

## Using Sustainable Technique to Recycle Waste Paper in Academic Institutions

Mustafa M. Mansour

*Department of Mechanical engineering, College of engineering, University of Thi-Qar, Thi-Qar, 64001, Iraq*

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The datasets used in this study are publicly available

### Author Contributions

The author solely contributed to all aspects of this work, including conceptualization, methodology, data curation, software, formal analysis, writing – original draft preparation, review and editing, and project administration.

## ORIGINAL STUDY

# Using Sustainable Technique to Recycle Waste Paper in Academic Institutions

Mustafa M. Mansour

Department of Mechanical Engineering, College of Engineering, University of Thi-Qar, Thi-Qar, 64001, Iraq

### Abstract

It has been clearly demonstrated that it would be feasible to consider recycling paper in an academic institution. This can be achieved through combining specific waste paper baskets, a pulping machine and power supplied by a renewable energy source, with an already established local paper making company. The paper making company would be able to gain a subsidy from the government which pays them to actually recycle paper, to counteract the cost of the pulped paper which is 30% more expensive than raw wood pulp. The academic institution would save money on waste disposal and decrease its carbon footprint by 600% with savings of up to around 5–6 tons of CO<sub>2</sub> per year, instead of the 1–2 tones carbon offset for just recycling the paper normally. This entire process could be adapted for recycling the vast quantities of waste paper produced by students, an initiative which often fails due to the high cost of disposal. This could be achieved through urged use of the same paper disposal methods already in use, with the paper being collected and pulped once a week directly from the student paper waste bins. This research aims to study and limit the quantities of paper consumed in academic institutions in Iraq, by identifying the steps of recycling, and the extent of its environmental and economic impact, on the one hand, and on the other hand, the extent to which the Iraqi university community accepts this idea, and then study these quantities and evaluate them economically and find out the possibility of establishing a paper recycling plant based on these quantities. As well as the current research deals with the accumulation of paper waste caused by the performance of exams. In the third semester of the research, the amount of paper waste at Thi Qar University was calculated as a model for conducting a detailed research study of all departments and colleges of the University. the amount of paper waste was (11,055 tons/year), as well as calculating the cost of paper processing for the University amounted to (126252271 Iraqi dinars) and at the end of the third semester, the amount of paper waste in Iraqi academic institutions for the academic year 2022–2023, approximately (367,60976 tons/year). The cost of preparing exam books in Iraqi academic institutions for the academic year 2022–2023 amounted to approximately (4202150971 Iraqi dinars). The devices used in the practical aspect and each device and its purpose in the paper waste recycling process were explained. In addition, in the fourth chapter of the research, waste recycling was carried out in a practical way, and the results were satisfactory. We proposed a project to establish a paper and cardboard waste recycling plant in Nasiriyah, detailing its technical processes and stages in a mature way, the costs of establishing such projects in detail, as well as the annual profit of the project. At the conclusion of the research, some important recommendations were attached that help the paper waste recycling process and its success.

**Keywords:** Recycling, Sustainable techniques, Paper waste, Environmental impact

## 1. Introduction

This preliminary chapter outlines the rationale and the purpose of this study; it also makes clear the limitations and scope of this research. Basically, this study is a form of assessment on the work of a group of students taking Industrial Chemistry EBB 3443F. This group is posed with the

task of determining whether Soda Ash can be obtained from the process of Solvay process by using common salt as the source of NaCl. The idea of doing this project sparked off when the group attended a lecture on the topic of “Green Chemistry.” It was mentioned that Green Chemistry is the way to go in the future. Due to increased awareness of the environmental damages that chemical plants

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E-mail address: [mustafa.muhammedali@utq.edu.iq](mailto:mustafa.muhammedali@utq.edu.iq).

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have posed to the environment, this subject was established to train professionals to be aware and be responsible for their actions in the future [1,2].

This group then tries to relate the knowledge of “Green Chemistry” to a process not learned in the class, in order to find possible ways of reducing costs for that certain process. Then the group encounters a lecture on the Solvay process while doing a group presentation on Industrial Chemistry. This process was not taught during the lecture class hours, and thus curiosity arose in the minds of the group's members. The comparison of the environmental friendliness of the Solvay process to other processes of obtaining soda ash is what attracts the group to choose this topic. After seeing the quality of soda ash in the market today, the group is wondering if there is any cost-efficient and “green” way to obtain soda ash with similar quality compared to the Solvay process. Fig. 1 show Classification of different types of waste.

### 1.1. Purpose of the study

This study aims to look into identifying and introducing the use of significantly sustainable paper-recycling technique and motivating the use of the same in academic institutions. The study anticipates a substantial change in paper-recycling methods from the very basic “waste paper collection” technique to a more advanced and environmentally effective technique such as “vermicomposting of waste paper”. The objective is to reduce the quantity of paper-waste, and to have an economically beneficial and environmentally friendly way of recycling

paper using techniques that can be implemented and replicated with ease in any academic institution. By using the case-study approach and an action-research method over a period of approximately one year, the study will involve various environment-conscious student and faculty groups, staff of the institution, and the personnel of surrounding communities where institutions are located, with active participation in paper waste collection and its recycling. The results will be observed over the course of this experimental year. This study will be deemed successful if it can motivate academic institutions to endorse paper-recycling by identifying the vermicomposting method as a very effective way of reducing paper-waste [3,4].

### 1.2. Scope of the study

At this point, the gathered information was simplified in the form of a flowchart and general figure to give a better illustration as a comparison only between the general procedure and the real initiative step. This comparison will be the base comparison in producing the proposed method as well as the final stage comparison to measure the rate of effectiveness in creating a better impact using sustainable techniques in recycling paper. This next step will be a continuation to the second part in future publication for a better conclusion and the opinion for further steps in decision making.

