent with the Schwartz altruism model and is impacted by social norms, personal norms, and consequences awareness. Recycling rates are influenced by demographic and economic factors. Open economies that trade in recyclable materials have better rates of usage and recovery. Structured recycling programs increase recycling rates, and individual attitudes influence recycling behavior in communities where such programs are easily accessible.

Effective of waste- Waste management systems' performance is critical for recycling wastepaper (WP). To increase WP collection rates, a conscious attitude and cultural shift toward recycling are required. Efficient collection systems that include waste pre-sorting are critical for increasing recyclability and reducing re-sorting in paper processing. Recycling should be included in a comprehensive waste management strategy. Recycling involves methodical planning and a mix of private and public cooperation.

Wastepaper (WP) recycling policies include projects, programs, and measures to coordinate and implement recycling procedures. These measures are intended to minimize pollution, conserve energy, battle climate change, and protect biodiversity. Recycling helps to safeguard the environment by reducing raw material use and trash generation. Sustainable consumption and production initiatives, as well as EU proposals on industrial pollution, encourage recycling programs for secondary fibrous materials.

The availability and collection of used paper goods are two limits of recycling wastepaper (WP), which might be improved. Global raw material trends might also have an impact on WP availability and costs. The manner of collecting paper is determined by the area, population, housing structure, and industries present. Wastepaper is generated by industries, residences, and individuals, and various collecting mechanisms, such as colored bins and recycling centers, are utilized [5].

Eco-designing paper and cardboard products are critical for manufacturing high-quality recycled material and boosting the use of secondary fibrous materials in the paper industry. High prices, legislation, and restrictions, on the other hand, impede the implementation of eco-design approaches.

Climate change concerns are included in the notion of eco-efficiency, which leads the recycling process to reduce carbon footprint.

Recycling's operational and economic components are intertwined, with tangible indications such as cost reduction, resource and energy savings, and greater control of wastepaper (WP) trade markets. In a mutually beneficial partnership, these factors should be taken into account.

Paper is highly recyclable, and the waste hierarchy has been altered to prioritize recycling over disposal. When compared to the European average, our country has higher levels of paper and cardboard recycling. Audit reports and industry figures demonstrate the wide capacity of local processing plants as well as the relevance of paper recycling for a circular economy. The high costs of alternative waste management solutions such as incineration or landfilling boost the recycling process even more. It should be highlighted that paper recycling is only environmentally superior to incineration when high-performance recycling technologies are used.

Recycling costs include expenses for collection, pre-treatment, and the recycling process. Economic profit is a major motivator for recycling. Waste collection and sorting costs are critical to overall profitability. Market conditions and demand for recycled goods have the potential to lower net material recovery costs. The elimination of trash collection and disposal costs is required for successful recycling. Recycling expenses are influenced by landfill costs. Paper manufacturers can save money on raw materials by reusing secondary fibers. Technological principles enable the creation of white paper goods from recycled fibers at a low cost. Replacing fibrous raw materials in paper packaging lowers costs while meeting product specifications. Wastepaper price regulations are critical for protecting cellulose fibers and fostering economic development.

The cost of primary raw materials has an impact on recycling's economic appeal. Secondary materials become more enticing when primary resources become more expensive. WP prices are driven by market conditions and factors that WP merchants control. WP value is determined by a variety of factors, including waste losses, paper machine performance, fiber kinds, primary fiber costs, and waste disposal costs. WP prices are primarily governed by the cost of paper and cardboard. WP collection and delivery costs include collection fees, transportation expenditures, sorting expenses, and administrative fees. Recycling lessens

the demand for imported pulp, offering economic benefits to countries that do not have their own sources of wood pulp [5].

Total costs, production cost per mass of recycled paper, the production cost range for primary fibers, determining the economic limit for recycling, WP and cardboard prices, equipment amortization, operating expenses, and WP utilization are all operational and economic aspects of WP recycling. These elements are critical in evaluating the financial sustainability and efficiency of the recycling process.

