Paper and Pulp Industry Manufacturing and Treatment Processes -A Review

[1] A. Latha, [2] M. C. Arivukarasi, [3] C. M. Keerthana ,
[4] R. Subashri , [5] V.Vishnu Priya
[1,2,3,4,5]Department of Civil Engineering,
Panimalar Engineering College,Chennai-123.

Abstract— **Paper plays a key role in our daily life and papers have been used for many years.The manufacturing of paper and pulp industry have an harmful effect on environment.The process uses intensive energy , water and various chemicals in which some are hazardous . The waste water from the industries is harmful, causes pollution and contaminates other water bodies too . The manufacturing of paper generates significant quantities of wastewater as high as 60m^3/tonne of paper produced. A recent survey within UK industry has found that their chemical oxygen demand can be as high as 11000 mg/l. This review consists of the process involved in paper making and the harmful effects that poses to the environment.**

Index Terms— Harmful Effect, Pollution, Contaminates, Chemical Oxygen Demand

I. INTRODUCTION

Paper is a thin material produced by pressing together moist fibres of cellulose pulp which is obtained from wood, rags or grasses and drying them into flexible sheets . It is a versatile material with many use like writing ,printing ,packing etc [1].Pulp is a lignocellulose fibrous material prepared by chemically or mechanically separating cellulose fibres from wood , fibre crops , waste paper or rags.Paper was first invented in ancient China. The papyrus and amate which are contemporary precursors existed in the Mediterranean world and Pre-Columbian Americas respectively and such that these materials are not demarcated as true paper [2]. The initial papermaking process was recognizedinitially in China during Eastern Han period (25-220 C.E), conventionally attributed to the court authority Cai Lun.During the 8th century , Chinese papermaking spread to other parts of world , where pulp mills and paper mills were used for earning money. By 11th century were brought medieval Europe where it was refined and known as paper mills utilizing waterwheels. Later it spread to other parts of the world.

II. MANUFACTURING OF PULP AND PAPER

Manufacturing of paper and pulp industry involves the following steps

- After pulping processes refining procedure will be followed
- To form a thin fibre mixture , dilution process is done
- Fibre formation on a thin screen
- To enhance the material density pressurization is followed

To eliminate the density of materials is done

- A suitable surface for usage is provided by following finishing procedure

The paper making process involves four inputs which are source of fibre , chemicals , water and energy[3].The primary source of fiber is the wood and composite material consisting of flexible cellulose fibers[4]. The three main component of wood are cellulose, hemicellulose and lignin. The concentration the components vary according to species. The proportions are roughly 50% cellulose , 25% hemicellulose and 25% lignin .

III. BASIC RAW MATERIAL REQUIREMENT

The basic raw material requirements are Timber, Water, Coal and Chemicals - which are Chlorine , Limestone Sulphur

A. Debarking

Drum debarking is the most usual way of eliminating bark in the pulp and paper industry.As the drum rotates, the logs tumble and slash against each other and either in presence or absence of water elimination of bark take place by abrasion.

B. Chipping

Debarked logs pass on like a log which move to the chippers . The chippers are large rotating discsequipped with chopping knives. The chips are either conveyed straight into the process orstored in stockpiles.

C. Pulping

Bagasse from the sugar industry can also be used . The chipped wood or bagasse then proceeds to the pulping process.It can be mechanical or chemical pulping or else combination of the both .

1.Mechanical pulping

Mechanical pulping is the defibrisation of timber which takes place mechanically. This process neglects the usage of chemicals. The logs of timber are ground against a grinding stone, or the timber chips are pulverized timber between rotating discs. Water is required in the pretreatment of the wood and fibre, in the pulping as well as the screening operations. The filtrate is partly recirculated and partly discharged from the process . The water is lost from the process in rejects and through evaporation.