The general procedure and practices on recycling paper and the real initiatives or involvement from each institution were then evaluated. The evaluation was based on the interviews and personal

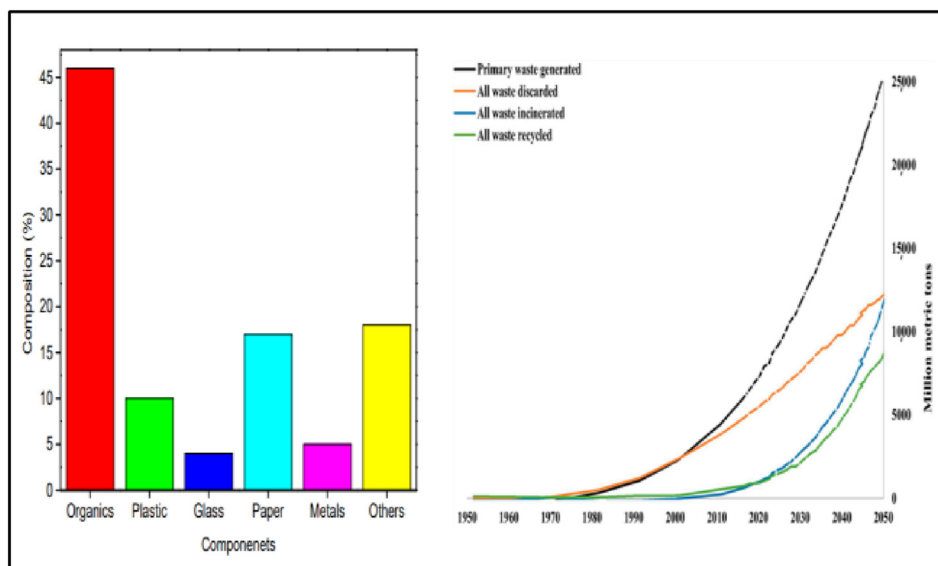


Fig. 1. Classification of different types of waste.

communications with the respective authorities in order to validate the information gathered. Photographs were also taken of recycling behaviors if given permission. Measures such as discussions and observations were tools implemented in order to gather as much information to produce better evaluation and a clearer statement. From those findings, higher impacts could be shown using some comparison to other institutions, thus stating the opinion that the step must be reevaluated or further decisions should be taken in creating a better impact and producing better end results [5].

To gather relevant information and present a clear discussion, a number of academic institutions using various sustainable techniques in recycling paper were involved. The institutions were chosen based on their initiatives or involvement in practicing recycling behavior in their community and events. Informal meetings and discussions were conducted with the authorities responsible in order to gain transparency in the real initiatives. Information on general recycling procedure was obtained either through method of observation, trial and error, or through information given by related authorities. These steps were taken to have a clear picture of what basic steps should be taken in order to produce a better impact in recycling paper behavior.

## 2. Importance of paper recycling in academic institutions

Environmental impact of paper waste there may be a limited number of issues policing paper waste, but yet the problems are still widespread. Most paper is composed of organic materials such as wood. When paper is dumped in a landfill, it ultimately decomposes due to the anaerobic conditions within the landfill. The process of decay emits methane gas as well as acidic leachate. Both of these are severely hazardous to the environment and have been blamed for the increase in global warming as well as the contamination of water and soil. The emissions of greenhouse gases are said to be 21 times higher global warming potential than carbon dioxide and have largely attributed to the effects of climate change today. It has been said that every ton of paper recycled will prevent the release of 2 tonnes of greenhouse gases. This is done by diverting the paper away from the landfill and using the paper as a feedstock in the pulping process, thus reducing the amount of destruction to forest resources. With the prevention of such harmful gases, we are attempting to revert any effects done on the environment today and prevent any further damage to future generations [6].

Paper recycling can have a major impact on the environment as it accounts for more than half of the waste found in staff offices and study areas. Publications and other paper products made up 37% of the waste stream in 2006, which is the second most waste produced under corrugated boxes. Paper contributes to air and water pollution through the release of solid waste, as well as pollutants such as lime, sulphur, carbon dioxide, and dioxins. Dioxins form when combusted materials containing chlorine are burned. These toxins are a popular issue today as they are known to cause reproductive and developmental problems, damage the immune system, interfere with hormones, and also cause cancer. Today there is a fine line when it comes to paper that has been derived from forests and paper made up of recycled content. Virgin wood pulp is washed and bleached, emitting harmful chemicals to air and wastewater. Every bleach of a thousand tons of paper emits 250 tons of chlorine dioxides. This does not occur in the recycling process, rather renewable energy is used. Dioxin levels have been known to decrease by an extra 70% in paper using ECF (elemental chlorine free) bleaching. Thus, with the increased amount of pollution and less release of recovered chemicals, the demand for paper recycling will soon exceed the excelling demand for paper [7].

### 2.1. Environmental impact of paper waste

Deforestation is a primary focus due to the close relationship between paper and the rainforests. The pulp and paper industry is the 5th largest industrial consumer of energy worldwide, using as much wood as possible to avoid the cost of recycling. This depletes the world's forests and has led to the already extensive deforestation of large areas of the world. In Canada, which is the largest exporter of wood, 21% of the deforestation is logged for wood pulp. This doesn't seem significant but in time the rate of paper consumption is not slowing, and if it does not, we will soon run out of forests. As well as this, there is an inestimable loss of species, some of which being endangered cannot survive in smaller fragmented and isolated populations. Often these areas are developed by foreign companies who are not aware or do not consider the environmental impact of their development [8].

Altering the habitat of the would be considerably damaging to its hydrological function and in many cases has led to a loss in the amount of fresh water available from the area. As soil is eroded and the landscape degraded, water is often no longer stored and is released quickly causing unnaturally high

river flows. This creates problems such as widespread flooding. In Europe, about 18% of the damage is classified as severe, in Canada an estimated 40% of the floodplains in Alberta are affected and in Central America, studies have found no less than 30% of the river basins to be affected.

## 2.2. Benefits of paper recycling

A more specific yet indirect environmental benefit concerns the recycling habits of students. By providing the means for students to recycle paper at their places of study, it is hoped that they will adopt similar practices in their homes and other areas of life. This can be important, as it is today's young people who will shape the future condition of the environment. If a more conscientious attitude towards recycling can be established, the cumulative environmental benefits could be very significant. On the economic side, recycling paper can potentially save academic institutions a substantial amount of money on their waste disposal. This is because paper and cardboard often make up a high percentage of the waste and these are materials which can be recycled relatively cheaply. By decreasing the volume of general waste, a decrease in waste disposal costs can be achieved. If institutions take it a step further and decide to purchase only recycled paper products, this can also help accelerate the demand for recycled paper and its long-term economic feasibility.

The benefits of paper recycling in academic institutions are undoubtedly far-reaching. Not only are the environmental benefits significant, but also the potential cost savings and impact on student attitudes. Probably the most apparent benefits of paper recycling are the environmental ones. These have been noted widely and it is generally accepted that it is more sustainable to recycle paper than to send it to landfill or incinerate it. By doing so, deforestation can be decreased along with the many environmental effects that result from it. It is the same story with regards to energy - the amount of energy saved from recycling paper as opposed to making it fresh is reported as being up to 60%. This subsequently means less burning of fossil fuels and less impact on the world's climate. The result of this is a reduction in the release of greenhouse gases, which can further alleviate the effects of global warming and climate change [9].

