Paper Industry and It's Effects on Environment-An Overview

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Abstract- *This seminar is a brief review on the Effects of Paper Industry on Environment and Treatment of Paper Industry Wastewater. The importance of wastewater treatment to the environment is discussed, followed by the benefits and limitations of treatment technique. Though the industry has positive externalities from the point of view of employment and income opportunities, urbanization and concentration of commercial activities and property price appreciation, it has also negative externalities that are environmental pollution which arises from the operation of the industry.*

The aim is to introduce the environmental impact of paper production of the paper industry on Environment and different treatment methods of paper industry wastewater.

Keywords- Paper Industry, Water Pollution, Air Pollution, Solid Waste.

I. INTRODUCTION

'Environment' is defined as the sum total of water, air and land and the inter relationships which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organisms and property.

Any solid, liquid or gaseous substance present in such concentration as may be or tend to be injurious to environment is called an environmental pollutant [EP, Act, 1986]. (1)

Papermaking is thought to have originated in China in about 100 A.D. using rags, hemp and grasses as the raw material, and beating against stone mortars as the original fibre separation process. Although mechanization increased over the intervening years, batch production methods and agricultural fibre sources remained in use until the 1800s. Continuous papermaking machines were patented at the turn of that century. Methods for pulping wood, a more abundant fibre source than rags and grasses, were developed between 1844 and 1884, and included mechanical abrasion as well as the soda, sulphite, and sulphate (kraft) chemical methods. These changes initiated the modern pulp and paper manufacturing era. (3)

Pulp and paper industry is considered as one of the most polluter industry in the world (Thompson et al., 2001; Sumathi & Hung, 2006). The production process consists two main steps: Pulping and Bleaching.

Pulping is the initial stage and the source of the most pollutant of this industry. In this process, wood chips as raw material are treated to remove lignin and improve fibers for paper making.

Bleaching is the last step of the process, which aims to whiten and brighten the pulp. Whole processes of this industry are very energy and water intensive in terms of the fresh water utilization (Pokhrel &Viraraghavan, 2004). The wastewaters generated from production processes of this industry include high concentration of chemicals such as sodium hydroxide, sodium carbonate, sodium sulfide, bisulfites, elemental chlorine or chlorine dioxide, calcium oxide, hydrochloric acid, etc (Sumathi & Hung, 2006).

II.THEORETICAL CONTENTS

Paper manufacturing is a highly capital, energy and water intensive industry.

In India, around 905.8 million m3 of water is consumed and around 695.7 million m3 of wastewater is discharged annually by this sector. (1)

Manufacturing technologies and process description:

Pulping process is the first step of the production. The main steps of this part are debarking, wood chipping, chip washing, chip digestion, pulp screening, thickening, and washing.

Mechanical and chemical operation processes in pulping are used in the worldwide. While mechanical processes involve mechanical pressure, disc refiners, heating, and light chemical processes to increase pulping yield; wood chips are cooked in pulping liquors at high temperature and under pressure in the chemical pulping processes. (Sumathi & Hung, 2006).

Additionally, mechanical and chemical processes can be combined in some applications. The yield of mechanical processes is higher (90-95%) compared to chemical processes (40-50%).

However quality of the pulp obtained from mechanical processes is lower and also the pulp is highly coloured and includes short fibers (Pokhrel &Viraraghavan, 2004).

Therefore, chemical pulping carrying out in alkaline or acidic media is mostly preferred. In alkaline media generally referred as Kraft Process, the woodchips are cooked in liquor including sodium hydroxide (NaOH) and sodium sulfide (NaS2). Mixture of sulphurous acid (H2SO3) and bisulfide ions (HSO3-) is used in acidic media named as sulfide process.

During the pulp processing, approximately 5-10% of the lignin comes from the raw materials cannot be removed and these are responsible from the dark colour of the end product. (2)

Water in the Paper Manufacturing Process

Water is intricately associated with all the three stages of paper production namely, pulp making, pulp processing, and paper/paper board manufacturing, and their associated activities of cooking, bleaching, and washing. About 85 percent of the water consumed in the pulp and paper industry is used only for processing, thus, leading to the generation of large volumes of contaminated wastewater.