It is critical for successful recycling to regard wastepaper as a valuable raw material. Separate collection is being promoted, and wastepaper is being redefined as a valuable resource. Legal and regulatory elements play a role in creating quality standards and resolving definitional inconsistencies. Best practices should take into account the whole waste life cycle and be updated as needed.

Waste material trading, particularly wastepaper (WP), is essential and is based on contractual agreements and trading quotas. WP's pricing and trade are governed by its classification under an agreed standard list, such as EN 643:2014. Proper categorization allows for the efficient use of WP while also ensuring the creation of high-quality paper products. Contractual connections and process efficiency are facilitated by clear regulations and standardized commerce.

Waste legislation is critical in encouraging recycling, but legislative constraints and administrative obstacles must be addressed to ensure resource efficiency. For effective recycling targets and integration with other policies, coherence and exact regulation are required. To develop a European recycling plan, operational definitions, coordination, research funding, best practices, databases, and integration with other policies are required.

### **3. RECOVERED PAPER COLLECTION AND PROCESSING**

#### **3.1. Types Of Recovered Paper**

The internally recycled waste, preconsumer recycled paper from converters, and postconsumer recycled paper from various collection techniques are some of the sources of recovered paper. Generally speaking, as paper moves along the life cycle (from leaving the mill to being used by the consumer), it becomes more contaminated, is more difficult to recycle, and has a lower market value for recovered paper. Numerous organizations have identified the different grades of paper and their traits in order to aid in the marketing of the recovered paper [6].

The Institute of Scrap Recycling Industries, Inc. (ISRI) specifies recovered paper grades. The qualities and quality of the recovered paper are determined by these grades, allowing comparisons between various suppliers. Examples of the ISRI grades are shown in Table 02, which is divided into preconsumer paper and postconsumer paper categories. The term "prohibitive materials" in this table refers to any item that, by being present in a packing of paper stock in an amount greater than that which is permitted, renders the packaging unfit for the grade stated or any material that might be harmful to equipment. In addition, sorted recovered paper needs to be devoid of any food, hazardous or dangerous materials, or medical waste. The definition of outthrows is "any papers that are so made, handled, or are not the grade described because they are unfit for ingestion. The postconsumer recovered papers have a substantially higher tolerance for contaminating contaminants than the preconsumer grades, as shown by the table. The quantity of contamination that is present, which typically needs to be removed throughout the recycling process, has a significant impact on the price that each grade demands [6].

TABLE 02. SELECTED RECOVERED PAPER GRADES AS DEFINED BY ISRI [6].

Grade	Definition	Prohibitive Materials (%)	Outthrows Allowed (%)
<b>Postconsumer grades</b>			
Residential mixed paper	Consists of a mixture of various qualities of paper not limited as to type of fiber content, normally generated from residential, multimaterial collection programs.	2	5
Old newspaper	Consists of sorted newspapers and other acceptable papers as typically generated by voluntary collection and curbside collection programs.	2	4
News, de-ink quality	Consists of sorted, fresh newspapers, not sunburned, and other acceptable papers. This grade may contain magazines.	1	2
Old corrugated containers (OCC)	Consists of corrugated containers having liners of either test liner or kraft.	1	5
Double-sorted old corrugated (DS OCC)	Consists of double-sorted corrugated containers, generated from supermarkets and/or industrial or commercial facilities, having liners of test liner or kraft. Material has been specially sorted to be free of boxboard, off-shore corrugated, plastic, and wax.	0.5	2
Unsorted office paper (UOP)	Consists of printed or unprinted paper typically generated in an office environment that may include a document destruction process. This grade may contain white, colored, coated and uncoated papers, manila and pastel colored file folders.	2	10
Sorted office paper (SOP)	Consists of paper, as typically generated by offices, containing primarily white and colored groundwood-free paper, free of unbleached fiber. May include a small percentage of groundwood computer printout and facsimile paper.	1	5
Sorted white ledger (SWL)	Consists of uncoated, printed or unprinted sheets, shavings, guillotined books, and cuttings of white groundwood-free ledger, bond, writing, and other paper which has similar fiber and filler	0.5	2

