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## COLLEGE OF ENGINEERING AND TECHNOLOGY

## DEPERTMENT OF CHEMICAL ENGINEERING


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**Title: Production of paperboard from waste paper**


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# DECLARATION

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# ABSTRACT

*In this study paperboard produced from waste paper by using chemical pulping process the general step used in laboratory was raw material preparation, pulping process, washing, bleaching, molding and pressing and finally dried the sheet to obtain paper board.*

*The experiment was conduct pulping process with NaOH chemical and without chemical; we can possible to observed the effect of chemical(NaOH) in pulp and final product. The effect of NaOH concentration on pulp yield and weight of paper board was studied.*

*The result showed that first experiment pulping with NaOH at $90^0$c temperature and 35 min was obtained 62%, 19%, and $256g/m^2$ of pulp yield, moisture content and weight of paper respectively and then pulping condition without chemical at $90^0$c temperature and 60min 64%,16% and $216g/m^2$ of pulp yield, moisture content and weight of paper respectively.*

*In order to design and sizing of the basic equipment's and to evaluate the economic feasibility of the process. From the result of the economic analysis net present value is positive This implies that, the study was feasible and profitable.*

***Key words**: Waste paper, paper board, pulp, paper production*

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# LIST OF ACRONYMS

| | |
|---|---|
| A | Area of the paper |
| ASTM | American Society for Testing and |
| APPITA | Australian pulp and paper industry technical association |
| BOD | Biological oxygen demand |
| CIF | Cost Insurance and Freight |
| COD | Chemical oxygen demand |
| CPPA | C1anadian pulp and paper association, technical section |
| CSA | Central statically agency |
| GHG | Greenhouse gas |
| GSM | Internationalstandardazation |
| ISO | organization |
| | Gram per square meter (gsm) |
| $Mp_i$ | Weight of paper after drying |
| $Mp_o$ | Weight of paper before drying |
| MOW | Mixed office waste |
| OCC | Old corrugated container |
| ONG | Old news print |
| RH | Relative humidity |
| RP | Recovered paper |
| SS | Suspended solids |
| TAPPI | Technical association of the pulp and paper industry |
| USD | United states dollar |

# CHAPTER ONE
# 1. INTRODUCTION
## 1.1 Background
Traditionally, wood is considered the primary raw material and the major source of pulp in paper production. The recent global production of paper and paper board is 406 million tons per year which is derived from 225 million tones recycled paper, 176 million tonnes wood pulp and 12 million tonnes other fibres pulp. [1]
Numerous researches conducted on a global scale are focused on identifying alternative non wood raw materials as a source of cellulose fibers. Some types of non-wood fibres have been are already used in some paper grade productions, although the paper quality varies based on the source of the fibres. In Ethiopia there are about 22 companies that involved in paper making and trading businesses, of which only 'Ethiopia pulp and paper share company' and 'Barguba' plc. Uses imported pulp for their paper mills while others import and produce paper rolls for further processing. Ethiopia has been imported 7.8 million tonnes of pulp at a cost of 6.3 million USD and 151 million tonnes of paper at a cost of 167 million USD in 2016. Only about 5% of the country's paper demand is produced in the country and the rest will be covered by importing finished paper from abroad.

Recovered paper (RP) became a valuable raw material for the paper industry already in the early 20$^{th}$ century. Over the past decades, the recovery and utilization of paper in the paper and board industry has increased throughout the world, and this trend will continue.

The pulp and paper industry is very diversified, using many types of raw materials to produce very different kinds of paper by different methods in mills of all sizes. Pulp and paper are manufactured from raw materials containing cellulose fibers, generally wood, recycled paper, and agricultural residues. In developing countries, about 60% of cellulose fibers originate from non-wood raw materials such as bagasse (sugarcane fibers), cereal straw, bamboo, reeds, esparto grass, jute, flax, and sisal .[1]

The paper manufacturing process has several stages: raw material preparation and handling, pulp manufacturing, pulp washing and screening, chemical recovery, bleaching, stock preparation, and papermaking.

Paper production is basically a two-step process in which a fibrous raw material is first converted into pulp, and then the pulp is converted into paper. The harvested wood is first processed so that the fibers are separated from the unusable fraction of the wood, the lignin. Pulp making can be done mechanically or chemically. The pulp is then bleached and further processed, depending on the type and grade of paper that is to be produced. In the paper factory, the pulp is dried and pressed to produce paper sheets. Post use, an increasing fraction of paper and paper products is recycled. Non recycled paper is either landfilled or incinerated.

Recycling is to use waste paper products in the production of paper as raw material. Therefore, environmental pollution and deforestation can be prevented. To produce paper, waste paper can be mixed with other raw material or with the new technology; solely waste paper can be used to produce new paper. Secondary fibers which are extracted from waste paper are now vital due to the increasing demand, limited forest resources and environmental pressures. Modern paper industry procures raw material largely from waste paper.

In this study process pulp from waste paper is used. It is the oldest and very famous process to prepare a pulp. Today the pulp from waste process is the dominating chemical pulping process worldwide due to the superior pulps strength properties compared with sulphite process. The paper production from waste paper is a process for conversion of waste paper into pulp consisting of almost pure cellulose fibers. This process entails treatment of waste paper pulp with a mixture of sodium hydroxide and sodium sulphide, known as white liquor, which breaks the bonds that link lignin to the cellulose. A dark brown pulp is obtained through this process. After that through the bleaching process, a white pulp is obtained and this pulp gives a very good strength paper.[2]

## 1.2 Statement of the problem

The pulp and paper industries have been rising due to the increased demand of paper-based products and it is a must to find raw material sources for these industries. The consumption of paper and paperboard has been also steadily increased over the world.

Paper and paperboard are found wherever products are produced, distributed, marketed and used and account for about one-third of the total packaging market. With the increase in economic and commercial activities paper consumption has increased rapidly over the world. Industries, commerce, households and Government institutions consume a lot of paper and also produce a lot of waste paper. And these waste papers are discarded in the environmental hence destroys the aesthetic beauty in communities and can lead to environmental degradation. The primary raw material for the paper production is pulps fibers obtaining by a complicated chemical process from natural materials, mainly from wood. Paper production from virgin fiber uses cellulose, the form of wood chips obtained by felling trees, which increases global warming. This virgin fibers production is very energy demanding and at the manufacturing process there are used many of the chemical matters which are very problematic from view point of the environment protection.

Specifically, in governmental institutions like school many of paper is used for a different purpose, like for student handout notes, exam papers, for staff members to prepare teaching materials, for notice posts, and many others. After this paper is used for one more time it's simply discarded to the environment. Therefore, this project is important to investigate the possibility of recycling waste paper into useful product, and contributing towards environmental protection as well as creating an employment opportunity.

## 1.3 Objectives of the study

### 1.3.1 General Objective

- The general objective of this study is to produce paperboard for packaging purpose from waste paper.

### 1.3.2 Specific Objectives

- ✓ To prepare good quality pulp from waste paper by using chemical and without chemical to produce paperboard.
- ✓ To look the effects of NaOH used on quality and quantity of pulp and paperboard property.
- ✓ To characterize paperboard physically, obtained from waste paper
- ✓ Conduct material and energy balance for each unit operation
- ✓ To estimate the economic cost and profit of the plant

## 1.4 Significance of the study

This study has benefits as it goes without saying that economy will always be a primary concern when it comes to developing sheltering solutions. Nowadays, in paper making industry, the environmental problems have brought forward the need for cleaner technology where the new technique have been introduced to recover the wasted paper as raw materials for paper making.

Generally, the significance of use recycled waste paper for paper production is:

- Paper produced from recycled paper represents an energy saving of 70% compared to produce paper from wood or virgin fibers

- Reduction of the raw material consumed (trees felled)
- Saving resources
- Recycling paper saves 80% of water compared to production from virgin fiber
- Improved air and water quality
- Savings in greenhouse gas(GHG) emissions
- Less waste is sent to landfill or for incineration

# CHAPTER TWO
# 2. LITERATURE REVIEW

## 2.1 Overview

This chapter reviews the relevant literature about waste paper recycling in the world. It looks at the definitions and materials used in paper making, potential environmental impacts of continuous use of virgin wood pulp and also focus on environmental quality of recycling. We provide several case studies of researchers who attempted to recycle waste paper with different methods. The design and results of these studies have helped us to design our own methodologies. Lastly it focuses at the technical of pulping and previous work done on paper recycling.[3]

## 2.2. Global pulp and paper production and demand

The manufacturing of pulp, paper and paper products ranks among the world's largest industries. The global production of paper and cardboard stood at approximately 407 million tons in 2014. More than half of that production was attributable to packaging paper, while almost one third was attributable to graphic paper. In 2015, the regional distribution of pulp and paper production was as follows: Asia-Pacific, 195 million tons (48%); Europe, 104 million tons (26%); Northern America 83 million tons (21%); Latin America and the Caribbean, 21 million tons (5%); and Africa, 4 million tons (1%) as shown in figure 2.1. In terms of future capacity, trends in the paper and board industry show a stable production over the next five years.

North America, Europe and China accounted for 28%, 26% and 15% of the global paper and board consumption in 2005, respectively. However, there are drastic regional differences in paper and board consumption. Per capita consumption in developed countries is close to 300 kg/cap, whereas in Africa the consumption is less than 17 kg/cap.

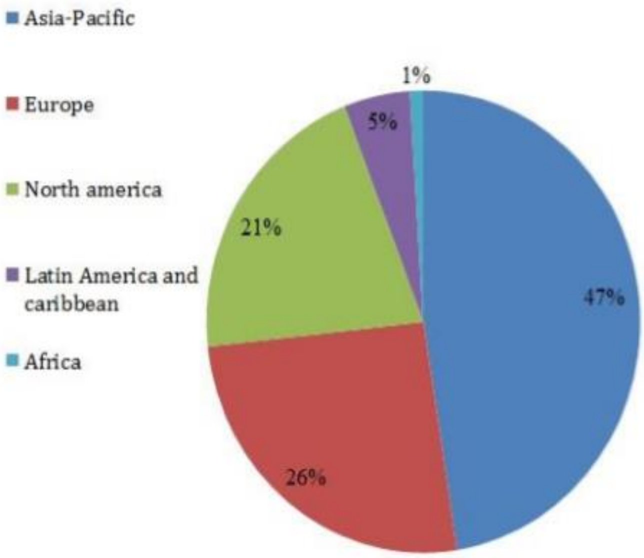



Figure 2.1 Global paper and paper board production in 2015

### 2.2.1. Pulp and paper manufacturing and demand in Ethiopian

In Contrary to the extremely rising global demand and production of paper and paper products, paper production in Ethiopia is at its infant stage where there are only very few paper mills producing a maximum annual output of 35 thousand tones in aggregate which is less than 0.01% of global production. The huge capital investment and absence of pulp mill processing the raw material in the country are considered as the major reasons for these limited number of paper mills. These make the local production of paper inefficient and less competitive when compared to other sectors in the industry, which significantly affects the overall economic growth of the country. According to the CSA report from 2009 to 2016, the imported amount of paper and pulp by Ethiopia increased from nearly 82 thousand tons to 154 thousand tons and from 4 thousand tons to 8 thousand tons respectively (Table 2.1).[4]