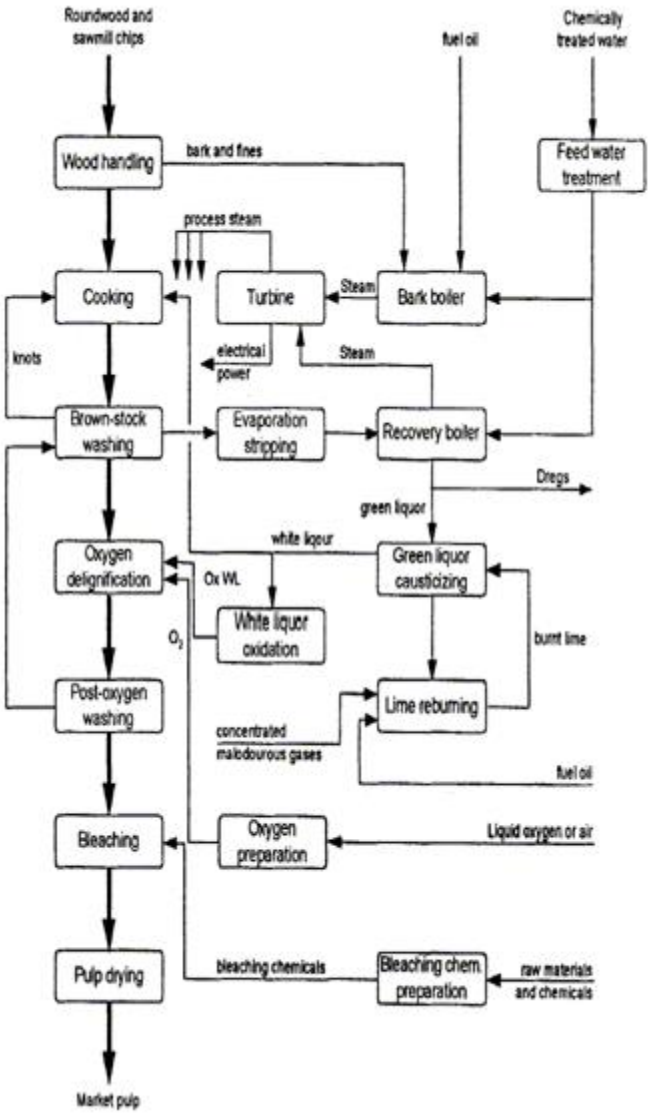

Fig.1 Manufacturing process of pulp and paper mill.

III. POLLUTIONS

• Water Pollutants:

Table No 1: Common Water Pollutants from Pulp and Paper Process

SOURCE	EFFLUENT CHARACTERISTICS
Water used in wood handling/ debarking and chip washing.	Solids, BOD, colour
Chip digester and liquor evaporator condensate	Concentrated BOD, can contain reduced sulfur
"White waters" from pulp screening, thickening, and cleaning	Large volume of water with suspended solids can have significant BOD
Bleach plant washer filtrates	BOD, colour, chlorinated organic compounds
Paper machine water flows	Solids, often precipitated for reuse
Fiber and liquor spills	Solids, BOD, colour

Source: United States Environment Protection Agency (EPA)

Different pulping processes utilize different amount of water and all of these processes are water intensive. The quality of wastewater generated from pulping and bleaching is significantly distinctive because of the process and chemical types (Billings and Dehaas, 1971). Approximately 200 m3 water are used for per ton of produced pulp and most of them are highly polluted, especially wastewater generated from chemical pulping process (Cecen et al., 1992). Wood preparation, pulping, pulp washing, screening, washing, bleaching, paper machine and coating operations are the most important pollution sources among various process stages. Wastewaters generated from pulping stage include mostly wood debris, soluble wood materials, and also some chemicals from chemical pulping process. Bleaching process wastewater has a different quality. These wastewaters are not higher strengthen than pulping process wastewater, however they include toxic components.

The wastewater characteristics and their strengths changed depending upon the pulping processing. Kraft process is widely used worldwide approximately 60% within all pulp production includes both mechanical and chemical pulping.

The wastewaters generated from pulping process consist various wooden compounds such as lignin, carbohydrate and extractives and the treatment of these wastewaters by biologically is difficult. Addition of them, some toxic compounds such as resin acids, unsaturated fatty acids, diterpene alcohols, juvaniones, chlorinated resin acids, and others can exist in the wastewaters subjecting to the process (Pokhrel&Viraraghavan, 2004). The most important reaction in the bleaching step is oxidation of chlorine and the main problem about the wastewater content is chlorinated organic compounds or AOX (Sumathi& Hung, 2006).

Various studies reported that fish living in pulp and paper industry wastewaters have toxic/lethal effects on the daphnia, fish, planktons and other bioata in the receiving water bodies (Owens et al., 1994; Hickey and Martin, 1995; Yen et al., 1996; Vass et al., 1996; Liss et al., 1997; Lindstrom-Seppa et al., 1998; Leppanen and Oikari, 1999; Johnsen et al., 1998; Erisction and Larsson, 2000; Schnell et al., 2000b; Kovacs et al., 2002).