	content.		
<b>Preconsumer grades</b>			
Boxboard cuttings	Consists of new cuttings of paperboard used in the manufacture of folding cartons, setup boxes, and similar boxboard products.	0.5	2
Mixed kraft cuttings	Consists of new brown kraft cuttings, sheets, and bag scrap free of stitched paper.	0	0.1
White blank news	Consists of unprinted cuttings and sheets of white newsprint or other uncoated white groundwood paper of similar quality.	0	1
Hard white shavings (HWS)	Consists of shavings or sheets of unprinted, untreated white groundwood-free paper.	0	0.5

### 3.2. Recovered Paper collection

Various techniques can be used to gather recovered paper, depending on the type of paper being collected and the source of the paper. Pre-consumer recycled paper is generally easier to gather since it is more uniform and less contaminated, and it is concentrated in particular industrial regions. These collections, which frequently take the form of clippings, trimmings, and overgrowth, are frequently bale- and package-packed right at the collection location with little additional processing required [6].

Recovery of post-consumer recycled paper is more challenging since the sources tend to be less concentrated and the paper is frequently mixed with other debris and other types of paper. Some post-consumer wastepaper grades, like sorted office paper, can be collected, baled, and collected in designated areas, rendering them comparatively clean. These collections can frequently be sold directly to the consumers of recovered fiber with little additional processing. Municipal collection systems are used to collect additional post-consumer recycled paper [6].

These sheets often exhibit the least homogeneity and demand the most treatment and processing in order to be useful as recovered paper. These forms of paper can be collected using a variety of methods, such as curbside collection, pickup containers, drop-off containers, and other systems [6].

### 3.3. Processing of Recovered Paper

The recovered paper may need to be processed before being transferred to a mill for recycling, depending on its origin and manner of collecting. As was previously noted, some collected grades can be delivered directly to the mill for processing, while other grades need to undergo extra processing before being sent to the mill. Even after being delivered to the mill, the paper frequently needs substantial processing to get rid of impurities and get the fibers back to being able to make paper [6].

Recovered paper frequently contains several common contaminants that make the recycling process difficult. These contaminants include large junk such as metals (nuts, screws, foil, cans) and plastics (films, bags, envelopes), as well as unwanted materials like dirt, cloth, yard waste, and leather. Inks and toners from previous printing can also be found in recovered paper, along with stickies, which are particularly problematic. Stickies refer to adhesives and residues that are difficult to remove and can cause issues during paper production. Additionally, coatings, appearing as white or colored chips, and wax coatings



present in certain boxes further contribute to the contamination. Fillers, which can be damaging to the tissue creping process, and papermaking additives like dyes and wet strength agents are other substances commonly found in recovered paper. Managing and minimizing these contaminants is essential to ensure the quality and effectiveness of the recycling process [7].

Contaminant removal is a challenging task due to the diverse nature of contaminants. They can differ in terms of size, density, shape, surface properties, solubility, and strength. Each contaminant type requires a specific approach for effective removal. Since no single separation device can efficiently eliminate all types of contaminants, recycling processes incorporate multiple sub-operations that work together synergistically. These complementary sub-operations collectively target different aspects of the contaminants, ensuring thorough purification. By employing a combination of techniques and treatments, recycling systems can effectively address the wide range of contaminants encountered, contributing to the production of cleaner and more sustainable materials [7].

To prepare the fibers for papermaking, a variety of unit operations are required when turning recovered paper into new paper products. As shown in Table 03, additional unit activities are also used to recycle paper into new paper goods.

TABLE 03. UNIT OPERATIONS USED IN THE PROCESSING OF RECOVERED PAPER [7].