Table 2.1 Pulp and paper imported by Ethiopia between 2009 and 2016

| Year | Gross weight of imported pulp(kg) | CIF value(USD) | Gross weight of imported paper(kg) | CIF value(USD) |
|---|---|---|---|---|
| 2009 | 4,060,624.00 | 2,200,849.78 | 82,217,748.96 | 84,651,044.37 |
| 2010 | 1,765,788.16 | 1,632,848.18 | 76,512,841.77 | 82,450,928.73 |
| 2011 | 6,763,884.00 | 5,668,217.546 | 86,112,164.82 | 101,833,766.21 |
| 2012 | 8,689,498.00 | 6,759,688.00 | 103,951,203.64 | 116,359,837.88 |
| 2013 | 10,311,278.00 | 8,059,794.46 | 109,789,963.25 | 132,301,772.92 |
| 2014 | 5,140,705.60 | 4,214,596.83 | 139,078,195.66 | 127,237,688.80 |
| 2015 | 7,323,832.40 | 6,025,699.99 | 110,747,096.32 | 135,953,748.31 |
| 2016 | 7,949,797.12 | 6,310,023.24 | 154,157,617.08 | 167,529,679.09 |

## 2.3 Raw Materials for Pulp and Paper Production

The raw material for all papers is cellulose fiber which comes from a wide range of natural materials. The large scale producers rely almost entirely on fiber from timber although, especially in India, other materials such as bamboo, straws and grasses are also used. The cellulose fiber can also be extracted from such things as waste cotton rags, banana pseudostem, bagasse, - in fact almost anything which has grown naturally. However, the quality of fibers varies a great deal depending on the natural material from which it is collected. The quality, usually assessed according to the length of the individual fibers, is extremely important to the quality of the paper which can be made. A high proportion of long fibers is essential for reasonable paper quality, regardless of scale or method of production. Recently, due to the shortage of wood supplies and the environmental concern related to deforestation, alternative raw material is needed to supplement or replace wood source to maintain the pulp industry. [5]

### 2.3.1 Raw material aspects

The deinking of paper is very much dependent on the raw material. The recovered paper can very roughly be divided into 4 groups:

- Old newsprint (ONP)
- Old magazines (OMG),
- Mixed office waste (MOW) and other high grade papers
- Old corrugated containers (OCC).

There are numerous recovered paper qualities but the four mentioned above give a good description of the recycling process. The dominant raw material used for newsprint production is a mixture of ONP and OMG. CEPI statistics from 2000 show that more than 90 % of the recycled fibre for newsprint production is based on an ONP/OMG furnish. The ratio between these two components is very important and is very dependent on the regional usage of various types of paper. A high ratio of magazines is usually considered as favorable for the deinking results (better optical properties) but also results in a lower yield due to a higher ash content1. The MOW mainly consists of computer printouts and xerography printed papers. MOW is considered as a high quality raw material and is usually used for production of fine paper or tissue. As seen in Figure 2.2, 39 % of the fine paper and 60 % of the tissue production of recovered fibre are based on high-grade raw material.[6]

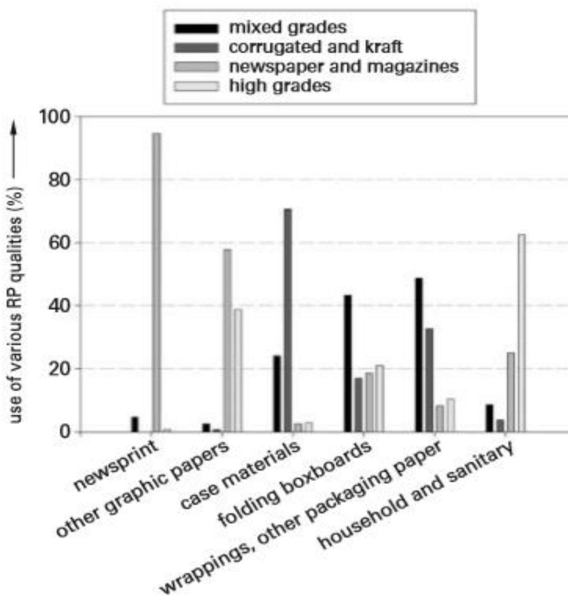



Figure 2.2 the use of different types of recovered paper for production of various types of paper the data is based on western European statistics from year 2000 compiled by CEPI

OCC on the other hand is mainly used for packaging paper production and is usually considered as a contaminant in a printing paper or tissue furnishes. 57 % of the raw materials for packaging material are based on OCC. The OCC furnish is usually not deinked since the optical properties of the paper produced from it is not a primary concern. There are also a number of higher quality raw materials as residual material from printer's shops and as well as sorted paper grades. The price of the raw material varies and therefore an aim is to be able to run as low quality recovered paper grade as possible.[7]

## 2.4 Pulp and Paper Technologies

Pulp and paper are manufactured from raw materials containing cellulose fibers, which generally include wood, recycled paper, and agricultural residues. Paper is made by pulping wood, bleaching this pulp and then spreading it out into sheets to make it into paper. At various stages of the process, chemicals are used to give the paper particular properties, such as the bleaching chemicals that make paper white and which also enable it to subsequently be colored. The manufacturing of paper or paperboard can be divided into six main process areas, which are discussed further in the sections below: (1) wood/raw material preparation; (2) pulping; (3) bleaching; (4) chemical recovery; (5) pulp drying (non-integrated mills only); and (6) papermaking. Figure 2.3 presents a flow diagram of the pulp and paper manufacturing process. Some pulp and paper mills may also include converting operations like coating, box making, etc.; however, these operations are usually performed at separate facilities. Some integrated pulp and paper mills perform multiple operations (e.g., chemical pulping, bleaching, and papermaking; pulping and unbleached papermaking; etc.). Nonintegrated mills may perform either pulping (with or without bleaching), or papermaking (with or without bleaching).[8]

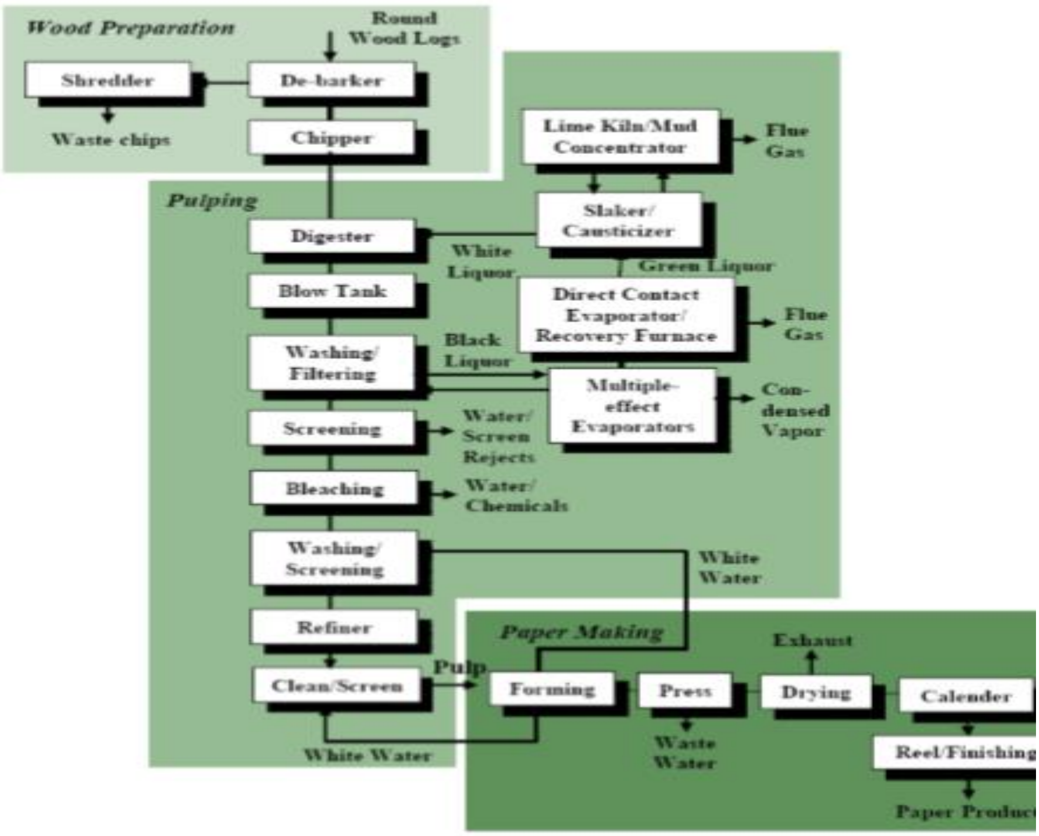



*Figure 2.3* flow diagram of the pulp and paper manufacturing process

### 2.4.1 Steps in the Pulp and Papermaking Process

**1.Raw Material Preparation**

Wood received at a pulp mill may be in several different forms, depending on the pulping process and the origin of the raw material. It may be received as bolts (short logs) of round wood with the bark still attached, as chips about the size of a half-dollar that may have been produced from sawmill or veneer mill waste or pre-chipped from debarked round wood elsewhere, or as waste sawdust in the case of some pulping processes. If round wood is used, it is first debarked, usually by tumbling in large steel drums where wash water may be applied. The debarked wood bolts are then chipped in a chipper if the pulping process calls for chemical digestion or are fed into a grinder in the case of some mechanical pulps. Chips are screened for size, cleaned, and temporarily stored for further processing. [9]

**2.Fiber Separation**

The fiber separation stage is the point at which the several pulping technologies diverge. In kraft chemical pulping, the chips are fed into a large pressure cooker (digester), into which is added the appropriate chemicals (white liquor). The chips are then cooked (digested) with steam at specific temperatures long enough to separate the fibers and partially dissolve the lignin and other extractives.

Some digesters operate continuously with a constant feed of chips (furnish) and liquor, others are charged intermittently and treat a batch at a time.[10]

**3.Bleaching or Brightening**

Since the raw pulp (brown stock) still contains an appreciable amount of lignin and other discoloration, it must be bleached to produce light colored or white papers preferred for many products. Bleaching is normally done in several stages (multistage bleaching). Through chlorination and oxidation, the fibers are further “delignified” by solubilizing additional lignin from the cellulose.

A number of bleaching agents may be used and are applied in a stepwise fashion within a bleaching sequence. These include chlorine gas, chlorine dioxide, sodium hypochlorite, hydrogen peroxide, and oxygen. Between bleaching treatments, a strong alkali (usually sodium hydroxide) is used to extract the dissolved lignin from the surface of the fibers. The bleaching agents and the sequence in which they are used depend on a number of factors, such as the relative cost of the bleaching chemicals, type and condition of the pulp, desired brightness of the paper to be produced, and sometimes in response to environmental guidelines and regulations.

Bleaching of mechanical pulp is much different than that for chemical pulp. Mechanical pulping leaves the lignin and the cellulose intact, whereas the purpose of chemical pulping is to chemically separate the lignin from the cellulose fibers and remove it from the pulp.[11]

## 2.5 Recycling of Waste Paper

Status of Paper Recycling Among various recycling activities, paper recycling, including copy paper, postcards, and envelopes made of recycled pulp, is very popular. Some people were involved in paper recycling activities even before they started to attract attention.

Sources which are known as secondary fibers are also important in paper production in addition to wood, cotton, milk, jute, hay, cane and cannabis. Even though paper that is produced from a main row material has superior qualities; because these sources are limited especially in our country, forestation takes a long time, natural resources need to be preserved, and energy costs are increasing; waste paper or secondary fiber becomes attractive.

Recycling is to use waste paper products in the production of paper as raw material. Therefore, environmental pollution and deforestation can be prevented. To produce paper, waste paper can be mixed with other raw material or with the new technology; solely waste paper can be used to produce new paper. Secondary fibers which are extracted from waste paper are now vital due to the increasing demand, limited forest resources and environmental pressures. Modern paper industry procures raw material largely from waste paper.