• Solid and hazardous wastes:

Wastewater and consequently solid wastes are the main environmental problem of the pulp and paper mills because this industry has a very water intensive production processes (Cabral et al., 1998; Thompson et al., 2001). Solid wastes from pulp and paper industries are mainly treatment sludges, lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludges, and wood processing residuals. Wastewater treatment sludges have a significant concern for the environment because of including chlorinated compounds (EPA, 2002). The characteristics of all solid waste generated from the pulp and paper mills are organic exception of boiler and furnace ash. The chemicals of the solid wastes are varied depends on the process type. Solid wastes, sources and qualities are given in Table 2.

Table No.2: Solid waste types and sources from pulp and paper mills

SOURCE	WASTE TYPE	WASTE CHARACTERISTIC
Wastewater treatment plant	Sludge	Organic fraction consists wood fibers and biosludge.
		Inorganic fraction consists clay, calcium carbonate, and other materials
Caustic process	Dregs, muds	Green liquor dregs consisting of nonreactive metals and insoluble materials, lime mud
Power boiler	Ash	Inorganic compound
Paper mill	Sludge	Colour waste and fibre clay including slowly biodegradable organics such as cellulose, wood fibres and lignin

Source: (EPA,2002;Nurmesniemi et al., 2007)

• Gas emissions:

Air pollutants and gas emissions are the other concern about the pulp and paper industry. The most important gas emission is water vapours. Additionally, particulates, nitrogen oxides, volatile organic compounds (VOCs), sulfur oxides and total reduced sulfur compounds (TRS).

The gas emissions sources and types are given Table 3.

Table No.3: Air pollutants types and sources from pulp and paper mills

SOURCE	MAJOR POLLUTANTS
Chemical pulping process	VOCs (alcohols, phenols, methanol, acetone, chloroform)
Bleaching	VOCs (chloromethane, acetone, chloroform)
Wastewater treatment plant	VOCs (alcohols, phenols, methanol, acetone, chloroform)
Power boiler	SO2, NOX, fly ash, coarse particulates
Evaporator	Evaporator noncondensibles (alcohols, phenols)
Recovery furnace	Fine particulates, SO2, NOX
Calcining (Lime Kiln)	Fine and coarse particulates

Source: (EPA,2002)

IV. EFFECTS OF PULP AND PAPER INDUSTRY ON ENVIRONMENT:

The production and use of paper has a number of adverse effects on the environment which are known collectively as paper pollution. Pulpmills contribute to air, water and land pollution. Discarded paper is a major component of many landfill sites, accounting for about 35 percent by weight of municipal solid waste.

1. Deforestation

Worldwide consumption of paper has risen by 400% in the past 40 years, with 35% of harvested trees being used for paper manufacture. Plantation forest, from where the majority of wood for pulping is obtained, is generally a monoculture and this raises concerns over the ecological effects of the practice.

Deforestation is often seen as a problem in developing countries but also occurs in the developed world. Wood chipping to produce paper pulp is a contentious environmental issue. (7)

2. Water Pollution:

The set of indicators measure pollutants released to a paper mill's receiving waters typically, rivers or streams. These indicators are:

Effluent Flow, Biochemical Oxygen Demand (BOD), Chemical Oxygen demand (COD), Color, Total suspended solids (TSS), Dioxins and dioxin-like compounds

3. Air Pollution:

For gaseous emissions, the particulate matter and hydrogen sulfide are the most important parameters. Since some pulp and paper mills use lime-kilns and all the mills operate boilers for steam generation for meeting their process heat and power requirements, they burn coal/fuel & furnace oil/agricultural wastes or a combination of them (i.e. multifuel boilers), and emit SO2, PM, HC and CO into the atmosphere.

4. Greenhouse gas emissions:

The pulp and paper industry is the fourth largest emitter of greenhouse gases among manufacturing industries, and contributes 9 percent of total manufacturing carbon dioxide emissions (U.S. Energy Information Administration 2002; Martin et al.).

5. Nitrogen oxides:

Nitrogen oxides (NOx, which include NO and NO2) are products of the combustion of fuels in boilers.

6. Volatile organic compounds:

Volatile organic compounds (VOCs) are a broad class of organic compounds that are gases at room temperature, such as vapors from solvents. VOCs react with nitrogen oxides (NOx) to form ground-level ozone, the major component of smog and a severe lung irritant. The pulp and paper industry is the fourth highest contributor of VOC emissions to the atmosphere by industry sector (U.S. EPA 2002).