## 2.3. Current practices in paper recycling

In a study done by Wright and Fulton, they provided insights into the success and failure of various

source separation recycling programs in nine colleges and universities. They noted that programs yielding the best results had strong support from the university administration, and a well-planned and executed publicity and education plans. These programs also tended to use single stream recycling, where all recyclables are put in a single bin, rather than multiple-sort, where the consumer must separate recyclables into various containers. The latter option is often seen as inconvenient and time-consuming for the consumer, and results in contamination of the materials. Wright and Fulton contrasted this with the failure of an organic waste recycling program at a university in the study, where the staff was not educated about what qualified as organic waste, and there was inadequate infrastructure in place. This resulted in only one magnitude of waste being collected and the program was terminated due to unprofitability.

Adopting initiatives on waste minimization and source separation should be the initial steps taken towards recycling in academic institutions. Both these approaches have been used extensively in the private sector and government agencies, but not widely recognized in academic institutions. Waste minimization is the process of reducing the amount of waste generated by an institution or individual. This could be done by purchasing items that are long-lasting or have excess packaging. Source separation is referring to the recovery of specific materials for recycling. Bins are set up to collect different types of material [10].

## 3. Sustainable techniques for paper recycling

Separation at source is a procedure by which recyclable waste paper is segregated at the place of generation and collection. It is then gathered and classified by grades of similarly like characteristics. The main prerequisites for efficient source separation of paper are its relevance, convenience and efficiency in being the paper collected in the useable condition. The efficacy of this strategy is not uniform where sometimes it is a hard task to convince people to use different waste dumping methods from those that have been in use.

Coping with the resistance from the staff and students may come because the trashing of waste papers to centralized centers is seen as arduous and cumbersome and the contamination with other kinds of waste product could have a negative impact on paper quality. Policies to be put for the enhancement of the effectiveness of source separation comprise of enlightenment on the reasons behind separation, the provision of widespread



collection points at the central places, and the holding of paper recycling events to bring together waste papers. Where source separation is not a recommended option, the modalities of paper collection, inclusive of single stream recycling will be implemented. Here, it is important to be able to follow the origin of the recycled paper where the paper is due for reuse and reissue [11].

### 3.1. Source separation of paper waste

Source separation is putting waste paper in separate containers at the point where it is discarded. Separate collection decreases the risk of contamination of the paper and allows for the paper to be easily sorted and recycled. Separate collection is the more environmentally friendly option in all circumstances; however, it may not be economically viable due to increased costs in collection.

Contamination by other waste matter is a problem in both paper recycling and waste paper which has been sorted and separated for recycling can still contain a high proportion of contaminants. In some cases, it might be more appropriate to recycle the paper as part of mixed waste (e.g. newspapers and magazines in deinking process); however, both paper and other waste collected this way should still be sorted at source to limit the degree of contamination. Recycled paper may still be used as a landfill disposal method for mixed waste, providing it is not too contaminated and there are appropriate facilities available.

### 3.2. Paper pulping methods

For the pulping of source separated paper, the pulping method is less defined. Asian countries tend to use repulping equipment designed for wood pulp at low consistency with a series of washing and cleaning steps. This method has been used for some grades of paper in the west, while other paper is mixed with higher-grade recovered paper and pulped in machines designed for recycled fiber at a higher consistency with less washing. Papers from

different sources are pulped separately to make different grades of paper. Recovery of high-grade fiber and utilization of recovered paper that was initially intended for a certain grade requires that the pulping be done in relatively small batches. This pulping method can take many forms and varies widely between mills [12]. However, the result is simply the disintegration of paper in water to liberate the paper fiber from the ink and contaminants. Table 1 show chemical analysis of wood.

The next step in the recycling process is the recovery of paper fiber from the collection. In most parts of Asia, and some developed countries, the collection is mixed paper. Most of the time, the paper recovered from mixed collection is sent to the landfill because it is usually dirty and has low value. At the same time, an enormous quantity of used paper is sent to deinked pulp mills. This is because the collection system of local newspapers is very effective in recovering old newspapers. Fig. 2 show represents the process of sorting and collecting paper waste from other waste.

### 3.3. Deinking process

In this process, the ink is removed from the paper fiber. A combination of various methods is used to achieve the separation of ink from the fiber. Flotation deinking involves introducing air bubbles at the base of a consistency tower that attach to the hydrophobic ink particles causing the ink to float to the surface. This ink can then be removed. This method is being widely employed in the paper industry due to its high efficiency. Another method is washing, where a thick fiber suspension is formed and agitated. This causes the ink particles to become detached from the fibers and to be carried away from the suspension. Washing can only remove particles which are already detached from the fiber so it is usually used in conjunction with another method. These methods are often followed by a stage of bleaching to remove any ink/fiber complexes and to enhance the brightness of the paper. In the past, deinking has only been possible on a

Table 1. Chemical analysis of wood.

n	%	Material	Comments
1	40–50	Cellulose	It is the material for which it is useful
2	2–2.5	Hemicellulose	White, non-crystalline sugar polymers fill between the fibers
3	5–30	Xylans	
	1–8	Extractives	A combination of light to high specific gravity polymers, which provide color, odor and resistance to degradation (solution with organic solutions or water).
4	0.2–0.4	Ash	Inorganic elements (minerals)
5	18–35	Lignin	A longitudinally and cross-linked complex polymer based on phenyl propane



Fig. 2. Represents the process of sorting and collecting paper waste from other waste.

low scale quality and efficiency level cheaper to produce virgin pulp. However, advances in this process have led to high quality recycled paper. This can now be a viable and sustainable alternative to paper made from virgin fibers.

#### 3.4. Bleaching methods for recycled paper

The color in paper is created by contaminants added to the fiber during the pulping or by the use of dyes. Under dry conditions, 90% of the color can be removed from the fiber, although it is more difficult to remove colored deinked papers. The residuals left in the fiber can have adverse effects during recycling. For instance, when ONP is reprocessed into newsprint, a high-quality paper, there is deeper absorption of ink into the fiber. Therefore, it is not recommended to bleach this grade of paper. Much of the dirt can be removed from the fiber using optional chemicals, avoiding the need for bleaching. This will save costs and is in line with the philosophy of using minimal amounts of chemicals.

The significance of this stage in the paper recycling procedure is to remove or change the color added to the paper by previous manipulation. The resulting color in the recycling stage can be dark or dirty, so it is often necessary to re-color the fiber. The goal of re-coloring is to produce a clean, bright colored fiber suitable for the standard grades of paper and board products. Depending on the final product grade, different colored papers may need to be produced.

For example, to produce white paper, darker colors are removed from the fiber by bleaching.