Several studies state that the importance of recovery of waste paper is explained from the perceptive of environment, forestry, energy saving, raw material resources and chemical material saving. Additionally, waste paper collection rate is about 30% and because waste paper is not dissolved in its source, it creates problems about quality and environment. Modern paper industry procures raw material largely from waste paper. Recycling of waste paper is one of the best options for sustainable development and zero waste targets. Because waste paper recycling supplies significant contributions to the sustainability of forestry resources, to energy saving efforts, to reduction of environmental pollution levels and to effective utilization of raw materials. [12]

### 2.6 Production process of recycle fibers

Operation steps in recycling of paper products in different qualities can vary according to the means of the facility and desired paper class.

#### 2.6.1. Sorting and feeding system

The worldwide recycling degree has increased and that the recycling systems for paper, plastics, metal etc. have developed a lot though the years. There are in spite of this a lot of contaminants / not wanted substances still remaining in the different recycled paper assortments. Therefore, there is a need for further sorting of the recycled paper coming especially from the household collection. This is normally done manually, but full or half automatic sorting procedures have lately been developed in Sweden (IL Retur) and in Germany (Trienekens). The recycled paper bales and loose paper arriving to the recycled paper plants still contains contaminants in the form of metal wire, staples, plastics, glass etc. Bigger contaminants are extracted by means of shredding of the paper and magnetic metal traps.

### 2.6.2 Pulping

Pulp consists of fibres, usually acquired from wood. The pulping processes aim first and foremost to liberate the fibres from the wood matrix. In principal, this can be achieved in two ways, either mechanically or chemically. Mechanical methods demand a lot of electric power, but on the other hand they make use of practically the whole wood material, i.e. the yield of the process is high. In chemical pulping, only approximately half of the wood becomes pulp, the other half is dissolved. In a modern chemical pulp mill, however, there is no demand of external energy. For a chemical process to be economically feasible, it has to consist of an efficient recovery system.

Recycled paper coming from the sorting system is slushed in conventional high or low consistency pulper, or in a pulping drum. The two main purposes with this unit operation are to dissolve the paper to separate fibres and to separate print inks and paper coatings from the paper surface.

There are two basic pulping categories batch and continuous pulping. Batch pulping, the feed recovered paper, water and chemicals are all charged at the beginning of the process and are removed all at once at the end of the process. The batch process is repeated. Continuous pulping, the feed recovered paper, water and chemicals are continuously added to the pulper and at the same time the pulped product is also being continuously removed.

- ❖ In this project use batch pulping categories process the feed are charged at the beginning of the process and discharged the output at once at the end of process.

**Hydro pulper**

- ❖ Hydro pulper used to convert recovered paper into slurry of well separated fibers and other waste paper components. It is basically a large cylindrical tank (varying in diameter between 1 to 6 m with an average depth of 6 m), open at the top and having a bowl-shaped bottom with blades fixed on the side. At the bottom of the bowl is the Vokes rotor, a large propeller carrying another set of rotable blades. The waste paper, chemicals and water added to the pulp tub. There is the rotors drum, spinning device for agitation, mechanical energy input to the system and Baffles protrusions to assist in mixing and prevent swirling. In the pulper waste paper and water is added together simultaneously and the pumpers digest the waste paper by way of the rotating propeller. Fibers swell, loosening the ink and then begin to separate and slurry of well separated fibers is discharged through the pulper exit. [13]

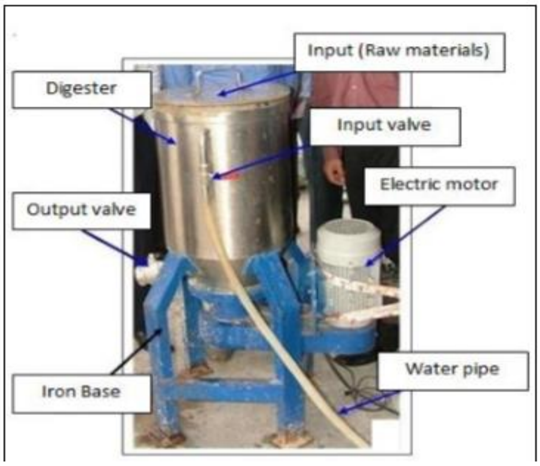



Figure 2.4 Hydro pulper

#### 2.6.2.1 Techniques of pulping

- **Chemical Pulping**

Chemical (i.e. Kraft, soda, and sulfite) pulping involves "cooking" of raw materials (e.g. wood chips) using aqueous chemical solutions and elevated temperature and pressure to extract pulp fibers. In Kraft pulping, white liquor, a water solution of sodium sulphide (Na2S) and sodium hydroxide (NaOH), is used under high temperature and pressure to chemically dissolve the lignin that binds the cellulose fibres of the wood together while the similar soda process uses only NaOH. This cooking liquor is mixed with the wood chips in a reaction vessel (digester). After the wood chips have been "cooked," the contents of the digester are discharged under pressure into a blow tank. As the mass of softened, cooked chips impacts on the tangential entry of the blow tank, the chips disintegrate into fibers or "pulp." The pulp and spent cooking liquor are subsequently separated in a series of brown stock washers. Kraft pulping is by far the most common pulping process used by all over the world for virgin fiber, accounting more than 80 percent of total pulp production.

Table2.2 summary of commonly used chemical pulping methods

| Chemical pulping methods | Chemical used | Common uses of isolated pulp |
|---|---|---|
| Sulphite | Sodium sulphite | Used in making paper for special purposes |
| Kraft /sulphate | Combination of sodium hydroxide and sodium sulphide | Making boxes, paper bags and warping paper. Can also be used for writing paper and paperboard. |

- **Process of pulp derived from wastepaper**

The Law on Promoting Green Purchasing will come into effect on April 1, 2001 to further improve the social foundation for the use of recycled paper. The paper industry, which had set a target to achieve a wastepaper utilization rate of 56 percent for 2000, achieved the target almost one year earlier. The industry has started a new scheme to achieve utilization rate of 60 percent by 2005 in order to further improve the wastepaper utilization rate. The processes of pulp derived from wastepaper can be divided roughly into four parts: (1) defiberization, (2) dirt removal, (3) deinking, and (4) bleaching. paper manufacturing requires (1) through (4) to satisfy quality requirements.[14]

### 2.6.3. Pulp screening

Apart from fibers, the cooked pulp also contains partially uncooked fiber bundles and knots. Modern cooking processes (together with good chip screening to achieve consistent chip thickness) have good control over the delignification and produce less "rejects". Knots and shaves are removed by passing the pulp over pulp screens equipped with fine holes or slots. The focus of the design of the screening operation in recycled fiber pulp production lines is to minimize the amount of detrimental substance / contaminants as; plastics synthetic, widely used polymers as catalogue backs, coatings, glues and other adhesives, metal clips and wet strength packaging papers can also be rejected. In order to succeed with rejecting heavy particles, the coarse screens not just only contain rotors and hole screen baskets but also a cyclone function separating the heavy reject from the light reject. In advanced recycled fiber and deinking systems coarse screening, prescreening and fine screening is included to insure clean enough pulp for papermaking.[15]

### 2.6.4. Pulp deinking

The process of de-inking is just as it sounds the removal of ink from a pulp slurry. Ink toners, as well as other hydrophobic substances, are removed from the pulp slurry and ultimately the finished paper product by the process demonstrated in this activity. Since the pulp slurry is aqueous, air bubbles running through the solution attract hydrophobic substances in the mixture. The bubbles and hydrophobic molecules rise to the surface and foam out of the slurry. This process is aided by use of a chemical surfactant. A surfactant reduces the force of surface tension in water thus allowing the hydrophobic substances to be removed from the pulp. The chemical used as a surfactant in this work is regular dish soap, which also works as a foaming agent to carry the hydrophobic substances away from the pulp.

The thin Stock still contains the ink which is chemically separate from the paper fibers in the pulper. Further the pulp is sent for deinking process that involves putting the pulp in a floatation washing device made up of chemicals and air bubbles that takes away any form of dyes or ink to enhance purity and whiteness. Deinking is therefore a way of improving the quality of printed waste. [9]

**Flotation Cell**

The pre-screened pulp fiber and liquid is pumped through a series of flotation cells in which, dyes, soap and fatty acids are added in the machine chest to react with the Calcium in the aqueous mixture. The reaction creates a surface “scum”. Then air is introduced into the mixture (at the bottom of the cell) to promote the formulation of bubbles to which the ink particulates become attached as the bubbles rise and expand. The scum turns into a black froth is skim or overflows from the top of the cells. During the above process the individual fibers is dispersed to aid removal of the ink particles. The flotation cell is capable of removing ink particles from 5-500 microns (0.0002" to 0.020").

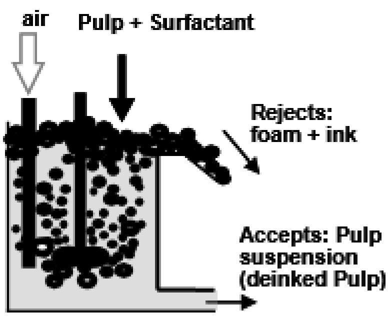



Figure 2.5 A simple flotation cell for recycling paper

**Wash Cells**

This is similar to the above process however the pulp is dispersed and washed without the aid of air and collected mechanically from the wash bath. Now this pulp can be used to generate white paper or can be colored to a single colored paper. This where visited as decolorized to make it in a single color. Certain chemicals added to make the color of the pulp white. After that a dye of certain color is added so as to obtain a paper of specific color. From now the pulp of desired color is ready to convert into paper. After that Secondary screening is used, a second series of Hydro cyclones and Pressure Screens employed to remove more of the smaller contaminants. The particulates removed are much smaller and therefore the screens have slots typically sized 0.003"(0.08mm) to 0.018" (0.45mm) wide. After it is completely cleaned, it is injected into a forming machine to create a sheet of paper.[16]

#### 2.6.5. Bleaching

Bleaching is the treatment of cellulosic fiber with chemicals to increase brightness. Brightness may be achieved by either lignin removal (delignification) or lignin decolorization. Lignin remains a major constituent of pulp even after digestion by chemical pulping. For example, Kraft pulp may contain up to 6% lignin based on its dry weight. Unbleached ground wood spruce pulp may contain 27% lignin. Bleaching of high-yield chemical pulps is achieved by decolorizing with either an oxidizing agent (combines oxygen) or a reducing agent (combines hydrogen). Chlorine gas, sodium hypochlorite, chlorine dioxide, oxygen gas, and hydrogen peroxide are oxidants. Sodium hydrosulfite is a reductant. Alkali is used to remove the solubilized lignin from the cellulose.[1]

## 2.7. Process condition that affect Kraft Pulping

### 2.7.1. Effects of Sodium Hydroxide Concentration

The increase in concentration of caustic soda improves the delignification and provides better quality pulp with lower lignin content. Pulp yield decreases with increase of caustic soda concentration in liquor due to increase of delignification and solubilization of hemicelluloses in caustic soda. But the quality of pulp obtained at higher pulp yield is not suitable for further processing in paper industry due to high kappa number and residual lignin in pulp.