2. Chemical pulping

Pulps which are produced mechanically produced are basically wood without the bark. Chemical pulps are those largely composed of pure cellulose and some of the less desirable elements of the wood having been removed by the chemical treatment processes. The earlier soda and sulphite pulp processes have been widely replaced by the Kraft process due principally to the demand for higher pulp strengths and a greater degree of chemical recovery and reduced water pollution[5]. The main steps in the manufacture of chemical pulps are described in the following sections :

a) Cooking

Chips are cooked for between 2 and 6 hours in digesters at about 10 atmospheres pressure and a temperature of 140°.Lignin is solubilised during pulping process thus releasing individual fibres , sugars ,alcohols and extracting resins. at the termination of the cook during the batch process the pulp and liquor are "blown" beneath pressure into the blow tank. The pressurized steam in the digester serves the purpose of cleaning the digester, prepared for another cook whilst the steam from the blow is utilized to heat water for mill use. Continuous processes are considered to offer more control of product quality and are becoming the norm for the Industry[6].The blow tank contains the pulp and black liquor, where the latter comprising of the spent cooking chemicals which is extracted from the wood . The chemicals mainly lignin and other solids . The pulp and black liquor are diluted and pumped to the brown-stock washers where the liquor comprising the soluble residue from the cook, is swept out of the pulp.

b) Washing and screening

Multi-stage, counter-current washing systems are employed to achieve high brown stock washing efficiency. The mingling water of the washing-screening system can also be linked with oxygen bleaching (delignification).Fresh water may only be introduced to the washing stage after oxygen bleaching in a closed system. After washing and screening the pulp is sent to the bleach plant or paper mill.

c) Chemical recovery system

The black liquor from the brown-stock washers, containing about 16% solids, is evaporated From the multiple-effect evaporators the black liquor from brown -stock washers comprising of 16% solids is evaporated to about 65cc solids. For reuse or disposal purpose condensate is recovered. Resinous soaps are detached and recovered as a by-product during evaporation . In the conventional mills the liquor may be partly concentrated in a direct evaporator. In special furnaces combustion takes place. Combustion of lignin and other extracts produces heat which is able to maintain combustion and produce steam. In the Kraft process the recovery furnace further assists the function of reducingsulphate to sulphide. To produce green liquor containing mainly sodium sulphide and sodium carbonate , the smelt formed from the chemicals is dissolved. The green liquor is treated with lime to change the carbonate present to hydroxide. The calcium carbonate formed is kilned to produce calciumoxide that is slaked to reform calcium hydroxide. The white liquor containing thesodium hydroxide and sulphide is reprocessed as cooking liquor. Extraction of lignin during chemical pulping can be 50% of the pulpproduction of an unified mill. This can be recovered for by-products such as adhesives, resins,adhesives and epoxys.

3. Sulphate pulping

The sulphate process produces a tougher, duskier pulp than other methods and requires chemical recovery to compete affordably. Evolved from soda pulping (which uses only sodium hydroxide for digestion) it started to acquire prominence in the manufacturing from the 1930s to 1950s with the progress of chlorine dioxide bleaching and chemical recovery processes, which also produced power and steam for the mill. The sulphate pulping utilizes various chemicals for its processes. The cooking liquor of sulphurous acid (H_2SO_3) and bisulphite ion (HSO_3^-) is prepared in the site. To produce sulphur dioxide (SO_2) elemental sulphur is burnt , which is passed up through an absorption tower .The absorption tower contains water and one of four alkaline bases ($CaCO_3$, the original sulphite base, Na_2CO_3, magnesium hydroxide ($Mg(OH)_2$) or ammonium hydroxide (NH_4OH)) which gives the acid and ion and govern their proportions. Sulphite pulping takes place in brick-lined batch digesters. To prevent other reactions are not unwanted , the digester is heated gradually to a extreme temperature of 130 to 140°C and the chips are cooked for a elongated time (6 to 8 hours). As the pressure in the digester increases, gaseous sulphur dioxide (SO_2) is bled off and remixed with the raw cooking acid. When roughly 1 to 1.5 hours of cooking period remains, heating process is stopped and the pressure is reduced by bleeding off steam and gas . The pulp is blown into the holding tank which is further washed and screened.

The spent digestion mixture which is red liquor, my be utilized for chemical and heat recovery for all but calcium-bisulphite-base operations. To remove residual SO_2 in ammonia-base sulphite pulping, the dilute red liquor is first exposed, then concentrated and burned. The flue gas comprising SO_2 is cooled and moved through an absorption tower where the fresh ammonia associates with it to restore the cooking liquor. Finally, the liquor is filtered and then stimulated with fresh SO_2 and finally stored.