Pulping	The primary goal of the pulping process in paper recycling is to disperse recovered paper into separated fibers while simultaneously detaching contaminants from the fibers. This is achieved by mixing the paper with water and chemicals at precise ratios to create a pulp mixture. It is important to maintain contaminants as large as possible during this process to facilitate their subsequent removal. Additionally, great care is taken to avoid any damage to the fibers, ensuring that they remain intact without experiencing fiber cutting. Finally, the pulping system includes measures to effectively remove large debris, such as oversized materials, to prevent blockages and maintain smooth operation.
Cleaning (Centrifugal)	Is a process used in the paper industry to remove impurities from the pulp stream based primarily on their density. It involves the use of centrifugal force to separate and eliminate various contaminants present in the pulp. Centrifugal cleaners are specifically designed to target impurities such as metals, inks, sand, bark, and dirt. The centrifugal force generated in the equipment causes the heavier impurities to move outward, while the lighter fibers and cleaner pulp remain in the center.
Screening	Crucial process in the paper recycling industry, separating contaminants from fibers based on size, shape, and deformability. It uses slots or holes to block larger contaminants, ensuring efficient capture and removal of unwanted materials. This process reduces contaminants, resulting in cleaner, higher-quality fibers for paper production.
Deinking	Washing: a separation method that rinses small particulate contaminants away

	from fiber while minimizing fiber loss Flotation: a process in which hydrophobic contaminants are preferentially removed from a pulp stock by attachment to air bubbles.
Dispersion and Kneading	Mechanical processes in the paper recycling industry reduce contaminants' particle size, releasing them from paper fibers. Dispersion and kneading break down larger contaminants into smaller particles, enhancing efficiency and promoting separation from fibers. These processes contribute to cleaner, more purified pulp for high-quality recycled paper products.
Bleaching	Is a chemical process used in the paper industry to remove chromophores, increasing brightness and reducing color in paper products. It involves the destruction of dye and fluorescence whitening agents, as well as the breakdown of lignin from wood fibers. There are two main types: oxidative and reductive bleaching. Bleaching enhances paper's aesthetics, quality, and overall whiteness, making it a crucial aspect of the industry.

## 4. EXPLORING THE PROS, CONS AND CHALLENGES OF PAPER RECYCLING

### 4.1. Advantages of paper recycling

Among the methods of creating paper, the production of recycled paper is found all over the world today. The reason for this is that it can provide economic and social benefits. But looking at the present, the rate of wastepaper recycling in many countries is still lower than the world average of 47.7%, and about 70% in developed countries [1].

- Can reduce the amount of tree cutting.

Instead of recycling paper, we have to cut down trees to make new paper. In this way, seventeen trees need to be cut to make one ton of paper. An average person uses about 300 kg of paper and five trees are required for that [1]. If we calculate according to that, if we have to produce new paper like this for all the people of the world, it seems that a lot of trees will have to be cut down. Therefore, paper recycling can prevent the cutting down of a large number of trees.

- Can save energy.

Different processes are involved in making new paper. Different machinery is used for that. A lot of power is required to operate those machines. Recycling paper can reduce that energy. This recycling can save about 4000 kilowatts of energy used to make paper [1].

- Can reduce water pollution.

In making new paper, water is used for various tasks such as preparation of raw materials, pulping process, cleaning activities. Also, water is needed to recycle paper. But recycling paper can save 30 000 liters of water [1].

- Free up landfill space for non-recyclable waste.

If used paper is removed without recycling, it will have to be sent to the landfill. If so, the possibility of disposing of non-biodegradable waste is minimal. Recycling paper can save three cubic yards of landfill space [1].

- It can protect the environment from pollution and excessive use.  
According to MacFadden & Vogel (2007), paper recycling can reduce air emissions by 74% and water pollution emissions by 35% [1].
- Can reduce greenhouse gas emission.  
17 trees can absorb about 120 kg of carbon dioxide in a year [1]. But cutting down trees to make new paper increases the amount of carbon dioxide in the air. The environment has to face a lot of problems. Recycling paper avoids this problem.
- Job creation due to recycling infrastructure  
Job opportunities are created here for the collection, transportation and recycling of raw materials required for recycling. This is another advantage. An example of this is that according to data from the US Environmental Protection Agency, over 757,000 people work in the recycling industry in the US and they receive more than \$6.7 billion in wages and benefits annually [8].