### 2.7.2. Effects of Temperature

The increase of temperature of reaction from 60 $^{0}$C to 190$^{0}$C has shown the decrease of Klason lignin percentage by slightly more than 50%. This is again supported by decrease of kappa number of pulp from nearly 65 to 26. The constituents of raw material get degraded in reaction; the overall yield decreases significantly During pulping both lignin and cellulose are dissolved at different rates. This rate is much accelerated by increasing the temperature. There was a general decrease in the pulp yield and Kappa number due to increases in the pulping time at constant temperature.[17]

### 2.8 Pulp Characterization

By testing the properties of a pulp it is characterized and evaluated in comparison to other pulps. In the pulp mill, routine tests are performed for process control purposes as well as to characterize the product quality for the customer. The main purpose of this pulp characterization is to ensure a stable pulp quality. Pulp characterization is also a tool for improving existing and developing new products. However, it is not possible to take results from the pulp characterization to predict the properties of a paper made on a specific paper machine. To facilitate the communication between researchers, producers and customers, standard test procedures have been issued by the pulp and paper industry. Standardized tests make it possible to compare results in one laboratory to results from other laboratories. Industries within a geographical area have formed associations for the standardization of tests.

- SCAN, Scandinavian Pulp, Paper, and Board Testing committee (Finland, Norway and Sweden)
- TAPPI, Technical Association of the Pulp and Paper Industry, USA
- CPPA-TS, Canadian Pulp and Paper Association, Technical Section
- APPITA, Australian Pulp and Paper Industry Technical Association

The standards set up by ISO, the International Standardization Organization, are used in connection with international trade and are officially recognized around the world. As ISO standards get available the corresponding SCAN methods will be withdrawn and replaced by the ISO standards.[18]

#### 2.8.1 Fiber level properties

- **Fiber strength**

The strengths of individual fibers have an influence on the strength of the paper web they form. Additionally, the paper strength is also dependent on the bonds between fibers. Most strength properties, such as tensile and tear strength, are influenced of both the fiber and bonding. The strength of individual fibers can be estimated by the zero-span tensile strength test. The denomination zero-span derives from the distance between the clamps fastening the strip of paper to be tested. The two clamps grip the paper strip as close to each other as possible, in practice the distance between the clamps is zero. The idea behind the test is that fibers thus are fastened and pulled in both their ends and each fiber fastened by the two clamps will be broken. The force needed for rupture is recorded and defined as fiber strength, given in Nm/g. However, it is not possible to accomplish absolute zero distance between the clamps. A residual span will always exist; however small it may be. Because of this, only straight, undeformed fibers will add to the zero-span fiber strength. Ideally, the zero-span test would only give the strength of the individual fibers and not the strength of the bonds between fibers. In dry sheets, however, deformed zones in the fiber may be over-bridged by bonds or a fiber, only clamped in one of its ends, may form a bridge to other fibers and thus be activated in the breakage. Zero-span testing may therefore also be performed on re-wetted sheets. The re-wetting reduces the influence of bonds between fibers and fewer fibers will participate in the process of fracture. [13]

### 2.8.2 Properties on molecular level

- **Carbohydrate content**

Pulp strength can be related to the amount of cellulose as well as the ratio between the amounts of cellulose and hemicelluloses. In general, more cellulose gives a stronger pulp and lower cellulose/hemicellulose ratio reduces pulp strength. The hemicelluloses make the pulp easier to beat and increased content of xylem contributes to the bonding ability between fibers. The amount and distribution of cellulose and the various hemicelluloses is therefore of interest. The most frequently used analysis of the carbohydrates is through acid hydrolysis. By treating the pulp with sulphuric acid of 72 %, the carbohydrate chains are degraded to the monomers they are made of. Cellulose ends up as glucose and the hemicelluloses as glucose, xylose, mannose, arabinose etc. depending on the hemicellulose in question.

- **Cellulose**

Cellulose is the most common polysaccharide in nature and consists of repeating units of **cellobiose**, two glucose anhydride units (Figure 2.6). It is the principal component of plant fibers and the largest naturally occurring homo polymer. It is a glucan polymer consisting of D-glucopyranose where the glucose units rotated 1800 to each other and linked together by β-(1,4) glycosidic bonds which gives the linear structure. The number of glucose units in a cellulose molecule (i.e. the degree of polymerization) reaches 9,000–10,000 in plant and possibly as high as 15,000 in cotton. The glucose units in cellulose molecules aggregate each other with hydrogen bonding and form micro-fibrils, which are the building blocks of fibrils, and in turn build the cellulose fiber. Hydrogen bonding between the cellulose molecules results in high strength of the cellulose fibers.

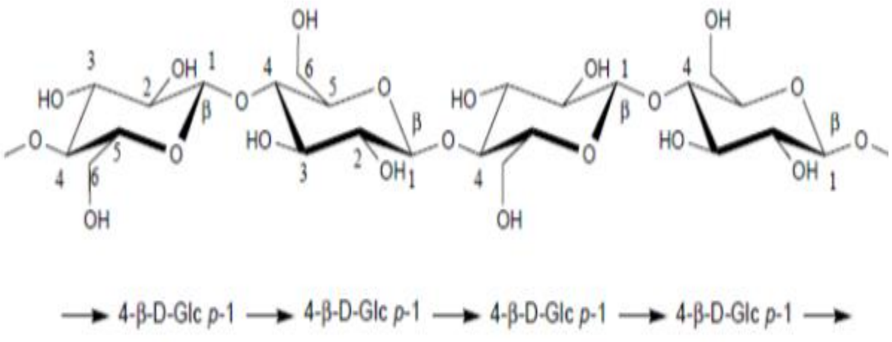



Figure 2.6Structure of cellulose

The cellulose content can be correlated with the yields of unbleached pulps. The alpha or true cellulose content of a fibrous material does not affect directly its pulp ability, but the higher the alpha-cellulose content of a material, the higher the yield of fully delignified, bleached chemical and semi chemical pulps.[19]

- **Hemicellulose**

The hemicelluloses are usually defined as the polysaccharide part of plant tissue, which is accessible to the action of dilute acids and alkalis. They are chemically complex and comprise a mixture of sugar monomers. For instance, besides glucose, sugar monomers in hemicellulose also including arabinose, galactose, mannose, and xylose, etc. Hemicelluloses exhibit lower molecular weights with little strength than cellulose. In the case of pulps free from lignin by adequate and controlled bleaching, the hemicelluloses have been shown repeatedly to contribute greatly to tensile and bursting strength and to folding endurance of the pulp sheet. Both the quantity and the type of hemicelluloses in a pulp influence the pulp properties and the type of paper that can be made from such a pulp.

When extractives (compounds which are soluble in cold water or in neutral organic solvents) and lignin are removed from wood, it yields a fibrous product termed holocellulose, which represents the sum total of cellulose and other polysaccharides. The later one is usually termed as hemicelluloses (polyoses). Hemicelluloses, highly branched heterogeneous polysaccharides, are the second most abundant natural polysaccharide after cellulose. [20]

- **Lignin**

The other most abundant and important polymeric organic substance in the plant world is lignin. In the tree it provides stiffness to the wood fibers and binds them together. This macromolecule plays a vital role in providing mechanical support to bind plant fibers together.

Lignin is an amorphous hetero-polymer, built up from phenyl propane units linked together by ether and carbon–carbon bonds including coniferyl alcohol, sinapyl alcohol, and p-coumaryl alcohol. The respective aromatic constituents of these alcohols in the lignin polymer are called guaiacyl (G), syringe (S), and p-hydroxyphenyl (H) (Figure 2.7).

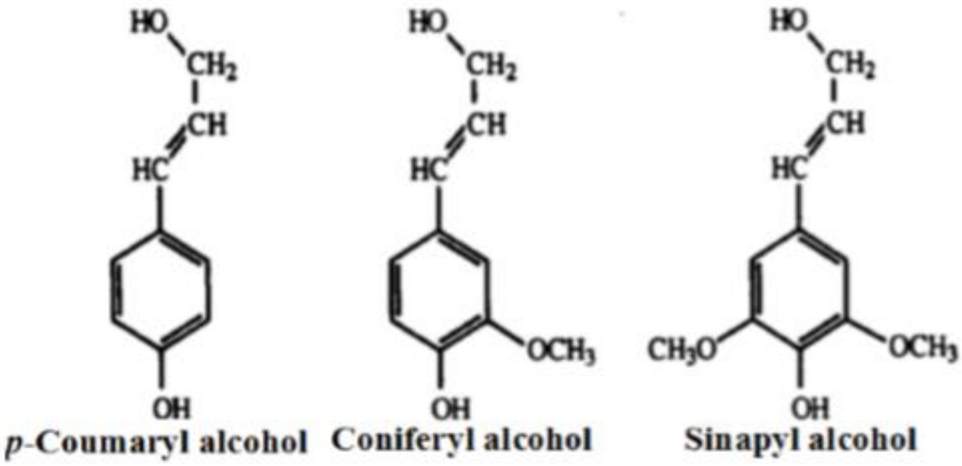



Figure 2.7 Lignin building blocks[21]

The lignin content of hardwoods is usually in the range of 18–25 %, whereas the lignin content of softwoods varies between 25 - 35 %. Herbaceous biomass usually has a lower lignin content (10-25%) compared to woody biomass.

Table 2.3 chemical constitutes of pulp and paper fiber sources (%)*[11]*

| Lignocellulose materials | Cellulose(%) | Hemi cellulose(%) | Lignin (%) |
|---|---|---|---|
| Hard wood | 40-55 | 24-40 | 18-25 |
| Soft wood | 45-50 | 25-35 | 25-35 |
| Cotton seed hairs | 80-95 | 5-20 | 0 |
| Newspaper | 40-55 | 25-40 | 18-30 |
| White paper | 85-99 | 0 | 0-15 |

## 2.8.3 Physical Properties of Paper

1. **Tensile strength**

The tensile strength is the greatest longitudinal stress a substance can take without breaking. Paper is often subjected to tensile forces, both in the manufacturing process and in product applications. Tensile strength is one of the basic strength properties tested on pulp and paper. Tensile strength is tested by fastening a strip of paper (15 × 100 mm) between two clamps and pulling the paper apart. In the process, the paper strip is extended until it no longer can bear the load and it breaks. The force applied vs. stretch of the paper sample is recorded.

The tensile forces applied extend bonds between and within the fiber as well as the fibers themselves. In the rupture zone of the paper strip, some fibers are broken and others are pulled out from the network breaking bonds in the action. Tensile strength is dependent on both the bonding strength in the sheet and the strength of individual fibers.

2. **Basis Weight or Grammage**

The basis weight, substance or Grammage is obviously most fundamental property of paper and paperboard. The Basis weight of paper is the weight per unit area. This can be expressed as the weight in grams per square meter (GSM or $g/m^2$), pounds per 1000 sq. ft. or weight in Kgs or pounds per ream (500 sheets) of a specific size. Paper is sold by weight but the buyer is interested in area of paper. The basis weight is what determines, how much area the buyer gets for a given weight. Paper maker always strive to get all desired properties of paper with minimum possible basis weight.