D. Bleaching

The spent digestion mixture which is red liquor, can be used for heat and chemical recovery for all but calcium-bisulphite-base operations. In ammonia-base sulphite pulping, the dilute red liquor is first exposed to eliminate remaining SO_2, then concentrated and burned. The flue gas comprising SO_2 is cooled and passed through an absorption tower where fresh ammonia associates with it to regenerate the cooking liquor.

1. Conventional Bleaching

The bleaching process of a pulp mill is a multi-stage (5 - 7 stages) system consisting of bleaching towers for each and every stage and drum washers for washing the pulp between the stages. A common sequence in Kraft bleaching is CEDED with individual chemical stage followed by a washing stage. (C is Chlorination, D is Chlorine Dioxide, E is Alkali). Sulphite pulps require a shorter bleaching sequence. Mechanical pulps are generally brightened in a single stage with sodium hydro sulphate ,hydrogen peroxide or sodium peroxide. To replace conventional systems displacement bleach plants have also been built, where the various bleaching stages can be performed in the same bleaching tower.

2. Oxygen Bleaching

In the Sapoxal process, which was advanced in South Africa, the unbleached pulp from the digesters is reacted with oxygen under high pressure and temperature together with caustic soda and magnesium oxide for approximately 45 minutes to obtain semi-bleached pulp. Fully bleached pulp is obtained by further treatment with chlorine and chlorine dioxide. Between each stage the pulp is thoroughly washed.

3. Bleach Effluent Quality

In bleaching Kraft pulp, the waste-water volume from an old bleach plant can be SO -120 m3/t pulp which is quite high . While in modern four- and five-stage bleach plants the waste-water volume is about 30 - 40 m3/t pulp. The waste-water volume of in displacement bleaching can be as low as 10 - 15 m3/t pulp, depending on the consistency of the chlorination stage. Bleach waste waters are not generally recovered and thus it tends to become the main pollution source of almost all the pulp and paper mills, holding degradation products from the lignin, carbohydrates, simple phenols and neutral and acidic compounds. These arenormally regarded as not readily biodegradable, owing to the existence of bio-toxic elements such as chlorphenolics.

4. Odour

The colour pollution arising from a modern conventional pulp mill principally originates from the first alkali stage of the bleaching process due to the lignins. tannins and hemicelluloses present from the wood processing.

Technologies for colour removal and by-product recovery include :

- Pre-bleaching with oxygen
- Ultra filtration
- Cross-flow microfiltration
- Carbon adsorption
- Lime addition and precipitation

E. Paper manufacture from pulp and waste paper

1. Slush production

The paper machines can draw wet or slush pulp direct from a baled pulp or paper mills from related pulp mills, and from waste-paper plants. The various types of pulp are blended when slush pulp passes to the stock preparation section .The proportions are being used depending upon the grade of paper which is made. To give the desired finished paper product qualities various chemicals and additives are combined with the pulp .Then the stock is diluted gradually from 4% to 0.5% which is cleaned and screened to eliminate grit and dirt particles. Sizing agents are added to increase the resistance of paper to water and fillers such as calcium carbonate are added to increase the density of the paper . This reduces the transparency and making it suitable for printing.

2. Paper Machine Feed

The clean and diluted stock is pumped into a head or flow box which has a slender opening. The head or How box jets a wide, thin sheet of stock on the fast moving "wire". This "wire" is a continuous woven flexible plastic mesh belt. Water drains from the stock through the wire, helped by foil elements and vacuum suction boxes, leaving a web of pulp fibres on the wire at about 65% moisture. This is known as the "wet end" of the machine. With the aid of roll pressure and felts the press section further dewaters the web to about 48% moisture content. The remaining moisture is removed in the dryer section by close contact with steam heated cylinders. The calender stack of steel rolls further smooths the sheet and improves surface properties. The paper is reeled up into large reels, known as jumbo rolls, prior to trimming, finishing and sale.

3. Coating

Coating with a clay slurry may be used to create a smooth, even surface for printing purposes. Gloss paper is created by passing the coated paper through the alternate metal and synthetic rolls of a super calender.

