CLEANER TECHNOLOGY IN PULP AND PAPER INDUSTRY

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INTRODUCTION

Clean technology includes recycling, renewable energy (wind power, solar power, biomass, hydropower, biofuels, etc.), information technology, green transportation, electric motors, green chemistry, lighting, Greywater, and many other appliances that are now more energy efficient. It is a means to create electricity and fuels, with a smaller environmental footprint and minimise pollution. To make green buildings, transport and infrastructure both more energy efficient and environmentally benign. Environmental finance is a method by which new clean technology projects that have proven that they are "additional" or "beyond business as usual" can obtain financing through the generation of carbon credits. A project that is developed with concern for climate change mitigation (such as a Kyoto Clean Development Mechanism project) is also known as a carbon project.

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- Investments in clean technology have grown considerably since coming into the spotlight around 2000. According to the United Nations Environment Program, wind, solar, and biofuel companies received a record $148 billion in new funding in 2007 as rising oil prices and climate change policies encouraged investment in renewable energy. $50 billion of that funding went to wind power. Overall, investment in clean-energy and energy-efficiency industries rose 60 percent from 2006 to 2007.By 2018 it is forecast that the three main clean technology sectors, solar photovoltaics, wind power, and biofuels, will have revenues of $325.1bn

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- **Cleantech** is any product or service that improves operational performance, productivity, or efficiency while reducing costs, inputs, energy consumption,waste, or environmental pollution. Its origin is the increased consumer, regulatory, and industry interest in clean forms of energy generation—specifically, perhaps, the rise in awareness of global warming, climate change,and the impact on the natural environment from the burning of fossil fuels.Cleantech is often associated with venture capital funds and land use organizations.

Cleaner technology in pulp and paper industries

1. Pulp and paper industry is considered as one of the most polluter industry in the world . 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 papermaking. 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)Water consumption changes depending on the production process and it can get as high as 60 m^3/ton paper produced in spite of the most modern and best available technologies (Thompson *et al*., 2001)

1. 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). The major problems of the wastewaters are high organic content (20-110 kg COD/air dried ton paper), dark brown coloration, adsorbable organic halide (AOX), toxic pollutants, etc.

The environmental problems of pulp and paper industry are not limited by the high water consumption. Wastewater generation, solid wastes including sludge generating from wastewater treatment plants and air emissions are other problems and effective disposal and treatment approaches are essential. The significant solid wastes such as lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludges, wood processing residuals and wastewater treatment sludges are generated from different mills. Disposal of these solid wastes cause environmental problems because of high organic content, partitioning of chlorinated organics, pathogens, ash and trace amount of heavy metal content (Monte., 2009).

The major air emissions of the industry come from sulfite mills as recovery gurnaces and burnes, sulfur oxides (SOx), from Kraft operation as reduced sulfur gases and odor problems, from wood-chips digestion, spent liquor evaporation and bleaching as volatile organic carbons (VOCs), and from combustion process as nitrogen oxidies (NOx) and SOx. VOCs also include ketone, alcohol and solvents such as carbon disulfide methanol, acetone and chlorofom (Smook, 1992).

Biological treatment both aerobic and anaerobic technologies are preferred for treatment of pulp and paper mills because of wastewater composition consisting of high organic compounds and economical aspects.

Disposal strategy of solid wastes generated from pulp and paper industry is varied depends on the country and the regulations obeyed. After sorting and handling, dewatering, thermal application such as combustion and anaerobic digestion to obtain energy and deposit in landfills are general applications. However, the solid wastes should be monitored after landfill deposition because of toxic characteristics of the compounds (Monte *et al.*, 2009).

1. Also gaseous pollutants are other environmental problems generated from pulp and paper industry. To minimize these pollutants, physico-chemical methods such as adsorption to activated coal filters absorption, thermal oxidation, catalytic oxidation and condensation have been widely used (Eweis *et al.*, 1998). In the last decade, low cost and effective trends have been developed to prevent the limitation of physico-chemical applications such as energy cost and generating secondary pollutants (Sumathi & Hung, 2006).