#### **4.2. Disadvantages of paper recycling.**

- Harmful substances can accumulate and become contaminated.  
Harmful substances such as paint and chemicals can contaminate paper. When these materials undergo the recycling process, the process can become contaminated. Then it becomes difficult to produce high quality recycled paper. Food, liquids, as well as non-recyclable materials such as plastic, can damage recycling equipment by contaminating it with paper. It can also reduce the quality of the paper [8].
- Difficulty identifying recyclable paper.  
Some papers are difficult to recycle. This is because of some of the materials they contain. Paper with glossy surfaces and paper with plastic coatings are difficult to recycle. They are not easily separated from recyclable paper. For example, many people think that pizza boxes are recyclable cardboard boxes because they are made of cardboard. But it is not so. That's because pizza boxes often stain food, making them difficult to take for recycling. Moreover, wax or plastic coatings such as paper cups or take-out containers make them non-recyclable [8].
- Being more expensive than virgin paper  
This is because the recycling process requires more labor and energy. Moreover, the cost of collecting, processing and transporting recyclable materials is high. There are several measures that can be taken to prevent these economic factors from hindering the paper recycling process. Among them, providing the right policies and incentives, using new techniques and techniques can be identified [8].

### 4.3. Challengers of paper recycling

- Inefficient and lack of adequate recycling infrastructure.

Inadequate infrastructure is a challenge affecting paper recycling in many countries. Inadequate recycling facilities include transport networks and staff shortages to collect and transport paper waste to recycling centers. Another problem here is the lack of curbside recycling programs in some areas. For example, in the United States, only 63% of the population has access to curbside recycling programs, according to the Environmental Protection Agency (EPA) [8]. Although this situation exists in developed countries, in some countries the percentage is very low.

- Inadequate demand for recycled paper.

The main reason for this is the quality. The quality is lower than the quality of virgin paper. Recycled paper may also contain residues such as ink or adhesives. It also affects the decrease in demand here. Overcoming this challenge can be achieved by developing policies and incentives that create a stable market, as well as setting minimum standards for quality [8].

- Lack of public awareness.

People do not pay attention to recycling because of lack of proper knowledge about it. Because there is no knowledge of its benefits. Education and outreach are essential to increase recycling rates [8].

## 5. SRI LANKA'S JOURNEY TOWARDS CIRCULAR PAPER WASTE MANAGEMENT

### 5.1. The State of Paper Waste Generation in Sri Lanka

Insufficient or inadequate management systems for collecting, transporting, and disposing of waste have led to the emergence of waste as a problem. The majority of waste is generated at the household level, with the remaining portion coming from industrial sources. Waste management is not a significant concern in rural and suburban areas due to the availability of space for waste disposal, unlike in urban areas, particularly in the western province of the country.

In 2014, the University of Peradeniya conducted a Waste Amounts and Composition Survey (WACS), which revealed that kitchens account for nearly three-quarters of the total waste generated. It is important to note that over 85 percent of the total waste is biodegradable at its source. Table 04 provides an overview of waste composition at the point of waste generation in Sri Lanka [9].

TABLE 04. WASTE AMOUNT AND COMPOSITION IN SRI LANKA [9].