The area of several sheets of the paper or paperboard is determined from linear measurements and the mass (commonly called “weight”) is determined by weighing. The Grammage is

calculated from the ratio of the mass to the area after conversion to metric units when necessary. Grammage of up to 200gsm are considered to be papers and from 200gsm upwards they are referred to as paperboard or low quality board. Paper that is used in offices is usually between 70gsm and 80gsm, with 80gsm being the most commonly found weight. Some accountants and solicitors use heavier weight paper ranging from 90gsm to 120gsm for formal correspondence. Above 120gsm come various thicknesses of card with 160gsm and 200gsm being most commonly used for file dividers. Newspaper sheet ranges between 45gsm and 50gsm. All paper machines are designed to manufacture paper in a given basis weight range. Tighter the range, more efficient will be the machine operation. The standard procedure of measuring basis weight is laid out in TAPPI T 410, SCAN P6, and DIN53104 & ISO: BSENISO536.
Typical value**.**[22]

Table 2.4 Weight of different paper

| Paper type | **Grammage** |
|---|---|
| Newsprint | 40-50 |
| Cigarette tissue | 22-25 |
| Writing paper | 60-99 |
| Paperboard | 120-300 |

**3. Tearing strength**

The tear strength is the energy needed to extend a crack in the paper. By measuring the tear strength of paper, information is obtained of its ability to withstand cracks. Tearing resistance or strengths is a measure of how well a material can withstand the effects of tearing. More specifically it is how well a paper resists or withstands the growth of any cuts when under tension. Tearing resistance indicates the behavior of paper in various end use situations; such as evaluating web run ability, controlling the quality of newsprint and characterizing the toughness of packaging papers where the ability to absorb shocks is essential. Fiber length and inter-fiber bonding are both important factors in tearing strength. The most commonly used tearing test is T-414, which is often called the Elmendorf tear test, and measures the internal tearing resistance of paper rather than the edge tear strength of paper, which is described in T-470. Internal tearing resistance is a measure of the force perpendicular to the plane of the paper necessary to tear a single sheet through a specified distance after the tear has already been started. Edge tearing strength (T-470) is a measure of the force needed to initiate a tear.[23]

## 2.9 Environmental Aspect

### 2.9.1 Wastewater treatment process

Pulp and paper mills use a large amount of water as reaction media and washing water in the pulp and paper manufacturing processes. At the chemical pulp manufacturing process and the mechanical pulp manufacturing process, organic waste liquor containing lignin and other polysaccharides, which are principal constituents of wood, is generated. The process of pulp derived from wastepaper generates waste liquor containing fines, ink, and filler (powdery mineral matter blended to give opacity to paper). Pollutants contaminating the liquor are processed to satisfy laws and regulations and released to bodies of water. The main wastewater treatment processes are pH adjustment using acid or alkali, removal of SS (suspended solids) using clarifiers, and decrease in BOD and COD by means of biological treatment and coagulative precipitation (flotation). The actual wastewater treatment is a combination of them. [24]

**(1) Neutralization process**

The waste liquor ranges from a low pH area to a high pH area depending on the treatment conditions at the source of release. Such waste liquor is adjusted to a pH suitable for activated sludge treatment (biological treatment) by adding acid or alkali.

**(2) Activated sludge treatment**

After the adjustment, waste liquor to be treated is sent to an aeration tank and air (oxygen) is blown in with aerobic bacteria (return sludge) to decompose and remove organic substances (BOD ingredients). In this process, volatile substances (e.g. chloroform) in the liquor to be treated are released to the air because air is blown into the aeration tank or a cooling tower which is used when the temperature of liquor to be treated is high.

**(3) Dehydration process**

Wastewater treatment sludge (paper sludge) that is naturally precipitated in the clarifier are pulled out as solid content at a concentration of about 3 percent, sent to a dehydrator, and dewatered to 40 - 60 percent in the solid content. Some of the dewatered products are effectively used as soil conditioner.[25]

# CHAPTER THREE

# 3. MATERIALS AND METHODS

## 3.1 Materials, Equipment's and Chemicals

Table 3.1 The materials used and their uses

| Material | Their purpose |
| --- | --- |
| Water | To removes weak black liquor from the pulp which is sent to the chemical recovery process. |
| Waste paper | It is a source of fiber |

Table 3.2 The equipment used and their uses

| Equipment | Their purpose |
| --- | --- |
| Mixer | To dissolve the paper to separate fibers and to separate print inks and paper coatings from the paper surface. |
| Digital weighing balance | Used to measure the weight of the sample |
| Oven | Used to dry the sample |
| Measuring cylinder | Used to measure liquids during white liquor preparation |
| Heating mantle | Used for heating |
| **Scissor** | Used for size reduction |
| Cloth (abujede) | Used for pulp filtered through a number of screens to remove impurities and water |

Table 3.3 The chemical used and their uses

| Chemicals | Their purpose |
|---|---|
| Caustic soda (NaOH) | Extraction of lignin uses in pulp and which improves the swelling of the fibers |
| Hydrogen peroxide ($H_2O_2$) | Is used, as a bleaching agent |
| Fatty acid/soap | Are used as collectors or dispersant and frothing agent<br>To improve the detachment of ink from fiber |

## 3.2 raw material collection

Paper recycling generally, it involves the collecting of waste paper processing them into raw materials and making new products which is paperboard using these recycled raw materials. The waste paper sample used for this study was print paper($A_4$). The collecting of waste paper was hold on December, 2020 in wolkite university.

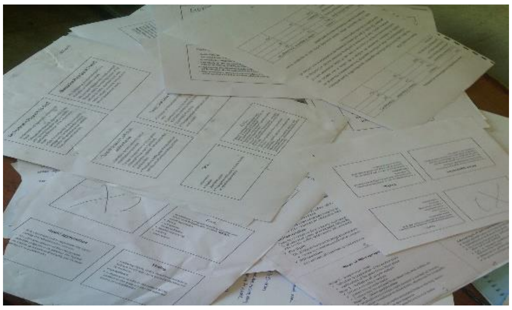


figure 3.1 Collected waste paper

## 3.3 Production Process step

After the waste paper was collected it prepared for experimental analysis.

1. 125g of waste paper was measured and soaked in 2500ml water.
2. 20% NaOH & 80% of water was prepared.
3. Then the prepared white liquor was poured in the mixer and mixed with the waste paper to form pulp.
4. The pulp was heated at $90^0$c for 60min
5. After heating the pulp was washed and cleaned by screener
6. The washed pulp was bleached by 200ml of hydrogen peroxide.
7. The bleached pulp was molded to the paper sheet.
8. The sheet was dried for 3 hours in sunlight.

9. The dried paper was measured.
10. This experiment was repeated one time for all of the above procedure without chemical (NaOH) in pulping process.

Table 3.4 pulping and bleaching condition of waste paper

| **Parameters** | **Pulping condition** | **Bleaching condition** |
|---|---|---|
| Concentration of NaOH(%) | 20 | |
| Cooking temperature ($^0$C) | 90 | 70 |
| Cooking time (min) | 60 | 60 |
| $H_2O_2$(%) | | 10 |

- The major production process used in paper production from wastepaper was passed in the following steps; these are:

**1. Shredding**

The process of break down the waste paper in to the small bits by using this method it become very easy to convert waste paper in to paper pulp. In this project 250 g waste paper sample was measured and cut into pieces using Scissor.

Figure 3.2 Shareded waste paper

**2. Pulping process**

In this step the shredded paper was subjected to large amount of water and mixed with chemical (white liquor: NaOH) and without chemical added in to mixer then the mixture was heated to break the paper down more quickly in to paper fibers finally the mixture turns in to a mushy mix, known as pulp.

 a  b

Figure 3.3 a) Pulp slurry without chemical and b)with chemical NaOH

**3. Deinking process**

Deinking is one way to remove the coloring matter or to clean stained raw materials. The pulp enters in to washing device. Soapy chemicals are added to help the ink separate from the pulp. As surfactant use in this lab was soap, which also works as a foaming agent to carry the hydrophobic substances away from the pulp.

 a  b

Figure 3.4 Washing(a) and b) after washing of pulp

**4. Bleaching process**

In order to further improve the quality of deinked wastepaper, a bleaching process was applied to increase brightness by adding bleaching chemicals 10%hydrogen peroxide.

 a  b

Figure 3.5 pulp after bleaching with chemical ( a) and (b) without chemical

**5. Molding of sheets and pressing**

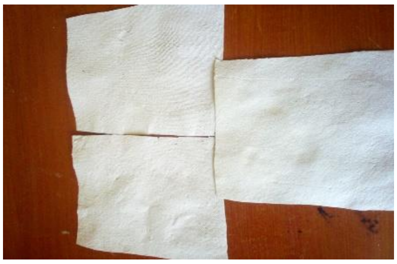
A piece of white cloth that has sufficient size to cover the entire outer surface of the molding frame was taken. Place a neat &wrinkle free cloth over the mesh (that now has the pulp) in such a way that no gaps, folding or water bubbles occurred in the pulp formed on the cloth. For each sheet of pulp use different layers of cloths and placed it one over the other. Once the sheets formed on the cloth or stacked together pressing by hydraulic presser to remove the water.

 a  b  c

Figure 3.6 pulp molding(a) pressing of wet sheet (b) and (c) after pressing

**6. Drying**

The sheet was dried in the `oven until the water completely removed. the sheet was dried in sun light for 3hr.

(a) (b)

Figure 3.7 dried paperboard sheet with chemical(a) and (b) without chemical

### 3.3.2 The overall Production process of paper from wastepaper

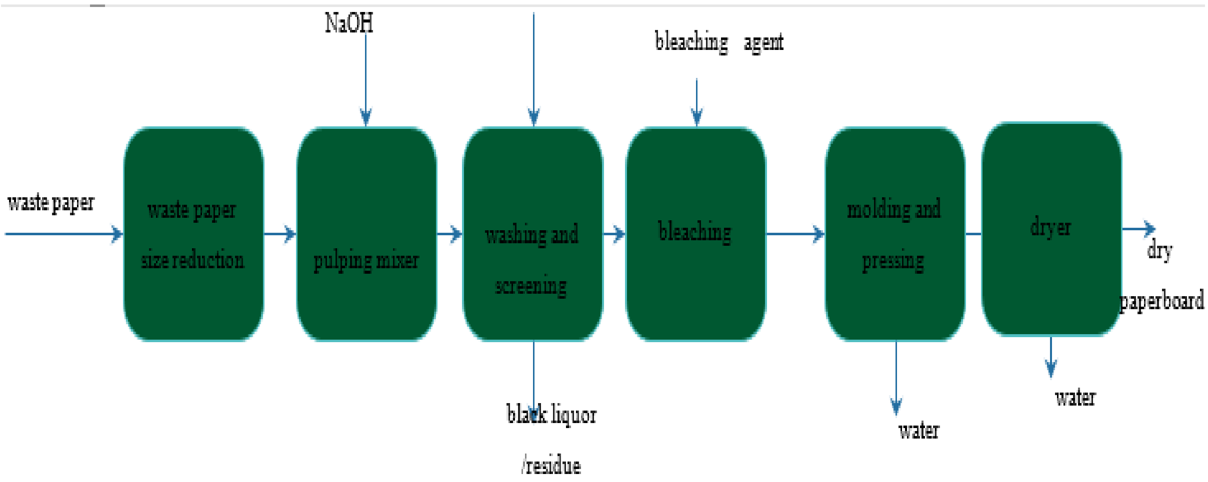



Figure 3.8 The overall Production process of paper from wastepaper

## 3.5 Data Analysis

- **Pulp Yield Determination**

Pulp yield due to recycling. pulp yield expressed as percentage of the oven dry pulp and will determined by the method as per Tappi standards.

Yield of the pulp from each experiment was calculated as:

$$\% \text{ yield of pulp} = \frac{weight\ of\ \ dried\ repulp}{Weight\ of\ waste\ paper\ before\ pulping} * 100 \ldots\ldots\ldots\ldots eq_1$$

### 3.5.1 Physical properties Analysis

- **Moisture Content**

The moisture content is defined as the ratio of the loss of mass of a test piece when dried by a standard method, to its mass at the time of sampling. The result is normally expressed as a percentage Most physical properties of paper undergo change as a result of variations in moisture content. Moisture in paper varies from 2 -12% depending on relative humidity, type of pulp used and chemical used.