Waste characterization and source

- Pulp and paper industry is one of the most water and energy consuming industry in the world. This industry uses the fifth largest energy consumer processes; approximately 4% of total energy is used worldwide. Also during pulp and paper process, the important amount of waste is produced. It has been estimated that 500 million tons of paper and etc. per year will be produced in 2020. Three different raw materials are used in the pulp and paper industry as nonwood fibers and wood materials; soft and hard woods. Waste and wastewaters are generated from both of pulp and bleaching processes. Additionally, 100 million kg of toxic pollutants are released every year from this industry.

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..

- 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 .
- 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 (NaS_2). Mixture of sulphurous acid (H_2SO_3) and bisulfide ions (HSO_3^-) is used in acidic media named as sulfide process.

Waste management

- During the pulp and paper production, high usage of water and energy results in large amount of waste generation like wastewater, solid waste and air emissions. Different types of waste are produced from different production steps and all these wastes pose important environmental problem. To solve this problem:

. Waste minimization can be done by using new and best available technologies.

. End-of-pipe treatment technologies should be used before the discharge and/or disposal.

Waste minimization

- Modern waste minimization approach is by two means. This first way is chemical recovery and recycling. This system especially in chemical pulping process significantly reduces pollutants and additionally economical return is another important aspect. Chemical recovery is necessary because of the basic economic viability of the kraft process. According to EPA, all kraft pulp mills worldwide use chemical recovery systems. However, there is still no recovery system in some sulfite mills. Additionally, scrubber system particulate "baghouses" or electrostatic precipitators (ESPs) are often mill air pollution control components (EPA, 2002).

- The second way to minimize waste production from pulp and paper mills is the application of best available techniques (BAT) according to the Integrated Pollution, Prevention and Control (IPPC) Regulation. An effective waste minimization method reduces cost, liability, regulatory burdens of hazardous waste management . Furthermore, hazardous waste generation can be reduced by waste management methods including:

- production, planning and sequencing
- process adjustment and/or modification
- raw material replacement
- House keepingwaste segregation and seperation
- recycling

- The industries have developed and applied new technologies instead of conventional pulping and bleaching processes. Some examples of these new technologies are given below:
- Organic Solvent Pulping: This process is more economical for small and medium scale plants for significant recovery and reuse of chemicals. In this process, organic solvent like ethanol, methanol, etc. are preferred. However, this process is more energy consumer than conventional ones .

- Acid Pulping: Acetic acid under the high pressure is used for treating of wood chips. The disadvantage of this process is to loss of acid, however recovery is possible .

- Biopulping: Microorganism or microbial enzymes such as xylanases, pectinases, cellulases, hemicellulases, ligninases, and their combination are used in the pulping process to improve the properties of pulp . Biopulping is preferred because:

- To reduce the chemical and energy utilization
- To reduce the pollutants
- To increase the yield and strength properties of pulp.

- Biobleaching: Fungal cells and or their enzymes are used for pretreatment of pulp. A number of studies showed that application of white rod fungi reduces the chemical dosage of bleaching and enhances the brightness of paper .
- Extended Delignification: Enhanced removal of lignin before bleaching step is the main concern of this method . It may be achieved by extended cooking, oxygenation, ozonation, and addition of chemical catalysts. Extended delignification positively affect on the bleach effluent quality parameters such as COS, BOD, color and AOX.

Treatment strategies

- **Primary Treatment**
- In this step, the aim is to remove suspended solid such as bark particles, fiber, fiber debris, filler and coating materials and consequently organic materials. Primary clarification can also be achieved without sedimentation and flotation. However mentioned that sedimentation is generally preferred application for the pulp and paper mills in UK and approximately 80% of suspended solid was removed successfully. Also reported 70-80% of removal in the sedimentation. Dissolved air flotation and filtration are the other option as primary treatment for pulp and paper mills.

