CONTROL OF POLLUTION IN THE PULP AND PAPER INDUSTRY

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Contents

Summary

The use of paper for various purposes is an essential feature of the modern society. Therefore pulp and paper manufacturing is very important part of modern industry. In

the present review different technologies for pulp production considering their advantages and shortcomings are discussed. More attention is paid to the kraft-process, one of the mostly used in pulp production. The environmental issues of these technologies, as emissions in air, wastewater treatment and chemicals recycling are considered. New development, as replacement of toxic chemicals with harmless ones, improvements in process technology, and process control, etc. are pointed out.

Attention is paid to the importance of secondary paper use for pulp preparation. It contributes to reduction of raw wood consumption, to simpler and safer processes of pulping with less adverse effect on environment.

1. Introduction

Pulp and paper production is based on the use of wood as raw material, but also on the consumption of large-scale chemicals, like chlorine, sodium hydroxide, etc. The development of pulp and paper industry is associated exclusively with the presence of own wood resources, as it is in the USA, Canada, Finland, Russia, Sweden, etc. From the developed countries only Japan relies on imported raw materials for its paper production.

From financial point of view, pulp and paper production is a considerable source of income for the manufacturing countries. On the other hand, however, the extension of this industry provokes serious concern because of the forest exhaustion and the very slow rate of their restoration. That is why some countries, like Norway, prefer to import wood for paper industry, instead of use of their own. Brazil for example has started a program for planting of rapidly growing trees for this purpose.

It is clear therefore, that paper industry and the consumption of paper have impact on environment not only through the pollution that the paper production enterprises exert on air, water and soils, but as well as to a higher extent by the deforestation that results for paper demand and production.

2. Technologies for Pulp and Paper Production

The usual substrate for paper production is the slurry of cellulose in water. The source of cellulose for paper industry is the wood, coniferous and deciduous. The wood contains two additional components: lignin and hemicellulose.

Whereas cellulose is a polymer of glucose units, the molecules of the monomer *n*-propyl-benzene, bound by ether -C-O-C- and -C-C- bonds compose lignin molecules. Because of the high content of benzene rings in its molecules, lignin is easily oxidized and darkens.

Hemicellulose is composed by polymers with lower molecular mass, being intermediates of the biosynthesis of cellulose.

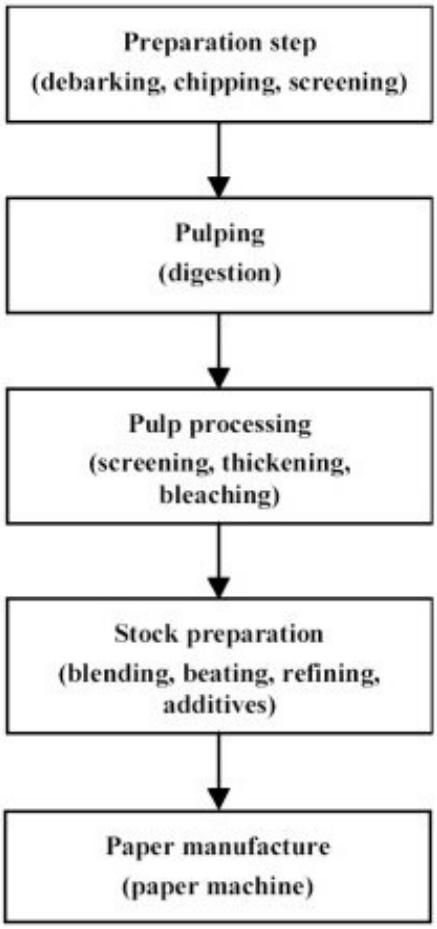

Figure 1: A principal sketch of the paper manufacturing process

Both cellulose and hemicellulose are components of the paper.

Paper production comprises the following main stages in technology: pulping (pulp making), pulp processing and paper (or paperboard, etc. paper goods) production, cf. Fig. 1.