#### 4. Implementing paper recycling in academic institutions

The first step in setting up a successful recycling program is to assess the waste generation. One must take into account the types of paper being discarded and the quantities. This information can be used to determine the quantities of different types of paper to be recycled and recycled into what products. It also serves as a benchmark with which the success of the recycling program can be measured. Any reductions in paper use or changes in the types of paper used should be reflected in the waste generation over time. A simple way to assess the waste generation is to sample the different types of paper found in the refuse on campus and trash bins near copiers/printers. An estimation of the amount of paper each day/week/month can be made and changes in paper recycling can be assessed by looking through the waste generation again [13,14].

In academic institutions, paper recycling programs can only be implemented successfully if they follow a step-by-step process. Many universities and colleges, in their efforts to be more environmentally friendly, skip to the last step and set up recycling bins without setting up a process to ensure the sustainability of the recycling program. The result is a waste of time and resources since much of the paper thrown in these bins may not be recyclable or the recycled paper may not be used. This ineffectiveness can discourage people from recycling in the future (see Table 2).

##### 4.1. Assessing paper waste generation

If it is found that the paper is not suitable for recycling at present or in the near future, ways to reduce the amount of waste and improve the quality can be considered. This may involve changing the type of paper used, reducing unnecessary printing,

Table 2. Highlights the types accepted for use in the recycling process.

Acceptable types	Unacceptable types
Exam books	Brown paper
Newspapers and accessories	Paper stained with food or paint
Magazines, brochures and catalogs	Products related to hygiene and health such as: used tissues and towels
White paper	Candy wrappers
Bulletins	Sticky notes or tape
Letter envelopes	Non-paper gift wrapping or bags



and encouraging staff and students to take greater care with the paper and to not mix it with other waste.

If the quality and amount of paper waste are sufficient to justify recycling and potential future use, it is then necessary to investigate local markets and recycling facilities. This is important to establish as it is no use to collect large amounts of paper if there is nowhere to recycle it.

Having identified the quantity and types of paper to be collected, it is then necessary to evaluate whether it is worth recycling and potentially using the paper again. Ideally, high-quality paper should be recycled into high-quality paper again and lower-quality paper into lower-quality paper again. This is not always possible as quality is often reduced in the recycling process, and sometimes it may not be cost-effective to recycle certain types of paper. An economic evaluation should be carried out to compare the costs of recycling with the potential savings and revenue.

This may involve discussions with recycling companies and analysis of the current and future markets for recycled paper. If the paper is to be stored and used internally, it is important to identify whether a closed-loop recycling scheme is viable.

Fig. 3 show Steps for recycling waste paper and the production process.

The main objective in assessing the amount and types of paper discarded is to identify the amount of waste paper and its location. Observational techniques and waste auditing can be used to determine the quantity and type of paper waste. Waste auditing is the sorting and weighing of waste to identify the types and quantities of paper. A complete waste audit could be very time-consuming and costly, hence it is more efficient to identify how much paper is being thrown away and in what form.

There are a number of steps to consider before embarking on a program to recycle paper. These include assessing the amount and different types of paper discarded the potential for using the paper again, and the availability of local markets or recycling facilities. The first step is the most crucial and will largely determine the overall success of your recycling program.

#### 4.2. Designing recycling infrastructure

There are two schools of thought upon the designing the recycling infrastructure. The conventional view suggests that the “best” recycling

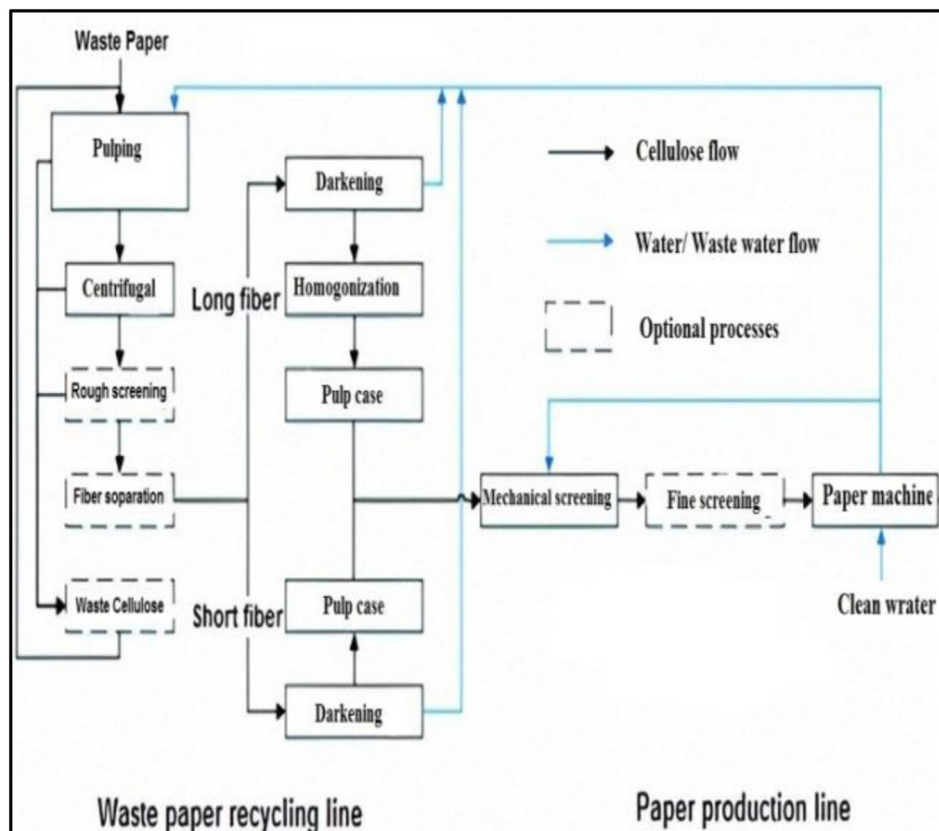


Fig. 3. Steps for recycling waste paper and the production process.

technology is the one with the lowest economic cost. In a free market, if the price of virgin materials is lower than the cost of recycling them, the rational society would dispense with recycling waste. However, because many people regard recycling as a moral issue, they advocate policies that subsidize recycling with public funds (see [Table 3](#)).

This is to ensure that the negative externalities of resource depletion and environmental degradation from the manufacture and disuse of products are not passed onto future generations. These policies are however based on a faulty understanding of economics, and there are numerous reasons why mandating more expensive recycling is not economically helpful for the environment. If monetary costs are not a factor in school recycling, it is not sustainable to just put numerous recycling bins throughout schools and simply increase the recycling rate. This is improving the “technology” of recycling; however wastepaper recycling does not seek to garner resources from paper, but to use fewer resources in using and disposing of paper. Also, free recycling technology does not embody any of the other ways in which the school can save on resources through recycling discussed previously. Any recycling must a sound economic use of resources as the revenue from selling recycled materials is often offset by the costs of collection and remanufacture. As such there should be a drive to recycle paper with paper, as mixed paper often cannot be reconstituted into the same product, and de-inking paper for remanufacture is both resource and energy intensive. The primary way in ensuring that there is an economic use of resources is to set the lowest possible quality of material that can be put through the recycling process, as recycling old paper to make new paper uses fewer resources than

wood pulping. This technology of setting levels of material quality is known as raw material substitution. Any such economic use of resources is essentially opportunity cost, the value of the next best alternative foregone, in this case minimizing the use of resources in recycling paper, by using more to accomplish the same end, using less today to save for tomorrow or investing the resources elsewhere.