Secondary Treatment

- Aerobic lagoons, activated sludge systems, anaerobic treatment and sequential biological treatment (aerobic-anaerobic or anaerobic-aerobic) are the most common biological treatment application for pulp and paper mills.

- This conventional treatment system is used in treatment of several industrial wastewater types in order to remove COD, BOD, SS, and AOX. There are a lot of studies in the literature to show the treatability of pulp and paper mills by activated sludge system. Some of them focused on the BOD, COD, AOX and other specific compound removal under different operation conditions. showed that 74% of filtered COD, nearly %100 BOD5, resin and fatty acid removal were achieved in the full-scale plant. reported that 82% and 60% COD removal efficiency at paper mills and pulp mills, respectively in full-scale activated sludge systems of Finland. Knudsen *et al.* (1994) claimed high COD and BOD removal efficiency by two stage activated sludge process. Chandra (2001)

Anaerobic Treatment Processes:

- Anaerobic treatment processes are more suitable for treatment of high strength wasteanaerobic microorganisms are more efficient than aerobics in order to degrade chlorinated organic compounds. However, the sulphur content in the wastewaters is the main disadvantages for application of anaerobic systems, water such as pulp and paper mills

Aerated Lagoons (Stabilization Basins):

- Aerated lagoons are the simple and economical biological systems and they have been studies very well as lab-scale and full-scale at the pulp and paper mills. These systems have been used for removal of BOD, low-molecular weight AOX and fatty acids at full-scale application.showed that 70% of AOX could be removed efficiently in a short residence time. reported that COD removal was achieved as 30-40% in a full-scale lagoon and 60-70% in a pilot-scale plant.

Fungal Treatment:

- Fungal species have been used to remove colour and COD from pulp and paper mills . Pencillium sp., P. chrysosporium and white rod fungi are the most widely used species. Choudhury *et al*. (1998).

Tertiary Treatment

- **Coagulation/Precipitation**
- that alum salts as coagulant were removed 96% of COD from the paper machine, 50% of COD from pulping, and %20 COD from bleaching effluents. The other study showed that polyelectrolytes were more effective than the conventional coagulant on the removal of turbidity, COD, and colour.

Adsorption:

- This method relies on the addition of an adsorbant such as activated coke, fuller’s earth, coal ash, activated carbon, and activated charcoal to the wastewater to remove the pollutants. High removal of colour by activated charcoal, fuller’s earth, and coal ash was reported Also showed that high removal of colour, COD, DOC, and AOX from bleaching wastewater by activated coke.

- Advanced oxidation methods such as photocatalysis, photo-oxidation, Fenton type reactions, wet oxidation, ozonation are used to achieve the destruction of chromophoric and nonchromophoric pollutants in pulp and paper mills. The achievement of photocatalytic reaction in the removal of COD is depended on the concentration of COD and chloride, which are below a certain level . Fenton and photo-fenton reactions are highly effective for the treatment of bleaching kraft mill effluent . Verenich *et al.* (2000)

Membrane Filtration

• Membrane filtration is a potential method to remove colour, COD, AOX, salts, heavy metals, and total dissolved solids from pulp and paper mills . The effluent of membrane filtration can be used again in production process or discharge directly to the receiving water bodies. showed that 88% and 89% removal of BOD and COD, respectively was achieved by reverse osmosis (RO).

Treatment of gas emissions

- Air pollution control at pulp and paper mills has been important concern in the recent years. Especially VOCs produced form pulp and bleaching steps and steam are conventionally treated by physico-chemical methods such as adsorption to activated coal filters, absorption, thermal oxidation, catalytic oxidation, and condensation .

Conclusion

- The paper demand increases every day as a result of developed population and industrialisation. Water and energy utilization and in particularly waste generation are becoming more important concern ever worldwide. A major goal is to decrease damage to environment by waste minimization, reuse and recycle. To use best available techniques and innovative methods is becoming more an issue. However, end-of-pipe treatment is still the major approach to minimize the risk. To evaluate pollutants and to develop treatment technologies need a holistic approach.