**Test Methods**

1. The most common method is to weigh a sample, place in a weighed, unsealed air-tight container, dry in an oven for a set period at 105 ± 2°C, cool in a desiccator, seal and reweigh the container.

$RH=\frac{MPo-MPi}{MPo} * 100$……………………………….eq2

Where, RH is relative humidity

MPi is weight of paper after drying

MPo is weight of paper before drying

### 3.5.2. Pulp hand Sheet Characterization

- **Weight of the Paperboard**

The basis weight of paper is the weight per unit area. This can be expressed as the weight in grams per square meter (GSM).[7]

$GSM=\frac{M}{A}$ ………………………………………..eq3

Test Method: The test method is described in Indian Standard 1060-Part-I Cut the test specimen of size 17cm x 17cm and then take the weight in weighing balance. At least, ten readings are taken and then take the average value and expressed in gm/square meter.
Where, GSM is the weight in gram per square meter;

M is the mass of paper in gram;

A is area of the paper in meter square

### 3.5.3. Tearing Properties

- **Tearing Resistance of the Paperboard**

Tear strength is a measure of how well a material can withstand the effects of tearing. More specifically however it is how well a material resists the growth of any cuts when under tension. To measure the tear strength, the sample is held between two holders and a uniform pulling forces applied until the aforementioned deformation occurs. Tear resistance is then calculated by dividing the force applied by the thickness of the material**.** Materials with low tear resistance tend to have poor resistance to abrasion and when damaged will quickly fail. The tearing resistance is the force required to continue the tearing of an initial cut in a single sheet of paper.[7]

- **Tensile strength**

The tensile strength of paper assesses the suitability of a product to withstand strain in end use.

In pulp evaluation the tensile test can assess the degree of refining a pulp requires to reach a certain strength level.

**Procedure:**

From specimens of undamaged paper 15 mm wide and 230 mm long test pieces were cut. The test piece was placed in the clamps making sure that any slack is eliminated. Any touch of the test area between the clamps with the fingers was avoided.

Calculation: Tensile strength

$$X1 = \frac{a}{b}$$

Where: -

X1 = tensile strength (kN/m)

a = maximum tensile force (N), instrument reading = kg, to change into (N) (34∗9.807)

b = initial width of the sample in (mm)[7]

# CHAPTER FOUR

# 4.RESULTS AND DISCUSSION

## 4.1 Pulping Results

**Pulp Yield**

The percentage yield was calculated by using equation 3.1. The amount of pulp produced from waste paper recycling was provided in the table below. The experiments were done two time first with chemical and then without chemical the result was given as percent.

*Table 4.1 pulp yield*

| Experiment | Temperature($^0$c) | Time(min) | Pulp Yield% |
|---|---|---|---|
| Pulp with 20%NaOH | 90 | 60 | 62 |
| Pulp without chemical | 90 | 60 | 74 |

The pulp yields obtained by 20% of NaOH concentration was low due to degradation of lignin and provides better quality pulp with lower lignin content. The highest pulp yield was obtained at 0% of NaOH concentration or pulp without chemical at this pulping condition the highest portion of the pulp was un delignified. With regard pulp yield was significantly influenced by alkali concentration.

Percentage pulp yield for pulping process with use of chemical caustic soda concentration in liquor was lower than pulping process without chemical due to increase of delignification and solubilization of hemicelluloses in caustic soda but the quality of pulp obtained at high.

## 4.2 paper board sheet property

**1. Weight of the paperboard**

The weight of paper board was calculated by using equation 3. The first experiment was done at temperature 90$^0$c, 20% of NaOH and 60min the weight of paper board was and other experiment was done at constant temperature and time the pulp without chemical weight of sheet was544 the result is summarized in table 4.3 below.

*Table 4.2 weight of the paperboard*

| Experiment | Temperature($^0$c) | Time(min) | Weight of paper (g/m$^2$) |
|---|---|---|---|
| Pulp with 20%NaOH | 90 | 35 | 256 |
| Pulp without chemical | 90 | 60 | 216 |

To observe the above result Concentration of sodium hydroxide plays a great role on the mass of paper. As the pulping condition with concentration of NaOH more lignin was removed whereas, when the pulping condition without chemical becomes small amount of lignin was removed and at this high temperature required to remove lignin. The maximum paperboard production was gained at 20% of sodium hydroxide concentration and 90$^0$c temperature. That means at 20% sodium hydroxide and 90$^0$c temperature more lignin removed.

**2. Moisture content of the paper**

The moisture of paper board sheet was calculated by using equation 3.2

RH=$\frac{MPo-MPi}{MPo} * 100$……………………………eq2

Where, RH is relative humidity

MPi is weight of paper after drying

MPo is weight of paper before drying

*Table 4.3 Moisture content of the paper*

| Experiment | Temperature($^0$c) | Time(min) | Moisture content (%) |
|---|---|---|---|
| Pulp with 20%NaOH | 90 | 35 | 19 |
| Pulp without chemical | 90 | 60 | 16 |

To compare moisture content of the two condition pulping with NaOH was high moisture content than pulping without chemical due to the effect of weight of paperboard. From table4.2 result of Weight of paperboard pulp with NaOH was high as a result the moisture content also high.

## 3. Strength of the paper

Here, we are not able provide and explain briefly about strength of the paper since inaccessibility of the equipment used. But strength of paper check by hand pulp with NaOH was more strength.

# CHAPTER FIVE
# 5. MATERIAL AND ENERGY BALANCE

## 5.1 Material Balance

Material balances are the basis of process design. A material balance taken over complete process was determining the quantities of raw materials required and products produced.

1.The process plant was operating 24 hours per day.

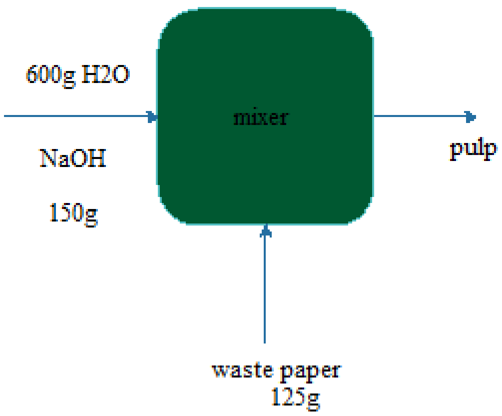
2. The process takes place at steady state

3.The total working days per year=310days/yr; 310days/ year *24hr/ day =7440hr/year

4.Assume mass of waste paper use per day is 400kg/day

**Material balance on Components**:

a) **Material balance on mixer**




**General mass balance**

Accumulation = In - Out + Generation -Consumption

In put = Out put

Hence, 125g of waste paper = 750g white liquor

400 kg/day = X(?)

X = 2400 kg/day of white liquor

Mass of the NaOH = 0.2*2400kg/day = 480kg/day

Mass of water = 0.8*2400kg/day = 1,920 kg/day

Mass of white liquor = 480kg/day+1,920 kg/day

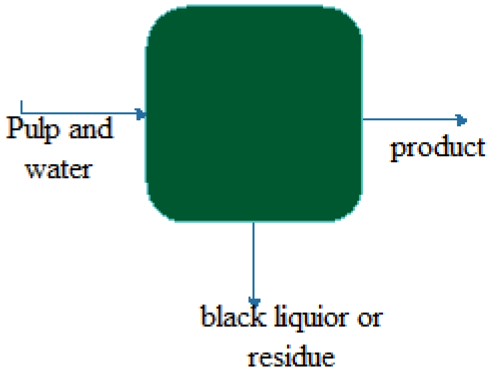
= 2400 kg/day

Mass of waste paper daily = 400 kg/day

Therefore, from general mass balance

Mass of the pulp slurry = 400 kg/day +2400 kg/day = 2,800 kg/day

**B) Material balance on Cleaning and washing**




Input = Out put

Pulp and water($P_1$) = Product($P_2$) + residue

From the mixer 1500g of $P_1$ Pass through the screen gain 500g of pulp gained

Therefore, 1500g produce =500g

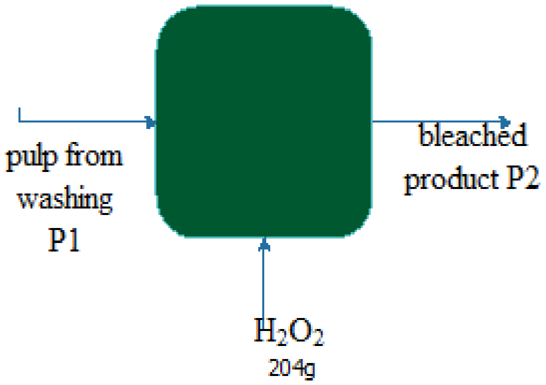
2,800 kg/day = X (?)

X = 933.33kg/day pulp

Mass of product (P2) = 2800 kg/day –933.33kg/day

= 1866.6 kg /day residue

### 3. Material balance On bleaching




In put= out put

$P_1$+204g = $P_2$

500g+204g = $P_2$; $P_2$= 704g

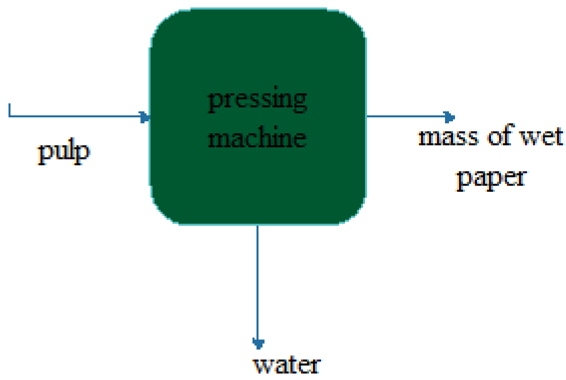
Then, 500g of $P_2$ = 204g of required bleaching powder

933.33kg/day pulp = X (?)

X = 380.78 kg/day is bleaching powder required

933.33 kg/day + 380.78kg/day = 1314 kg/day

### Material balance on pressing machine




Mass of wet paper +Water = pulp;

350g +water =704g

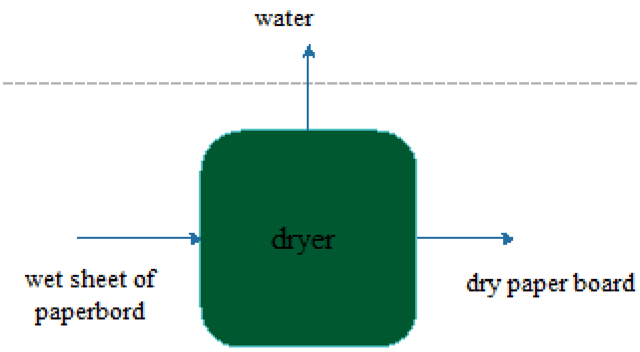
704g of pulp = 354g of water

1314 kg/day = X (?)