The second contemporary and novel view uses a thermodynamic analysis of recycling. Tendencies toward the complexification and sophistication of material combinations and systems result in increased entropy production, which is known to be the driving force of environmental degradation. It is therefore suggested that society must implement policies to minimize entropy production within systems by employing certain types of resources and materials in ways that produce minimum entropy. More specifically, the use of scrap material re-melts systems and conversion processes results in the reduction of the many forms of entropy associated with refining materials from their raw state. While a marginal increase in entropy is inevitable for recycling to occur, by ensuring that systems of recycling materials have minimal entropy, the cumulative entropy associated with the maintenance and evolution of society's diverse material goods can be stabilized. This method is very oriented to scrap material recycling and does not regard recycling as a single loop system, however because recycling paper incurs lower quality and lower quality material degrades faster. It provides an overall beneficial framework for the type of material and the systems that recycle it. Given that the cost of recycling technology for one loop paper recycling is not heinous or economically unviable, and that it takes fewer resources than wood pulping, the EPA's Resource Conservation Challenge Policy would promote the use of such technology, to foster a Recycling Community that is Informed, Committed, and Involved.

*Table 3. Machines and equipment needed to recycle paper and cardboard.*

no	Machine name
1	Dough mixer
2	Sieve
3	Centrifuge
4	Refining device
5	Vibrating screen equipped with trough
6	Water basins
7	Boiler
8	Dough warehouses
9	Polishing rollers
10	Squeezer
11	Production machine
12	Electric paper scissors
13	Pumps and accessories
14	Paper pressing device
15	Hydraulic carton press

#### *4.3. Educating and engaging students and staff*

For staff, a more direct approach is often necessary. At the administrative level, policy changes can be a very effective way to bring faculty on board. This can range from a simple policy such as mandatory double-sided printing, to a more in-depth policy with ramifications for individual departments based on their paper usage. However, the most effective strategy can often be a simple direct appeal to change behavior. This can take the form of a simple pledge signing to use the new printing policy or a personal appeal from a member of the research team.

Students also respond well to incentives. Utilizing promotions such as giveaways for students who give up printers or reams of paper can be an easy way to motivate students. However, it is important with this approach to make the incentives ones that would not undermine the environmental impact of the program.

For students, a lot of the engagement will come through educational outreach. This can take the form of class presentations, where concepts can be directly linked to each student's environmental impact. However, the most effective tool can often be involving students in the research process. Numerous students have to conduct research projects and case studies for social science classes, and by involving these students in the research level of the program you can both improve the project and allow them to see the link between their work and waste reduction.

Engaging students and staff in the program is critical to its success. Schools have a diversified community with various values and perceptions. Engaging the audience builds a sense of ownership and investment in the program, which is crucial for its sustenance.

#### *4.4. Monitoring and evaluating the recycling program*

In an effective recycling program, evaluation and monitoring must exist to measure the success in meeting its goals. In order to ensure progress is evaluated in terms of achieving the aim, a set of quantifiable indicators must be identified, so that future improvement can be based on past achievements. This will allow the recycling program at the academic institution to be monitored in terms of the activities as well as behavioral change. Therefore, this will provide insights into the key successes, as well as the areas that require further attention. Data collection and continuous monitoring of the recycling program compared to the baseline will provide an effective method to evaluate its success. This can involve quantitative measures of waste paper recycled, recycling rate, the cost incurred in recycling, and the quality of the paper recycled. In addition to this, qualitative measures such as increased awareness or changes in attitude toward recycling can be gauged from surveys of the students and staff at the academic institution.

Although evaluation is important, there must also be continual improvements made to the recycling program. Hence it is vital to compare the planned activities to the actual results obtained. This will assist in identifying any shortfalls and

understanding what has and has not worked in the recycling program. Evaluation in comparison to the overall goals is important to determine the success of the program. It may also be necessary to redefine goals for the recycling program if they are found to be unrealistic after monitoring and evaluation has taken place.

### **5. Overcoming challenges in paper recycling**

At the initial stage, the idea of recycling may seem complex and futile due to the perception that items requiring recycling are difficult to identify and sort. In the initial stages of recycling, recycling mills were not designed to de-ink paper. This could be seen as a lack of infrastructure and a financial challenge. A university interested in recycling may fail due to the lack of preventative measures or follow through from the students and staff that ultimately lead to an unsuccessful recycling program. Due to huge amounts of students and staff, papers may often become mixed with other types of waste, therefore becoming too expensive to separate and recycle. Often, the need to recycle paper may not be compelling or strong enough to entice the university to allocate resources and time for the process. Papers often recycle with food and other contaminated items. In some cases, this is a result of lack of awareness and motivation as well as the mistaken idea that paper is sent to a landfill to decompose. With many legal implications and societal pressures, the incorrect disposal of waste such as the dumping of papers into landfills can result in heavy fines and damage to a university's reputation.

#### *5.1. Lack of awareness and motivation*

According to Russell and Hon (2002), before waste can be recycled, it must first be separated from the general waste stream and collected. This is a major problem in Malaysia where the public are not used to separating their rubbish into categories. An effective recycling programme requires the cooperation of the public and government. If the public are not willing to help in the separation of waste, then recycling will not be fully effective. In the case of paper recycling in Universiti Teknologi Malaysia, there is no cooperation from the non-academic staff and students to segregate paper waste from other types of waste. This is due to lack of awareness on the effects of waste product to the environment. The study showed that the lack of awareness and understanding the importance of recycling is one of the main causes of lack of cooperation of the public in separating waste. The findings showed that 82.5%

of non-academic staff and students do not separate paper waste from other types of waste. This is higher than at UTM Skudai where 75% of the non-academic staff and students do not segregate paper waste. This shows that UTM Skudai is a bit better than the Kuala Lumpur campus. So, the cooperation of the university here is still considered low. This situation will further slow the efforts of Pusat Pengajian Sains Sekitaran UTM Kuala Lumpur to make this campus a role model in implementing activities that are friendly to the environment. Based on the interview with the Dean, he showed his deep concern on the low cooperation of the staff and students in separating paper waste. This situation is very contrary with PPSSE's intention to run the paper recycling project as the success of the project depends largely on the availability of paper waste supply with good quality. Thus efforts should be taken to increase awareness and provide understanding to the importance of paper recycling, so that everyone will cooperate to segregate paper waste. This can happen if there are campaigns and instructions to the staff and students on the benefits of paper recycling to the environment [15].