Kitchen waste	74.6
Garden waste	4.8
<b>Paper and cardboard</b>	<b>7.8</b>
Soft plastics	4.2
Hard plastics	0.9
Textiles	1.0
Rubber and leather	0.4

Metal	0.9
Glass	1.7
Ceramics	0.5
Hazardous wastes	0.4
E waste	0.2
Miscellaneous	2.7

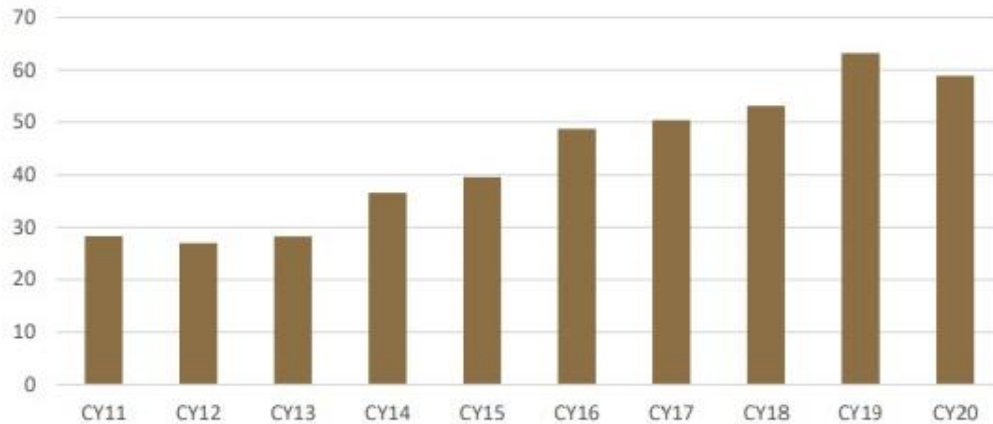


Fig. 1. GDP of paper and paper products (LKR Bn) Source: – Central Bank of Sri Lanka - statistics

The market size of the Sri Lankan paper and paper products was LKR 133bn in 2020. LKR 59bn was locally produced (0.4% of GDP) and LKR 74bn (USD 398mn) was imported. The industry grew at a CAGR of 3% from 2011 to 2018, after which it declined at CAGR of -7%. The Fig. 1 illustrate the growth of GDP of paper and paper products [10].

In the year 2019 397mn kgs of paper and paper products were consumed in Sri Lanka. Of this 25mn kgs (6%) was manufactured locally, and 374mn kgs (94%) was imported. Of the 397mn kgs of paper and paper products consumed in 2019, 216mn kgs were graphic paper including 33mn Kgs of newsprint. A further 172mn kgs were consumed for packaging purposes, 4mn kgs for household and sanitary purposes and 6 kgs for other applications. The Fig. 2 illustrates the consumption of paper and paper products in Sri Lanka [10].

In 2019, 170mn kgs of wastepaper were collected in Sri Lanka of which 115mn kgs were exported earning USD ~26mn [10].

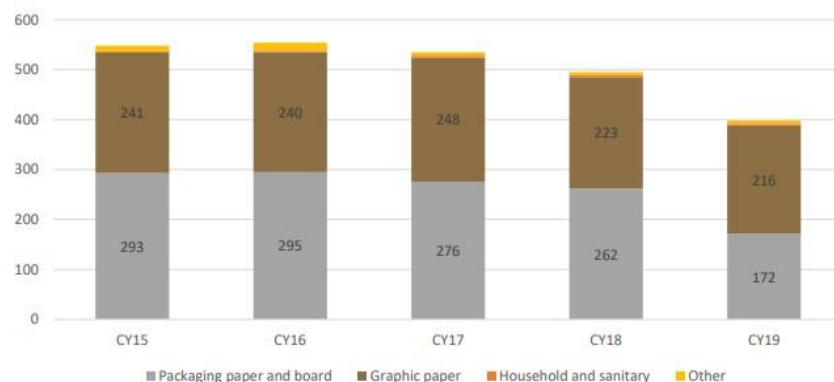


Fig. 2. Consumption of paper and paper products in Sri Lanka (1000 MT)

At the local level, the manufacturing of recycled pulp and paper is carried out, although the capacity is quite limited. This means that there are facilities or factories that specialize in producing pulp and paper using recycled materials. However, the scale or volume of production in Sri Lanka is relatively small. Recycled pulp and paper manufacturing involves the process of transforming used paper products, such as newspapers, magazines, or cardboard, into new paper materials. This process helps reduce the demand for virgin materials derived from trees and promotes resource conservation.