4. Tissue Paper

Tissue paper is created in a similar fashion to conventional paper with slushed pulp being blended and dyed in the stock preparation section prior to dilution . Clean, screened stock is pumped onto the moving synthetic wire. The wet web of paper at about 859c moisture content is taken from the wire with the help of pick-up roll which runs inside a felt. The paper is transferred by the pressure rolls onto the steam heated and pressurized Yankee cylinder which reduces the moisture content in one rotation. The tissue paper is reeled up into large reels at the end of the machine, either single or two ply.

5. Paper Production from Waste Paper

Wastepaper is principally utilized as pulp for the production of corrugated board, liner and fluting for cardboard packaging. The raw material is slushed with water, blended and fibre sorted and sent through the density cleaners and thickeners to a preparation chest. The cleaned pulp from the preparation chest moves to the wire press, forms table and vacuum box. The initial presses prepare the pulp exclusively for the couch roll and then moves to further pressing, drying, and rolling into a Jumbo roll, which is rewound and pared for sale. Dyes, starch, alum, retention aids and fillers (clay) are added during the process.

F. Wastewater treatment for paper and pulp industry

Waste water produced by manufacturing process of paper and pulp contain huge quantity of toxic chemicals present in it which have negative impact on environment and human being if it is untreated. The total quantity of waste water produced is nearly equal to the pulp produced in that process. The waste water generated have high content of BOD and various concentrations of other contaminants that depend upon various types.

1. Water and Waste-water Management

The outcomes of this study disclose that although a degree of water management is followed in many mills, and that the water use figures are normally impressive in terms of international practice, there is still substantial variation in water intake between factories manufacturing the same commodities. In many cases this occurs because the mill has ample process water available; historically the installed plant has not been designed or managed for optimum water intake; discharge of mill waste water to high volume rivers close to sea outfalls has generally been considered acceptable; until recently optimization of water intake, chemical and fibre recover, and curtailing pollutant loads have not been allocated a consistently high level of priority by the Industry. The pressure to improve efficiency in production coincides with advances in product loss control and chemical recovery, reduced bleach plant waste-water discharges and improved process sequences.

2. Reducing Water Consumption

The water consumption of a paper or board mill can be minimized by tightening the water system of the mill. This has the merit that the lower levels of suspended solids, suitable paper raw material are discharged to drain. With less fresh water being introduced to the system, the temperature of the white water rises, which makes it easier to remove from the paper web, so that energy can be saved. Increased tightening of the white water system, however, causes some problems in paper and board mills, preventing total closure of the water circulation system. The accumulation of salts and organic compounds dissolved from the fibre raw material increases significantly, which causes problems due to microbiological activity, corrosion and growth.

3.Reuse of Water

White water from the paper or board machine may be first treated mechanically by flotation, sedimentation or filtration, or a combination of processes. The flotation treatment, is suitable for the recovery of fine suspended solids. Sedimentation is better for white waters that contain large amounts of filler. Filtration is suitable for whitewaters that contain low levels of solids and filler. Normally , the brown grades of paper are most tolerant of recycled water, newsprint and tissue types. Fine papers (high whiteness) are very sensitive to colour and curtain metal ions, especially with respect to aging and colouring. The colloidal chemistry involving paper sizing and resin applications is sensitive to phosphate and other dispersants and some metal ions.

G. waste-water characteristics of pulp and paper mills

1. Suspended Solids

The suspended solids in mill waste waters is found mainly due to the fine bark particles and silt from pretreatment, the complete retention on the paper machines, which is exaggerated by the use of retention aids and save the the loss of fibre/filler in spillages or during wash-ups and grade changes .The load of suspended solids in untreated mill waste waters varies over the range 1.1 –51kg/t of product. At a number of mills, however, waste-water suspended solids are a loss since the waste-water clarification plant is operated to recover material for reuse in the mill, especially in the recovery of fibre in waste-paper-based paper production. The settle able solids portion is generally in the range of about 75-95% of the total suspended solids. Most of the non-settleable solids are difficult to remove by conventional means since they are colloidal material .Depending on the type of fibre (waste paper or pulp) and filler (clay or chalk) used, the composition of suspended solids is varied. The ash content of mill sludges varies from 5 to 50%.Of particular importance to secondary biological treatment is the concentration of non-settleable, colloidal solids present in the clarified waste water. The concentration of colloidal solids increases with increasing use of waste paper and starch and with decreasing specific water intake.