### 5.2. Infrastructure limitations

The most significant argument found when looking at recycling in a high-level educational institution is that the facilities are not equipped to deal with widespread recycling. Most buildings have one or two bins in which to put waste material. These are not separated and very often end up as general waste and thus cannot be recycled. Regular mixed waste bins are available in nearly all professional working and student areas within the university, and the lack of visible recycling facilities directly influences the choices made by staff and students, who generally do want to recycle. Unfortunately, the choice is not often theirs as accumulated waste is likely to be cleared by cleaners, many of whom are employed by external contractors rather than the university itself. These individuals may not be as motivated to change general waste disposal methods, nor may have specifics regarding what waste is general and what is recyclable, thus could end up disposing of both in the same way. Failure to involve outsourced catering services can also have a negative impact as food and drink packaging is a large component of recyclable materials. These materials often end up as contaminated waste due to the non-disposal of residual foods and the bins they are disposed in likely will not be known as recycling bins. All of these sustainability issues can be linked to a lack of interest and training for those employed

in services, making infrastructure development an essential part of raising recycling rates [16].

### 5.3. Financial considerations

A further economic issue faced by paper recycling is competition from other waste management options. In some cases, it is cheaper to dispose of paper into landfill or by incineration than to recycle. An example can be drawn from some confidential waste materials which require shredding. The product of this process is often used as a fuel for incineration because it has become too contaminated to recycle. Finally, paper recycling economics can be affected by legislation. Changes to environmental taxation or new recycling targets can influence the supply and demand of recyclable materials.

This has obvious repercussions for paper recycling economics. Where the market price for material is less than the cost to collect and process it, there is little incentive to undertake such activity. As a result, many local authorities and waste management companies have had to subsidize paper recycling in an attempt to carry out sustainable waste management. The economic climate for paper recycling is exacerbated by global markets and competition. To some extent, the price of waste paper is determined by the price of other raw materials and commodities such as plastic or metals. Furthermore, the price of imported paper and board as a commodity can determine the competitiveness of recycled material.

However, as with most processes in the paper recycling spectrum, it is the economic issues that ultimately dictate the level of success that can be achieved. The market price for paper and board has been steadily decreasing over the last decade. In the UK and Western Europe, the price has dropped from £75 per tonne in the early 1990s to around £25–30 per tonne in 2003.

### 5.4. Addressing contamination issues

A better prevention approach to contamination is source separation. This could involve direct distribution of waste paper within a facility to the recycling centre. As well as containing the waste generation to one central location for ease of collection and transfer. Material recovery facilities can also play a huge part in contamination prevention. They separate the waste collected into separate categories to reduce the amount of waste that is downcycled. While it is considered an effective approach to contamination prevention, the high costs and the negative associations with manual

sorting labour has resulted in reluctance of its implementation. Methods of source separation could be much more effective if economic measures were implemented for example the product charge/advance recovery fee could be refunded for returning the product into the loop and would act as a financial incentive for the consumer. This is a long term approach but no doubt effective.

Contaminants can range from high grades of paper down to ground glass. They also cause wear and tear and eventual failure of equipment. The implementation of quality assurance starts as soon as the items enter the recycling facility. This involves the suppliers adopting a 'right first time' approach to manufacturing and the minimization waste i.e. only producing the amount of product required [17].

## 6. Case studies of successful paper recycling programs

### *a. University A*

Best practices and Outcomes University A implemented a paper recycling program in 1997 by introducing newspaper and high-grade paper collection to a preexisting corrugated cardboard recycling program. Their initial focus on offices was later expanded to schools and departments. Before program implementation, a waste audit was conducted to identify the type and quantity of paper being discarded. During the recycling program, audits were repeated to measure the program's success. The paper recycling program was marketed using the slogan, "Don't trash it, and recycle it!" and the program coordinator worked to establish a cooperative relationship with custodial staff to ensure their participation. A recycling newsletter was published periodically to provide feedback to building occupants and to generate excitement for the program. A paper product purchasing policy was developed and recommended to the university's procurement department. The policy specifies purchasing uncoated, high-content recycled paper and paper products. This policy should help to close the recycling loop, creating a demand for the recycled paper material being collected. An environmental studies class adopted the recycling program as a class project, which involved students' participation in a waste sort at one of the buildings. This class project helped to bolster communication between the program coordinator and building occupants and also served as a tool to educate the students about recycling issues in the university's community. On a competitive note, the school's

participation in a collegiate recycling contest has brought \$3000 to \$4000 in prize money for each of the last two years. This money was directed to the recycling program to help develop it further. Success has been such that the paper recycling tonnage has continued to increase during each year of the program, and there are plans for additional program expansion with the hiring of a recycling student intern.

### *b. College B: Lessons learned and recommendations*

The College B recycling program began in 1998 with the hiring of a recycling coordinator for the entire campus, including administration, faculty, staff, students, and visitors. The program was initiated concurrently with a new program for waste minimization. The focus on administration was due to its high paper-generating activity, which was the source of over 40% of college solid waste. High involvement of students was thought to be important, and hence an event called RecycleMania was brought to the campus in order to spread interest and enthusiasm for the program. Family housing residents were a special target of frequent contamination and exclusion from previous recycling efforts, and so the new program provided them with recycling bins and information in an attempt to change this behavior. An inspection and recommended improvements report was written after the first year of the program, showing that there was a 66% increase in recycling with a 22% reduction in waste. The future focus of the program will be to hire a student to act as a liaison to building occupants in order to ensure correct and extensive participation in the recycling and waste minimization programs.

### *6.1. University A: best practices and outcomes*

Two full-time recycling coordinators spent most of their time devoted to the program and co-chaired a committee of 30 people representing all facets of the university community. A comprehensive marketing campaign had a strong impact on attitudes and behavior; it consisted of three weeks of intensive promotion using print media, bulletin boards, and University vehicles. The campaign kicked off with an "Earth Day" celebration and press conference. These efforts led to an increase in office and residential paper recovery to 750 tons in 1992, even with the addition of more stringent standards to the data. These standards included excluding paper sent to landfill.



Despite budget problems, the university was able to form a partnership with a local non-profit organization and received \$3500 of in-kind services from Americorps. These efforts led to the organization of a very successful “recycling blitz” in the residence halls at the end of the semester.