There are a few of the local paper manufacturers in Sri Lanka: National Paper Company Limited, Saveco Paper Corporation, Sun paper (Pvt) Ltd, Valaichchenai Paper Mill, Sanhinda Grinding Mills, Piyal Pulp & Paper Mills, Maximus, Yatiyana handmade paper center etc.

The limited capacity of local recycled pulp and paper manufacturing suggests that there may be constraints or limitations in terms of infrastructure, technology, or market demand. It could be due to factors such as insufficient recycling infrastructure, inadequate equipment, or a lack of awareness and support for recycled products in the local market.

Expanding the capacity of recycled pulp and paper manufacturing can have several benefits. It promotes a circular economy by closing the loop in the paper production process, reduces pressure on forests, and minimizes the environmental impact associated with paper production from virgin materials. It also creates opportunities for local employment and contributes to the development of a sustainable waste management system.

To enhance the capacity of recycled pulp and paper manufacturing, investments in infrastructure, technology, and market development may be required. This can involve improving recycling collection and sorting systems, upgrading manufacturing facilities, and raising awareness among consumers about the benefits of using recycled paper products. Additionally, collaborations between government, private sectors, and relevant stakeholders can play a vital role in supporting and promoting the growth of the recycled pulp and paper industry at the local level.

## **5.2. Paper Waste Management Strategies in Key Industries in Sri Lanka**

Several industries generate significant amounts of paper waste in Sri Lanka. Here are some industries that are major contributors to paper waste and how they manage it:

**Printing and Publishing industry:** The printing and publishing industry generates a substantial amount of paper waste from discarded misprints, obsolete publications, and printing process waste. To manage this waste, many printing companies implement recycling programs where wastepaper is collected, sorted, and sent for recycling. Some companies may also use wastepaper as a source of raw material in the paper manufacturing process.

**Packaging industry:** The packaging industry, including manufacturers of cardboard boxes, cartons, and packaging materials, produces a significant volume of paper waste. To manage this waste, recycling initiatives are commonly employed. Companies may encourage their customers to recycle packaging materials and may also use recycled paper products in their packaging processes. Additionally, some companies are exploring alternative packaging materials, such as biodegradable or compostable materials, to reduce the environmental impact of paper waste [11].

**Offices and Businesses:** Offices generate substantial paper waste through document printing,

photocopying, and general office operations. Many businesses have implemented paper reduction strategies to minimize waste, such as digitizing documents, encouraging electronic communication, and printing only when necessary. Recycling bins are commonly provided in offices to collect paper waste separately for recycling.

**Education and Institutions:** Schools, colleges, and other educational institutions produce significant paper waste due to note-taking, assignments, and administrative paperwork. Institutions often implement paper recycling programs and encourage students and staff to recycle paper waste. They may also adopt digital platforms for document sharing and communication to reduce paper usage.

**Retail and Consumer Goods:** The retail industry generates paper waste through packaging materials, receipts, and promotional materials. Some retailers have adopted eco-friendly packaging practices, including using recycled or biodegradable materials. They may also encourage customers to opt for electronic receipts and promote paperless transactions.

To manage paper waste effectively, industries employ various strategies such as recycling, waste reduction, and exploring alternative materials. Government regulations and environmental initiatives also play a role in encouraging responsible paper waste management practices.

### **5.3. Recommendations for sustainable paper waste management in Sri Lanka**

Sri Lanka requires a long-term objective to develop a sustainable and efficient Solid Waste Management (SWM) system that is not only cost-effective but also economically viable and environmentally friendly. To achieve this, various strategies have been proposed to minimize waste, which align with the waste management hierarchy. These strategies emphasize the principles of "3R": reduce, reuse, and recycle.