Table No.4: Air Emissions from the Pulp and Paper Industry:

Pollutant	Effects	Source
Carbon dioxide	Greenhouse gas	Fuel combustion
Hydrogen sulphide	Rotten egg smell	Kraft process
Sulphur dioxide	Acid rain	Fuel combustion and pulping process(Kraft 1-3 kg SO2/tonne), Sulphite 5 kg SO2/tonne)
Chloroform	toxic possible carcinogen	Chlorine bleaching

Above all air emissions are very harmful to subjects and objects on earth. (1)

7. Land Pollution:

Treated industrial waste water could be used safely and effectively with proper precautions to increase the soil productivity (Chhonkar et al., 2000). However, despite being a useful source of plant nutrients (N, P, K, Ca etc.), the paper mill effluent often contains high amounts of various organic and inorganic materials, as well as toxic trace elements, which may accumulate in soils in excessive quantities under long term use. Subsequently, these toxic elements may cause severe problems to human beings and animals by entering into the food chains. Untreated industrial effluents contain higher amounts of Cd, Pb, Zn, Cu, Mn and Fe and enhance the concentration of the heavy metals in irrigated surface soils (Xiog et al., 2001). Significantly higher values of EC, organic carbon, available K, exchangeable cations (Ca2+, Mg2+), exchangeable anion (Cl-, HCO3-) along with micro-nutrient cation (Cu2+) have been reported in soils being irrigated by paper and pulp industry effluents (Singh et al., 2007). (6)

8. Effects on Human Health:

The most well documented health problems encountered by pulp mill workers are acute and chronic respiratory disorders (Torén, Hagberg and Westberg 1996). Exposure to extremely high concentrations of chlorine, chlorine dioxide or sulphur dioxide may occur as a result of a leak or other process upset. Exposed workers may develop acute chemical-induced lung injury with severe inflammation of air passages and release of fluid into the air spaces, requiring hospitalization. The extent of damage depends on the duration and intensity of the exposure, and the specific gas involved. If the worker survives the acute episode, complete recovery may occur. However, in less intense exposure incidents (also usually as a result of process upsets or spills), acute exposure to chlorine or chlorine dioxide may trigger the subsequent development of asthma. This irritant-induced asthma has been recorded in numerous case reports and recent epidemiological studies, and current evidence indicates that it may persist for many years following the exposure incident. Workers similarly exposed who do not develop asthma may experience persistently increased nasal irritation, cough, wheezing and reduction in airflow rates. Workers most at risk for these exposure incidents include maintenance workers, bleach plant workers and construction workers at pulp mill sites. High levels of chlorine dioxide exposure also cause eye irritation and the sensation of seeing halos around lights.

Reduced sulphur compounds (including hydrogen sulphide, dimethyl disulphides and mercaptans) are potent eye irritants and may cause headaches and nausea in some workers. These compounds have very low odour thresholds (ppb range) in individuals not previously exposed; however, among long-time workers in the industry, odour thresholds are considerably higher. Concentrations in the range of 50 to 200 ppm produce olfactory fatigue, and subjects can no longer detect the distinctive “rotten eggs” odour. At higher concentrations, exposure will result in unconsciousness, respiratory paralysis and death. Fatalities associated with exposure to reduced sulphur compounds in confined spaces have occurred at pulp mill sites.

Skin problems encountered by pulp and paper mill workers include acute chemical and thermal burns and contact dermatitis (both irritant and allergic). Pulp mill workers in kraft process mills frequently experience alkali burns to the skin as a result of contact with hot pulping liquors and calcium hydroxide slurries from the recovery process. Contact dermatitis is reported more frequently among paper mill and converting workers, as many of the additives, defoaming agents, biocides, inks and glues used in paper and paper-product making are primary skin irritants and sensitizers. Dermatitis may occur from exposure to the chemicals themselves or from handling freshly treated paper or paper products.

Exposures to numerous substances designated by the International Agency for Research on Cancer (IARC) as known, probable and possible carcinogens may occur in pulp and paper operations. Asbestos, known to cause lung cancer and mesothelioma, is used to insulate pipes and boilers. Talc is used extensively as a paper additive, and can be contaminated with asbestos. (3)

V. CONCLUSION

Due to developed population and industrialization, the paper demand increases every day. The major pollution load constitutes wastewaters from pulp and paper mills. Water and energy utilization and waste generation are becoming more important concern ever worldwide. A major goal is to decrease damage to environment by waste minimization, reuse and recycle. Use of best available techniques and innovative methods are necessary.

A variety of wastewater is generated from various processes of paper making. Different technologies and their combinations have been used for their treatment. The most common applied systems are biological treatment, sequential anaerobic and aerobic systems, tertiary treatments followed after primary treatment. Solid waste management and disposal are also another concern. During the final disposal step, the aim should be chemical compound and energy recovery because of environmental and economic aspects.

The best available treatment technology for all three waste phases depends on the production processes, raw materials and the regulations, which the industries have to obey.

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