During the blitz, volunteers were in uniform and covered every area of the residence halls, going room to room to personally give residents information and incentives to recycle. The organizers learned that convenience and competition are the two best ways to increase recycling in the residence halls.

The University contracted with a local recycling company, which was able to keep paper processing costs very competitive. The program then faced its largest challenge when the recycling coordinator position was eliminated due to university budget cuts. This was a severe blow to the program as the coordinator was the key person in coordinating all recycling efforts. It was avoided, however, due to intense support from recycle committee members and upper-level administration. Today the university still maintains a high paper recovery rate and continues to find ways to improve recycled product procurement.

## 6.2. College B: lessons learned and recommendations

The implementation of a paper recycling program in an academic institution is of high value and a necessary first step towards a sustainable waste-reduced community. The knowledge that paper recycling is a simple method with various possible unfoldings provides easy optimism and attainability for success. However, the realities faced by different institutions in attempting this method may vary. College B's attempt to build a program and better its methods to suit the specific needs of its community provides a good example to others that may be in similar situation. The ideas and methods provided here are meant as general guidelines and should be adjusted and improved through trials and research in every case. Steps to keep an accurate account of all methods, paper use and waste and the seeking of outside learnings and resources were found to be common threads and most valuable to all methods attempted in this study. High value on building relations with recycling companies and contributing to increasing community awareness were best methods found to build productive steps in the program. Through these things and further improvements, it is hoped that College B can solidify a productive program and provide an example to

others which will decrease paper waste and depletion in the environment.

To consolidate a paper recycling program and ensure its long-term success in a school or university, one is advised to follow the best practices of successful institutions and go beyond to find innovative methods that may be more suitable to the unique situation of the institution being served. Emphasis must be placed on research and keeping accurate account of all methods applied, expenses made, and paper usage and waste from the beginning, that improvements may be made in each phase until an efficient and cost-effective system is achieved. As paper recycling involves varying unfoldings in different areas with many possible methods, no specific instruction is given which will give the best results for every institution. Therefore, it is recommended that any trials be not only implemented but used as a learning experience to understand better their individual paper use, waste, and recycling needs. High value should be placed on building relations with local recycling companies to further understand the current market and availability of recycling services and how it may affect the program. This was found most pivotal in building College B's program and is useful for any institution. Steps should also be made to involve the surrounding community to gain their support and paper contributions and educate them on the importance of recycling, though methods to do this may vary. With these things in mind College B and any institution following a similar progression should be adequately prepared to build a sustainable paper recycling method and work towards community waste reduction.

## 7. Future trends in paper recycling

Technological advancements in paper recycling are aimed at cost reduction, performance improvement, and environmental impact. Some of the objectives set forth by the industry are: increased use of recovered paper as a raw material; increased bleached chemical pulp substitution with recovered paper; an increase in the yield of deinked pulp from the recycled fiber; improvements in the quality of deinked pulp and products; and reductions in the stages and chemical usage in deinking processes. To increase the use of recovered paper (currently around 50% of the paper made in North America), there has been continual research into lower-cost methods for recycling. Low-cost methods are required due to the low return on reclaimed fiber when compared to the cost of wood. One recent development is recycling methods using oxygen

and ozone, which could replace the standard pulping methods used today. This process has been showing promise, although not a great deal of work has been done so far. Other interesting work has been done on a technology using a jet nozzle in the center of a flotation column, which produces a gas-liquid jet in the form of a cone. Other factors relating to process stream preparation have also been addressed, such as contamination removal and coated ink separation. These and the aforementioned factors relating to increased use of recovered paper are all aimed at using a sustainable technique to recycle paper in academic institutions.

### 7.1. Technological advancements

An EU-funded project in Spain, between a mix of research institutions and industry under the name of PULP-tech, is an attempt to increase the value of recycled paper by use of modified cellulose for the production of paper. With the uses of cellulose derivatives, an increased variety of paper qualities can be manufactured, in turn expanding the products available from recycling.

In Norway, there has been development of a new technology developed at the University of Life Sciences. It is a steam explosion method to be used on mixed waste which makes the fibers more available for use in the production of paper. The claimed end products from this method are both paper and bio-ethanol. Methods such as these, which try to expand the products received from recycling wastepaper, will be an area for increasing research. When compared with paper production, recycling is still a simpler process and development of new products will likely increase economic viability and future investment.

Advancement is occurring in Japan, where the previously mentioned LCA method is being trialed. They are also looking to use dissolving pulp technology which can separate cellulose fibers from a variety of sources including wastepaper and then used in the production of paper or other materials.

One such example is the NYU Steinhart's Clean Tech method developed in conjunction with the US Forest Products Laboratory. It is a two-stage hydrogen peroxide delignification process designed to allow the recycling process to skip the bleaching or de-inking stages. It claims to be able to use the pulp produced in this process to be used in white paper.

There are a number of developing and potentially economically viable technologies which can be applied to the paper recycling process in the future. Many of these technologies are being pioneered in nations where there is ongoing investment in

advanced waste management infrastructure. Most of the new technologies look to avoid the use of de-inking processes, instead favoring production of de-inked pulp.

### 7.2. Innovations in paper production

Perhaps the most revolutionary development in paper production is the exploration of producing synthetic paper from inorganic resins. While paper has its advantages as a renewable resource, it has the inherent disadvantages of being bulky and having relatively low strength and durability. These factors contribute to a high consumption rate and short useful life compared to the energy and resources used to make it, and a predominance of litter from discarded paper products. Synthetic papers can potentially match all the desirable attributes of paper, while being more durable and more resource efficient to produce. This innovation, which is still in its infancy, if successful can ease the environmental impact of paper and improve economic feasibility of recycling through making products with longer useful lives from fewer resources.

Alternative production processes designed to change the nature of paper itself are beginning to offer new and innovative methods for producing quality recycled paper. What has been termed "treeless" paper not only incorporates a higher percentage of recovered fiber, but also uses non-wood fibers such as agricultural residues (e.g. straw), and fibers from annual plants such as cotton, kenaf, or jute. These fibers can be of higher quality than some recovered paper, and their use can increase market demand for recycled fiber while improving the quality of the end product. Expanding the variety of fibers used in paper production reduces the strain on forests from which wood is harvested, and further closes the loop in fiber recycling by creating demand for specific recovered fibers.

### 7.3. Policy and regulatory developments

Policy and regulatory developments pertaining to paper recycling are integral to the future consumption of recycled fibers. Measures and decisions enacted currently will have lasting effects. It is important in this new area to avoid potential conflicts between economic and environmental objectives. Steps taken to avoid logging of natural forests increase the recycling of paper and board, and to ensure that governmental procurement effectively stimulates the market for recycled products are positive moves from the environmental standpoint.