2. Dissolved Solids

a) Organic matter

Depending upon the pulping process and yield coefficient of pulp from the wood ,waste paper or bagasse , the raw material is suspended or dissolved upto 60 % and becomes a potential organic pollutant load. The dissolved organic matter in mill waste waters are lost due to non-retained wet-end additives and also from the materials which are dissolved from pulp or recycled broke and waste paper. In practice the majority of this material is recovered for reuse. The waste water strength depends on the load loss and the specific water intake and varies over an extremely wide range .

b) Inorganic matter

Total dissolved solids loads ranged from 2 - 183 kg/t of product . Pulp liquors comprising discharges from the washing liquors, black liquor, storage residue overflows and contribute to the high TDS levels in the form of salt cake, sodium, calcium, carbonates and sulphates. Bleaching liquors are usually high in chloride content. The concentration of soluble cations (particularly calcium, sodium and magnesium) can attain high levels in closed water systems. Sulphides occur in mill systems as a outcome of microbial reduction of sulphate and contribute to corrosion of the system. As with anaerobic decomposition of organic solids, reduction of sulphate to sulphide occurs in attached slimes or stagnant, quiescent zones of the machine system. The sulphide levels in waste waters arise from soluble sulphides that have diffused from the generation zone or insoluble sulphides that have been scoured from surfaces by variation in water velocity.

H. waste-water treatment practices

1.Waste-water Treatment Technologies

The pulp and paper industry utilizes a wide range of technologies in the treatment of wastewater. Most mills uses primary methods of treatment such as screening and settling, while there are numerous secondary and tertiary methods that are used in various degrees. These include flotation, micro-straining, activated carbon absorption, steam or air stripping, polymeric resin treatment, and biological treatment.

2.Biological Waste-water Treatment of Pulp and Paper Waste Waters

a) Aerobic treatment

The conventional treatment of pulp and paper industry waste water has been by means of aerated biological systems with sedimentation. These have been in the form of aerated lagoons, aeration stabilization and settling basins, activated sludge treatment, or biofiltration plants. These processes differ primarily in the manner in which the organisms come into contact with the organic material. Aerobic treatment does have certain disadvantages, namely the high energy demand that is required for efficient aeration, and the excess biological sludge that is produced, requiring disposal.

b) Anaerobic treatment

Since the early 1980s interest has been increasing in the paper industry in the use of an aerobic systems for the treatment of waste water from pulp and paper mills, coinciding with developments in papermaking practice and closing up of water and effluent systems which have resulted in lower volumes of effluent but of high organic content. There are at least 20 systems functioning internationally in the Industry and many are at pilot or design stage. The most common systems utilized in the paper industry are the Up flow Anaerobic Sludge Blankets (UASBs) and Anaerobic Contact Filters (ACF).Anaerobic processes have the advantages that relatively little sludge biomass is generated, and that they do not need energy for aeration even though they do require some form of recycling to maintain optimal loading conditions. Anaerobic systems also produce methane gas which can be utilized within the factory.

IV. Conclusion

Although wastewater generation during various stages of pulp and paper manufacture are unavoidable it has to be treated . Otherwise it has a tremendous effect on environment. The wastewater is let into the water bodies if untreated it would lead to adverse effects . The animals and human being who consume it would suffer from dreadful diseases which may even pass on to several generations. The aquatic life living in the particular water body would deplete gradually affecting our entire eco-system. Both aerobic and anaerobic biological processes are effective for the wastewater treatment of paper and pulp industry.