X = 660.9 kg /day of water

Mass of wet paper = 1314 kg/day – 660.9 kg/day = 653kg/day

**4. Material balance On dryer**




Input = output

Wet sheet of paperboard =water + dry paper board

At the laboratory 350g of the wet paper dried to 105g

350=water+120g

Water=245g

At the laboratory 350g of the wet paper dried to 120g

653kg/day = X

X = 224 kg/day dried

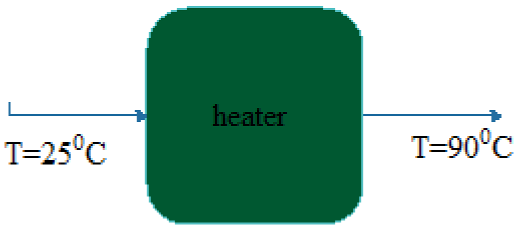
*Table 5.1*summary of material balance

| Unite operation | Input | | Out put | |
|---|---|---|---|---|
| 1. Mixer | Component | Amount | 2,800 kg/day pulp | |
| | NaOH | 150g | | |
| | Water | 600g | | |
| | Waste paper | 125g | | |
| 2. washing | Pulp and water | 500kg/day | 1866.6 kg /day residue | |
| | | | 933.33kg/day pulp | |
| 3. bleaching | H2O2 | 204g | Bleached product | 1314kg/day |
| | Pulp from washing | 500g | | |
| 4. pressing machine | Pulp | 704g | Mass of wet paper | 350g |
| | | | Water | 354g |
| 5. dryer | Wet sheet of paper | 350g | Water | 245g |
| | | | Dry paper board | 224 kg/day dried |

## 5.2 Energy balance

## Energy balance on pulping

To calculate heat required for pulping




Mass of the pulp slurry = 2,800 kg/day

Specific heat capacity of water= 4.18KJ/Kg K

Specific heat capacity of paper = 1.2585KJ/Kg K

$To = 25^0c$ , $Tf = 90^0c$

The heat required for pulp cooking is

$Q = mc_p\Delta T$ ; $\Delta T=T_f-T_i$

$Q= 2{,}800$ kg/day*2.71925*kj/kg*k$(363.14-298.15)^0$K

Q= 20620.9 Kj/hr

# CHAPTER SIX

# 6. EQUIPMENT SIZING

**Assumption**

1.Safety factor 10% and the reactor is 75% full

2.From material balance mass and density of use raw material is given below table

Table 6.1 density and mass of raw material

| Raw material | Density(kg/$m^3$) | Mass (kg/day) |
|---|---|---|
| NaOH | 2130 | 480 |
| $H_2O_2$ | 1442.5 | 380.78 |
| Water | 1000 | 1,920 |
| Waste paper | 1201 | 400kg/day |
| Pulp | 190 | 933.33 |

**1.NaOH solution storage tank**

Assume NaOH solution is stored for one day.;

Mass = 480 kg/day*1day = 480kg

Volume = mass/density

Volume =(480kg)/(2130kg/$m^3$) = 0.226$m^3$

Volume =0.126 $m^3$ *1.1 = 0.24 $m^3$

**2.water storage tank**

Assume water is stored for 1day.

Mass of water = 1920kg/day*1day = 1920kg

Volume of water storage tank = mass of water /density of water;

Volume =1920kg /1000kg/m3= 1.92$m^3$

Volume = 1.92$m^3$*1.1 = 2.11$m^3$

**3.Sizing of mixer**

Assume mixing time is 1hr

Volume = mass /density

$$\text{Volume} = \frac{\frac{\text{MNaOH}}{\dot{\rho}\text{NaOH}} + \frac{\text{M water}}{\dot{\rho}\text{water}} + \text{Mwaste paper}/\dot{\rho}}{75\%}$$

$$\text{Volume} = \frac{\left(\left(\frac{480}{2130}\right) + \left(\frac{1920}{1000}\right) + \left(\frac{400}{1201}\right) * 1.1\right)}{0.75}$$

Volume = 0.33 $m^3$/day = 0.013$m^3$/hr*1hr=0.013 $m^3$

**4. Sizing on washing**

Volume = mass /density

$$\text{Volume} = \frac{\text{Mpulp }/\dot{\rho}\text{ pulp} + \text{M water }/\dot{\rho}\text{ water}}{75\%}$$

$$\text{Volume} = \frac{((933.33/190)\ \ + (1{,}920/1000)) * 1.1}{0.75}$$

Volume = 0.68$m^3$ /day

**5.sizing on bleaching**

Assume bleaching time 1hr

$$\text{Volume} = \frac{\frac{\text{Mpulp}}{\dot{\rho}\text{pulp}} + \frac{\text{MH2O2}}{\dot{\rho}}\text{H2O2}}{75\%}$$

$$\text{Volume} = \frac{(933.33/190) + (380.78\ /1442.5) * 1.1}{0.75}$$

Volume = 7.59$m^3$

**6. Sizing on presser**

Assume pressing time is 1hr

Volume = mass of pulp /density

Volume =(933.33/190)*1.1=5.4$m^3$

**6.Sizing on dryer**

Assume drying time is 2hr

Mean density = $\frac{\text{density of paper} + \text{density of water}}{2} = \frac{1201+000}{2}$= 2201kg/$m^3$

Volume = (mass/mean density) *1.1= (2320/2201) *1.1

Volume = 1.15$m^3$/day=0.048$m^3$/hr*2hr=0.09$m^3$

*Table 6.3*Summary of equipment sizing

| Equipment | volume ($m^3$) |
|---|---|
| NaOH solution storage tank | 0.24 |
| Water storage tank | 2.4 |
| Mixer or pulper | 0.013 |
| Washing tank | 0.68 |
| Bleaching tank | 7.59 |
| Presser | 5.4 |
| Dryer | 0.09 |

# CHAPTER SEVEN
# 7.COST ESTIMATION AND PROFITABILITY ANALYSIS

## 7.1 Estimation of total capital investment

Cost estimation is a specialized subject and a profession in its own right. Chemical plants are built to make a profit, and an estimate of the investment required and the cost of production is needed before the profitability of a project can be assessed. By considering this we try to estimate the plant economic analysis by calculating.

### 7.1.1 Purchase equipment cost estimation

Equipment specifications for paper production plant. Take the transportation costs is 20% of purchased cost.

*Table 7.1 Purchased cost of equipment [26]*

| Sr.no | Equipment list | Cost ETB | No.(set) |
|---|---|---|---|
| 1 | Raw material preparation tank | 1710 | 1 |
| 2 | Pulpier | 2445 | 1 |
| 3 | Dryer | 9000 | 1 |
| 6 | Pulp washer | 1260 | 1 |
| 7 | black liquor tank | 843 | 1 |
| 8 | Bleaching tank | 7500 | 1 |
| 10 | Sheet equipment machine | 2450 | 1 |
| TOTAL | | 25208 | 7 |

### 7.1.2. Total capital investment estimation

*Table7.1 Total capital investment estimation*

| Total direct cost (TDC) | | |
|---|---|---|
| **Item** | **%PEC** | **Estimated cost(ETB)** |
| Purchased equipment cost | 100 | 25208 |
| Purchased equipment Installation | 39 | 9831 |
| Instrumentation & control | 26 | 6554 |
| Piping installation | 31 | 7814 |
| Electrical installation | 10 | 2520 |
| Building | 29 | 7310 |
| Yard improvement | 12 | 3025 |
| Service facilities | 55 | 13864 |
| Total direct cost TDC | 302 | 76128 |
| Engineering and supervision | 32 | 8066 |
| Construction expenses | 34 | 8570 |
| Contractor fee | 4 | 1008 |
| Start up | 19 | 4789 |
| Contingencies | 37 | 9326 |
| Total indirect cost | 126 | 31762 |
| Fixed Capital Investment | 428 | 107890 |
| **Total Capital Investment** | **503** | **126796** |
| Working capital(WC)=15%TCI | 75 | 18906 |

### 7.1.3 Total production cost Estimation

Total production cost = Manufacturing cost + General expense

I**. Manufacturing cost** = direct production cost + fixed charge + plant overhead cost

**A. Direct production cost:**( about 60% of total production cost)

Let, the total product cost be 'X'

**1.Raw materials:** (10-50% of total production cost) and consider the cost of raw materials = 30% of total production cost

Raw material cost = 0.30*X

**2.Operating labor (OL):**(10-20%of total production cost) and consider the cost of OL=15% of total production cost.

OL=0.15*X

**3.Direct supervisory and clerical labor (DS &CL):** (10-25% of OL) and consider the cost for DS &CL =15% of OL

DS &CL =0.15*0.15*X=0.0225*X

**4.Utilities**:(10-20% of total production cost) and consider the cost of utilities= 10% of total production cost

Utilities cost =0.10*X

**5. Maintenance and repair (M & R):** (2-10% of FCI) and consider the M & R cost =8%FCI

M &R cost = 0.08*107890=8631

**6.Operating supplies**:(10-20% of M&R or 0.5-1% of FCI) and consider 15% of M&R operating supplies

Operating supplies cost = 0.15*8631=1294

**7. Laboratory charges**: (10-20% of OL) and consider to be 15%

Laboratory charges=0.15*0.15*X=0.0225

**8.Patent and Royalties:** (0-6% of total production cost) and consider to be 2% of total production cost

Patent and royalties=0.02*X

Thus, direct production cost (DPC) =0.30X+0.15X+0.0225X +0.10X +9926+0.0225*X + 0.02X

**DPC=0.615X+9926**

**B. Fixed charge:** (10-20% total production cost)

**1.Depreciation** = 10% of FCI for machinery and equipment and consider 1%of building value for building.

Depreciation =0.11*107890=11868

**2.Local taxes:** (1-4% of FCI) and consider the local taxes of 3% of FCI.

Local taxes =0.03*107890=3237

**3.Insurances:** (0.4-1% of FCI) and consider the assurance =0.9% of fixed capital cost

**Insurances =** 0.009* 107890=971

- Thus, fixed charge =depreciation + local taxes + insurance fixed charge= 11868+3237+971

fixed charge =16076

**C. plant overhead cost**

Plant overhead cost is (50-70% of operating cost, supervision, and maintenance or 5-15% of total production cost); it includes: - general plant up keep and overhead, payroll overhead, packaging, medical service, safety and protection, restaurants, recreation, salvage, laboratory, and storage facilities. Consider the plant overhead cost 10% of total product cost

Plant overhead cost= 0.1*X

Manufacture cost=0.615X+9926+16076+0.1*X

Manufacture cost= 0.715*X+11533

II. **General expense** = Administrative costs + Distribution and selling costs + Research and development costs

A. **Administrative costs:** (2-6% of total production cost) and consider 3% of total production cost

   Administrative costs =0.03*X

B. **Distribution and selling costs:** (2-20% of total production cost) in this includes costs for sales offices, salesmen, shipping, advertising. And consider it to be 10%

   Distribution and selling costs=0.10*****X

C. **Research and development costs:**(about 2-5% of total production cost) and consider the research and development costs=2% of total production cost

   Research and development costs= 0.02*X

General expenses= Administrative costs + Distribution and selling costs + Research and development costs

General expenses= 0.03*X + 0.1*X + 0.02*X

General expenses = 0.15*X

Total production cost(X) = manufacture cost + general expenses

Total production cost(X) = 0.715*****X+11533 +0.15*X

Total production cost, X= 0.865*X+11533

Total production cost, X=$\frac{11533}{0.135}$ = 85429

## 7.2 Gross earning/income

Income =unit selling price* Quantity of product manufactured

From the material balance the amount of total production of paperboard is 224 kg/day dried

Working day per year=300day/year

Total annual product is 67200kg/year

Unit selling price of paperboard=60 birr/kg

Total income =67200kg/year * 60 birr/kg = 4032000birr/yr.

Gross income = total income – total production cost = 4032000– 85429

**Gross income = 3946571birr/yr.**

Gross income including depreciation = Gross income–depreciation

Depreciation= $\frac{FCI\text{–}salvage\ value,Vs}{life\ period}$

The service life of the plant is 10 years and fixed capital investment (FCI) of this plant is 107890 taking the salvage value of zero.