- The first principle, "reduce," aims to minimize the amount of waste generated in the first place. This can be accomplished through initiatives such as promoting awareness and education about waste generation, encouraging responsible consumption patterns, and implementing policies that discourage the use of unnecessary packaging materials.
- The second principle, "reuse," focuses on finding ways to reuse items or materials instead of discarding them as waste. This involves encouraging practices such as repairing and refurbishing goods, donating or selling items that are still usable, and implementing systems for sharing or exchanging resources within communities.
- The third principle, "recycle," involves the conversion of waste materials into new products or raw materials. This includes establishing recycling facilities and implementing effective waste segregation and collection systems to ensure that recyclable materials are properly sorted and processed. Additionally, promoting the use of recycled products helps close the loop in the production cycle and reduces the demand for new resources.

By incorporating these 3R principles into waste management strategies, Sri Lanka can work towards minimizing waste generation, maximizing resource efficiency, and reducing the environmental impact of waste disposal.

Encouraging circular design and packaging in the paper industry involves adopting principles that promote sustainability and minimize waste throughout the entire life cycle of packaging materials. Circular

design principles aim to create products and packaging that can be easily recycled, reused, or composted at the end of their life cycle. In the context of the paper industry, this involves designing packaging with materials that are renewable, recyclable, and biodegradable. It also includes considering factors such as ease of disassembly, modularity, and the use of non-toxic materials. As well as promoting the use of eco-friendly and recyclable materials in packaging, encouraging manufacturers to prioritize sustainable packaging solutions. Explore incentives and regulations that promote the implementation of circular packaging practices.

Emphasize the importance of research and innovation in finding novel solutions for sustainable paper waste management. Encourage investment in research and development to explore alternative paper sources, such as agricultural waste or innovative fibers. Promote the use of advanced technologies to improve recycling efficiency and develop sustainable paper production methods.

Highlight the significance of collaboration among stakeholders for effective paper waste management. Encourage partnerships between government, industry, NGOs, and communities to create a shared vision and action plan. Discuss the benefits of collaborative initiatives, knowledge sharing, and resource pooling [12].

Promote awareness and education about waste management at various levels, ranging from schools to higher education institutions. It can be supplemented with practical activities and initiatives. This could include organizing waste management workshops, conducting waste audits within schools, and encouraging students to participate in waste reduction and recycling projects. By involving students directly in waste management activities, they can gain hands-on experience and develop a sense of responsibility towards proper waste disposal.

The appropriate technical knowledge and equipment should be provided to local government institutions involved in paper waste management. This includes training programs and workshops focused on waste management practices. This training should cover various aspects, including waste segregation, collection, transportation, treatment, and disposal. It should also address safety protocols, environmental considerations, and best practices for sustainable waste management. By equipping local government staff with the required technical knowledge, they will be better equipped to handle waste management tasks efficiently.

Government policies and regulations play a vital role in incentivizing and driving sustainable paper waste management practices. By enacting policies and regulations that incentivize sustainable paper waste management, governments create a supportive framework for businesses and individuals to adopt environmentally responsible practices. Through strict enforcement, EPR programs, economic incentives, stakeholder collaboration, and public awareness campaigns, governments can drive positive change and contribute to the development of a sustainable paper waste management ecosystem. The practice of providing new textbooks for each grade level every year in government schools in Sri Lanka, followed by discarding the previous textbooks, can indeed result in a significant amount of wastage. To address this issue, we suggest that it would be beneficial to extend the usage of textbooks for a longer duration, ideally up to five years.

## 6. CONCLUSION

In conclusion, this review paper highlights the significance of sustainable paper recycling practices and their potential to create a more sustainable future. Globally, the demand for paper products continues to rise, resulting in increased deforestation and depletion of natural resources. However, paper recycling offers



a viable solution to mitigate these issues. The global trends show a positive shift towards paper recycling, with governments, businesses, and individuals recognizing its environmental and economic benefits. In the context of Sri Lanka, the trends also point towards a growing emphasis on paper recycling. Sri Lanka, like many other developing countries, faces challenges in waste management and environmental conservation. However, the country has recognized the importance of sustainable waste management practices, including paper recycling, to address these challenges.

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