REFERENCES

[1] B.C. Punmia, Ashok Kumar Jain., 1998. Waste Water Engineering .New Delhi : Laxmi Publications (p) Ltd.
[2] Canadian Pulp and Paper Association. 1995. Reference Tables 1995. Montreal, PQ: CPPA.
[3] Food and Agriculture Organization (FAO) of the United Nations. 1995. Pulp and Paper Capacities, Survey 1994-1999. Rome: FAO.
[4] Henneberger, PK, JR Ferris, and RR Monson. 1989. Mortality among pulp and paper workers in Berlin. Br J Ind Med 46:658-664.
[5] Nay O. T; Erdeml E; Kabdali I; lmez T, 2008. Advanced treatment by chemical oxidation of pulp and paper effluent from a plant manufacturing hardboard from waste paper. Environmental Technology, 29 (1045 – 1051)
[6] Pratima Bajpai and Pramod K. Bajpai, 1994. Biological colour removal of pulp and paper mill wastewaters. Journal of Biotechnology, 33 (211-220).
[7] http://www.lenntech.com/pulp-and-paper-industry-water-treatment.htm
[8] Thompsona G., Swainb J., Kayb M.and Forster C. F, 2001. The treatment of pulp and paper mill effluent: a review. Bioresource Technology 77 (275-286)
[9] Bernhart, S. 1994. Irritant bronchitis. In Textbook of Clinical Occupational and Environmental Medicine, edited by L Rosenstock and MR Cullen. Philadelphia: WB Saunders Co.
[10] Chan-Yeung, M and J Malo. 1995. Forestry products. In Occupational and Environmental Respiratory Disease, edited by P Harber, MB Schenker and JR Balmes. St. Louis: Mosby-Yearbook Inc.
[11] Food and Agriculture Organization (FAO) of the United Nations. 1994. 1993 Yearbook of Forest Products. Rome: FAO.
[12] Springer, AM. 1986. Industrial Environmental Control Pulp and Paper Industry. New York: John Wiley and Sons.
[13] Canadian Pulp and Paper Association. 1995. Reference Tables 1995. Montreal, PQ: CPPA.
[14] Food and Agriculture Organization (FAO) of the United Nations. 1995. Pulp and Paper Capacities, Survey 1994-1999. Rome: FAO.
[15] Henneberger, PK, JR Ferris, and RR Monson. 1989. Mortality among pulp and paper workers in Berlin. Br J Ind Med 46:658-664.
[16] International Agency on the Research of Cancer (IARC). 1980. Monographs on the Evaluation of Carcinogenic Risks to Humans: Wood, Leather and Some Associated Industries. Vol. 25. Lyon: IARC.—.1987. Monographs on the Evaluation of Carcinogenic Risks to Humans, Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs. Vol. 1-42 (supplement 7).
[17] Lyon: IARC.("Landfills, Municipal Solid Waste") Landfills Municipal Solid Waste. EPA. Environmental Protection Agency. Archived from the original on 8 January 2015. Retrieved 7 November 2014.
[18] MaCristina Yebern, Jaime Rodríguez, Juanita Freer, Jaime Baeza, Nelson Durán and Héctor D. Mansilla. 1999. Advanced oxidation of a pulp mill bleaching wastewater. Chemosphere, 39 (1679-88).
[19] Wonga S.S, Tengb T.T, Ahmada A.L, Zuhairia A and Najafpourc G, 2006. Treatment of pulp and paper mill wastewater by polyacrylamide (PAM) in polymer induced flocculation. Journal of Hazardous Materials 135 (378- 388)
[20] 20. Selvam K, Swaminathan K, Myung Hoon Song and Keon-Sang Chae , 2002. Biological treatment of a pulp and paper industry effluent by Fomes lividus and Trametes versicolor. Journal World Journal of Microbiology and Biotechnology 18 (523- 526).
[21] Mort Fels, János Pintér, David S. Lycon, 2009. Optimized design of wastewater treatment systems: Application to the mechanical pulp and paper industry: I. Design and cost relationships. The Canadian Journal of Chemical Engineering, 75 (437- 451).
[22] http://www.westfaliaseparator.com/applications/fluids-water/drinking-water-recovery-waste-water-treatment/treatment-of-paper-sludge.html
[23] http://www.docstoc.com/docs/13141412/Pulp-and-paper-industry-water-treatment
[24] Rix, BA and E Lynge. 1996. Industrial hygiene measurements in a new industry: The repulping and deinking of paper waste. Am J Ind Med 30:142-147 .
[25] Smook, GA. 1989. Handbook for Pulp and Paper Technologists. Atlanta, GA: Technical Association for the Pulp and Paper Industry.