Depreciation=107890 /10 =10789birr/year

Gross income including depreciation=3946571birr/yr – 10789birr/year

Gross income including depreciation=3935782 birr/year

Let the Tax rate be 35%

Net profit=Gross income including depreciation (1-Tax rate)

Net profit =3935782 birr/year (1-0.35) = 2558258birr/yr.

## 7.3 Profitability Analysis

Profitability is a measure of profit that can be obtained from a given situation. The most commonly used methods for profitability evaluation, can be categorized under the following headings:

- Cash flow
- Present value (PV)
- Measures of Profitability
  - Payback Period
  - Net Present Value (NPV)
  - Profitability Index

- Cash Flow is meant to illustrate incomes ("cash inflows") and expenses ("cash outflows").

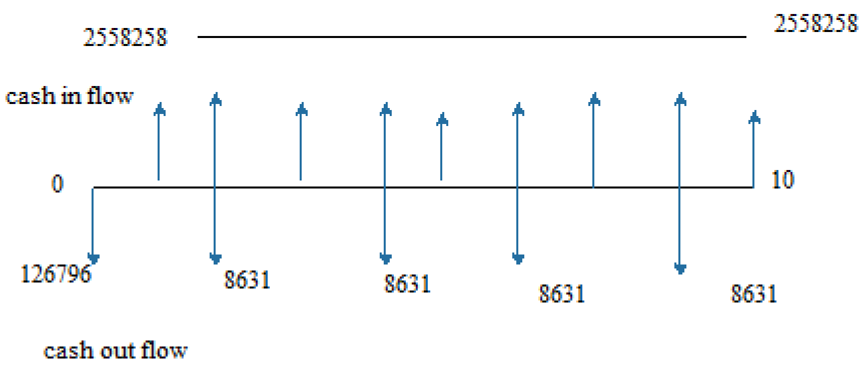
Plant life is 10 years, maintenance needed for our plant is every 2 years.

we have both total capital investment and net annual income from cost estimation and profit analysis.

Total Capital Investment =126796 birr/yr

Net annual Income= 2558258birr/yr.

Maintenance cost= 8631




**1.Payback period**

As the name suggests, the Payback Period is the length of time required to recover the cost of an investment.

Payback period = Total capital investment / average annual cash inflow.

Payback period =126796 birr/yr / 2558258birr/yr.= 0.05 years

The project's initial investment will be fully recovered within 0.05 years

2. **Net Present Value (NPV)**

❖ NPV may be defined as the difference between the total present value of the cash inflows and the total present value of the cash outflows considering the time value of money. NPV compares the value of the Birr today versus the value of Money/ Birr in the future.

$$NPV = \frac{CF_n}{(1+r)^n}$$

**Where n is number of years**

- If the NPV is positive (i.e. NPV > 0), Project is accepted
- if the NPV is negative (i.e. NPV < 0), project should be rejected, because cash flows are negative

- If the NPV is zero, then it should probably be rejected or get a pass mark as it generates exactly the return that is expected (i.e. NPV = 0)

Assume; Interest rate =10%

First calculate PV cash inflow and cash out flow.

1.PV cash inflow= $\boldsymbol{FC_n} \sum \frac{1}{(1+r)\ n)}$

PV cash inflow = 2558258birr/yr. [ 1/ (1+0.1) +1/ $(1+0.1)^2$+………………...1/ $(1+0.1)^{10}$]

PV cash inflow = 2558258birr/yr. (6.1445671) = 1571933birr/yr.

$PV_{out}=C_{fo}+C_{fn}\ /(\mathbf{1}+\boldsymbol{r})^{\boldsymbol{n}}$

$PV_{out}$=126796birr/yr + 8631 [1/ $(1+0.1)^2$+ 1/ $(1+0.1)^4$+ 1/ $(1+0.1)^6$+ 1/ $(1+0.1)^8$]

$PV_{out}$=126796birr/yr +8631 (2.54) =148718birr/yr

NPV=PV cash inflow–PV cash out flow

NPV=1571933birr/yr. –148718birr/yr

NPV =1557055birr/yr

Since NPV>0, the project is acceptable.

**3.Profitability Index (PI)**

- The PI is the ratio of the PV of cash inflows by the PV of cash outflows

$$\mathbf{PI} = \frac{\boldsymbol{PV\ of\ cash\ inflows}}{\boldsymbol{PV\ of\ cash\ outflows}}$$

- If the 0 < PI < 1, the project or option should be rejected
- If the PI > 1, the project or option should be accepted

$$\mathbf{PI} = \frac{\mathbf{1571933}\boldsymbol{birr/yr.}}{\mathbf{148718}} = \mathbf{11}$$

Since PI >1, our plant is economically feasible.

# CHAPTER EIGHT
# 8. PLANT LOCATION AND PLANT LAYOUT

## 8.1 Plant Location

- ❖ Plant location means to discover an exact place where an industrial experience can be started more profitable & a plant is a place where men, material, money, equipment, machinery etc. are brought together for manufacturing products. The final selection of the plant location has a strong influence on the success of any industrial venture.
- ❖ The site selection is decided based on the raw material availability, infrastructure, and other related facilities. Hence taking these things in to consideration the site for Plant erection could be in Wolkite town. Generally, this area has selected based on factors which enhance us to maximize feature targeted profit and to achieve our project without any obstacles.
- ❖ The points here under attract us to choose our site at the mentioned town by considering the following reason:
  - ✓ Availability and nearness to the sources of raw material.
  - ✓ The selected place is suitable for the transportation of raw material and finished product.
  - ✓ Climate condition, humidity, wind speed, rainfall etc. are suitable and do not ask any other cost
  - ✓ Road availability of adequate supply of labor force,
  - ✓ High proportion of skilled employees,
  - ✓ The infrastructure like road, electricity, water etc. are available
  - ✓ Proximity to the major markets
  - ✓ Raw material is readily available there the above envisaged plant is proposed to be located at Wolkite town.

## 8.2 Plant Layout

After the process flow diagrams are completed and before detailed piping, structural, and electrical design can begin, the layout of process units in a plant and the equipment within these process units must be planned. This layout can play an important part in determining construction and manufacturing costs, and thus must be planned carefully with attention being given to future problems that may arise. Since each plant differs in many ways and no two plant sites are exactly alike, there is no one ideal plant layout. However, proper layout in each case will include arrangement of processing areas, storage areas, and handling areas.

Preparation of the Layout Scale drawings, complete with elevation indications can be used for determining the best location for equipment and facilities.

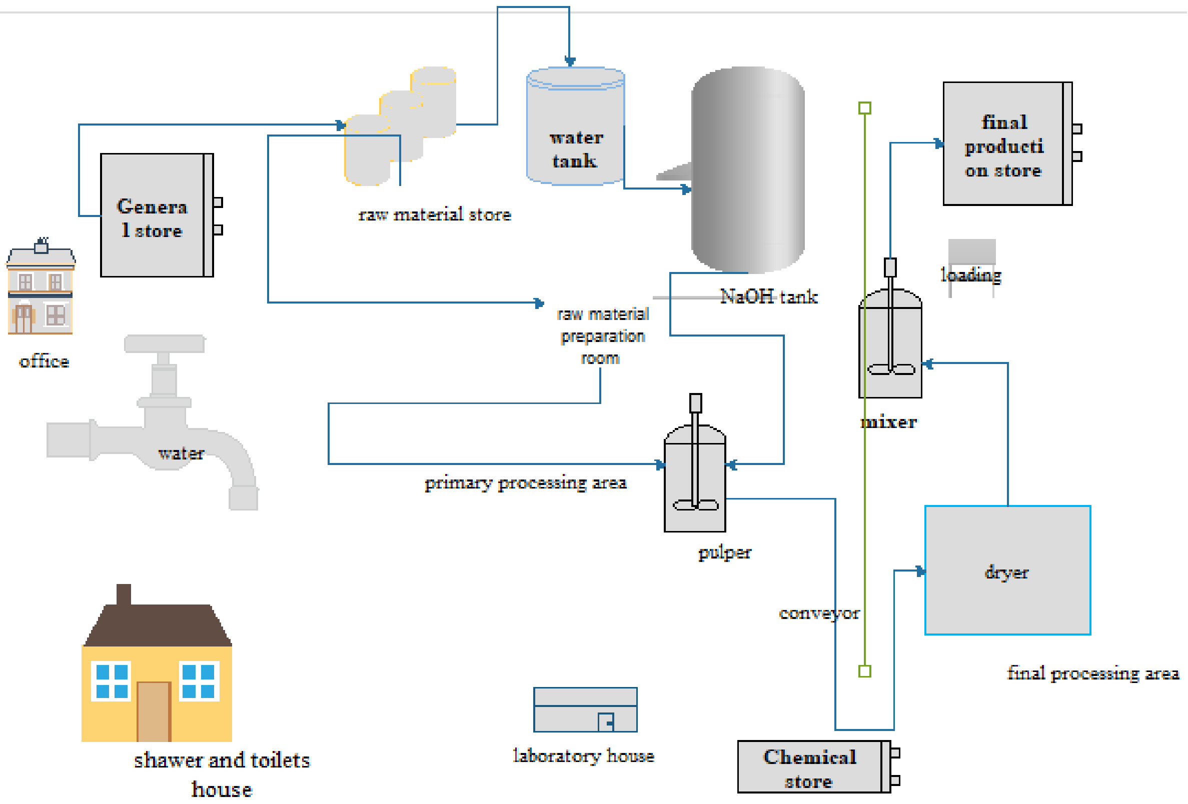



Figure 8.1 **plant lay out**

# CHAPTER NINE
# 9. CONCLUSION AND RECOMMENDATION

## 9.1 Conclusion

Today the paper production from waste paper recycling obtain attention from the angle of environmental and energy areas that is made by cooking the raw materials with chemical. The main purpose of this final year thesis was to look the effect of NaOH concentration on the paper production during recycling.

In this study paperboard production from waste paper experiment was conduct pulping process with NaOH chemical and without chemical; we can possible to observe the effect of chemical(NaOH) in pulp. To Compared the yield of Pulp with chemical and without chemical; percentage pulp yield for pulping process with use of chemical caustic soda concentration was lower than pulping process without chemical due to increase of delignification and solubilization of hemicelluloses in caustic soda but the quality of pulp obtained at high. And also we observe for strength of sheet pulping process with chemical was high strength.

Generally, in addition to the suitable properties of waste paper as a raw material for pulp and paper production, it can be alternative solution for those paper industries that contribute the pollution of the environmental. It can be reducing this problem by changing to usable product with perspective of environment.

## 9.2 Recommendations

- This study was done in short period of time so we don't possible investigate the effect of pulping condition or parameter for paper recycling production process we recommend further studies shall be conduct investigate the effect of pulping condition such as temperature, time and white liquor concentration and to determine the optimal pulping condition.
- In the paper recycling process, the raw material is useless or not suitable to the environment and availability in all place with suitable climate so we recommended that the government and other stock holders has to encourage and attracting investors to participate in this sectors.
- It is also possible to study the effects on pulp yield and paper sheet physical characteristics by using other widely available agricultural by products as raw material which might be feasible environmentally and economically.
- In this study Due to the lack of chemicals such as $Na_2S$, $TiO_2$ and $MgO_2$ difficulty to get smooth paper and the strength of product also low; however, the problem is solved by adding those chemicals and also we done recycling process was manually so we recommended for wolkite university chemical engineering department must fulfill all chemical, raw material, equipment used for paper production process and characterizing properties for further study.

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