A potential problem may arise if recovered paper is used as a cheap source of fiber for energy-intensive production of microcrystalline cellulose, cellulose derivatives, and synthetic fibers. This situation has arisen in some countries already, and often the industry concerned has been attracted by fiscal or financial incentives to the specific industries rather than the more diffuse incentives of a healthy environment. A global approach to environmental taxation, taking account of the varying social and environmental costs in different countries, would help alleviate such problems. This is a long-term goal but must be considered when making trade and investment decisions that will affect the future of fiber consumption and paper recycling in different regions. Fig. 4 show Simulation of waste paper recycling for a small academic institution.

#### 7.4. Calculating the amount of paper waste in the colleges and departments of Dhi Qar University

The amount of paper waste is linked to the number of actual students continuing to take exams, so we relied on student numbers statistics for the academic year 2022–2023 (1).

To calculate the number of exam notebooks and calculate the weight of paper waste resulting from the exam notebooks, as well as calculate the cost of preparing these exam notebooks, we do the following:

Number of exam books = actual number of students  
 × total study subjects during the academic year  
 Amount of paper waste = number of exam  
 notebooks × weight of one exam notebook  
 (0.035 kg)

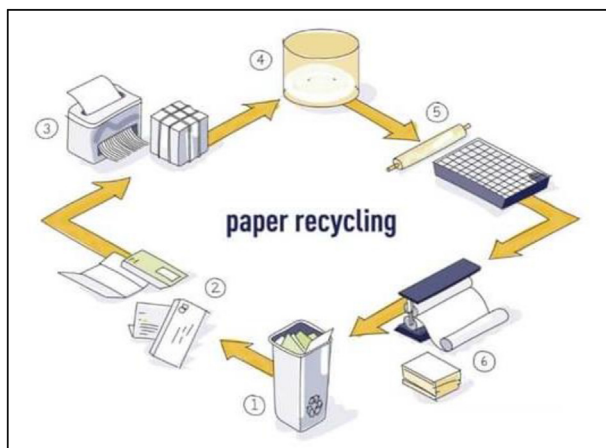


Fig. 4. Simulation of waste paper recycling for a small academic institution.

The cost of preparing exam notebooks = (weight of paper waste/weight of one exam notebook (35 g)) × (cost of preparing one exam notebook (400 dinars)).

There is a wide range of paper waste recycling available to suit usage in university, waste paper output, and storage facilities. A large waste paper can hold a greater amount of paper, meaning you don't have to arrange daily paper collection.

At least in institution in Iraq the traditional (typical to recent time) the manner to destruction this regularly produce large volumes of paper waste was burn. However, you may need to obtain a permit to permanently store a skip on your property, regardless of the size you chose. Paper was recycled services provide an effective way to manage your paper waste that benefits your business and the environment. Improve your paper waste management with a uniquely tailored paper recycling service. Arrange the right size and number of bins for delivery and collection as often as you need.

## 8. Conclusion

1. The increasing amounts of paper and cardboard waste in government academic institutions and its occupying the second place in the city's waste after food waste, which reflects the size of the environmental impacts and the loss of economic opportunities that the city bears due to the lack of interest in recycling waste paper and cardboard.
2. Most government academic institutions rely mainly on traditional methods (burning) to dispose of examination books, after a period of time has passed by forming committees to dispose of them in order to maintain their confidentiality.
3. Preventing the government from exporting waste paper outside Iraq and recycling it locally, because of the returns it achieves that far exceed what can be obtained from exporting it raw.
4. Opening a factory to recycle and manufacture paper, with universities as the source of the raw material, in addition to being a financial resource for the universities that open the factory, providing job opportunities for graduates, eliminating falsehood, and not purchasing papers or exam notebooks in the case of recycling the spent ones.
5. The approximate amount of paper waste in Iraqi academic institutions, according to the research

study for the academic year 2022–2023, was approximately (367.60976 tons/year).

6. The cost of preparing examination books in Iraqi academic institutions for the academic year 2022–2023 amounted to approximately (4202150971 Iraqi dinars).

Sustainable recycled paper in academic institutions has been widely acknowledged as environmentally important, as well as for generating an awareness of environmental issues in an age group crucial for the transition from awareness to action. Despite the increasing use of electronic media, which has undeniable benefits in it, it was found that the amount of paper used by academic institutions is unlikely to decrease significantly in the near future. The print practices of academic institutions demonstrate the type of false economy that, while generating short-term cost savings through the usage of internal wastepaper, generates the need to purchase a higher quantity of recycled paper, and sends a message to students that the quality of their work is directly related to the quality of the paper it is presented on. The available technologies for sustainable recycled paper were analysed according to their feasibility on a small scale, such as a departmental office, and on a large scale, such as a university wide system. The most feasible current method involves the recycling of paper internally at the same site it was used, using a small machine to convert waste paper into a more useable form. The more common method of recycling paper through collection by a recycling company and its later return as recycled paper is less appealing due to issues of mixer and the fact that it is often not recycled into paper but some other form of lower quality material. The provision of a feasible alternative is an important finding itself, as in the past recycling paper has often been seen as a somewhat altruistic act that was performed at the expense of quality and encompasses undesirable inconvenience. The availability of higher quality recycled paper, through any sustainable method, may help to remove the stigma attached to recycled paper and increase its usage. This would be achieved through what is known in economics as a “demonstration effect”, where the action of a certain group in purchasing an item sends a message to others that they should be doing the same. In this case the group is academic institutions and the item is recycled paper.

## 9. Recommendations for academic institutions

These recommendations should be viewed as the necessary initial actions for universities. The

exploration of paper consumption and recycling has proven to be a vital and contested issue, and many of these recommendations require further sustained investigation into their viability. The findings from this exploratory study into identifying best practices at universities throughout North America has given insight into a wide array of possibilities to create sustainable paper consumption and recycling patterns. However, there is still much work to be done in adapting these practices into the unique context and culture of specific academic institutions. Both large and small-scale initiatives have potential to effectively reduce paper use and waste. At the core, it requires a community effort and awareness of the importance of such measures. Changes are not likely to happen without increased availability of information and resources on these strategies. The feasibility and success of these initiatives seem to require that there is a mechanism for tracking paper reduction or waste diversion. This is essential to monitor progress and impact, and to justify continuation of efforts. The paper outlined by concrete examples, has identified and evaluated various strategies to reduce and/or improve paper consumption and waste at universities. By continuing to share information and experiences with these methods, institutions can learn from one another to adopt the most effective practices. Overall, the transition to more sustainable paper consumption and waste patterns is a multifaceted and dynamic process. The identified best practices are perhaps best viewed as works in progress, as they have potential for further refinement and evaluation.

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