2.1. Pulp making

Pulp making has as an aim digesting the raw material into its fibrous components via chemical, mechanical or combinations of different methods. There are mechanical methods, thermo-mechanical, chemical and semi-chemical ones for pulp making. The aim of these operations is to break down the wooden mass into fibers of cellulose. Chemical methods lead to release of cellulose fibers by destroying the chemical bonds in the glue-like lignin, which bonds fibers together.

The most important step in pulp and paper technology is pulp making, either from technological or environmental point of view. This is the most energy and chemicals consuming stage, as well as associated with harmful and nuisance emissions. It is the most water-consuming stage, i.e. for a large-scale pulp mills operating by the kraft-

method, it takes approximately 16 million cubic meters daily, or about 50 cubic meters /ton pulp. Below the following steps in pulp preparation are described.

2.1.1. Preparation Step

Preparation step includes debarking, cutting the wood timbers to chips and screening the latter. Timbers could be either dry or washed by strong water jets. In the second case debarking is more efficient, but waste water results. After debarking, the smaller timbers are chopped in stone mills or by cutting disks. The uniform size of the wooden chips is the important condition for the successful further treatment of wood. Sawdust is collected and treated separately. It could be recycled to the pulp making stage.

2.1.2. Pulping

Mechanical pulping. The pulp is obtained by mechanical operations only. Mills and disintegrators are used to convert the wooden chips to slurry. The latter is good for a low quality paper or wallpaper. Sometimes mechanical pulp is added to the bleached ones to give smoothness and opacity. Mechanical pulping is used in 10 per cent of the pulp producing facilities.

Thermo-mechanical pulping. In this case mechanical grinding is preceded by thermal treatment with steam at 120-130^{0}C during 2-3 minutes. At this procedure the wooden mass is disintegrated with longer fibers with a higher strength. The advantageous properties of the thermo-mechanically treated pulp make it possible to be used instead of the chemically treated ones. The yield (i.e., 90 per cent) is twice as much higher. It is beneficial for its use for newsprint.

Very important advantage of these pulps is the lack of serious pollutants of environment, because no chemicals are used for their production.

Chemical pulping. Chemical processes are aimed to soften or to remove lignin from the wooden mass and to separate the fibers. If these processes are applied after mechanical grinding they are called chemical-mechanical pulping. Another group of methods use the chemical processes to remove the whole amount of lignin from the wooden chips. In those cases the slurry is obtained directly, almost without mechanical operation for fibers separation from the wooden mass. Although the selectivity of the chemical methods, inevitably some chemical degradation of cellulose takes place.

The main advantage of the methods of chemical pulping is their broad applicability for various types of wood. Chemical pulping is used in 85 per cent of the pulp producing facilities.

Chemico-mechanical pulping. First, preliminary maceration of the wood (chopped or not) in hot solution of sodium hydroxide is carried out. Some amount of sulfur dioxide could be added in order to avoid the darkening of the broth. Chemico-mechanical pulping results in partial removal of lignin. Yields are up to 90 per cent, and the pulp properties enable its use for newsprint from mixed wooden substrates (coniferous and deciduous). Moreover, this treatment leads to considerable saving of energy for wood

conversion into fiber.

Semi-chemical pulping. In this method, the chemical methods are more applied. Different tools are used in this method: by reducing the chemicals: wood ratio, reduction of boiling time and/or the use of chemicals enabling the treatment to be carried out in almost neutral medium. Such chemicals are sodium sulfite, bisulfite and sodium sulfate.

One of the most widely used methods (neutral semi-chemical pulping) involves the treatment of wooden mass with a liquor consisting of aqueous solution of sodium sulfite and sodium carbonate, mixed in a ratio to give sodium sulfite and sodium bicarbonate (at pH 8.5). Sodium sulfate is produced by combustion of elemental sulfur.

The liquor contains, (per cent): sodium sulfite, 82; sodium bisulfite, 4; sodium bicarbonate, 14. Extreme decrease of pH has to be avoided, to prevent the cellulose acid degradation.

The pulp is boiled preliminary in solutions, containing sodium sulfite/carbonate. After that the pulp is filtered, washed, and refined. This product of this treatment still contains lignin, and it is not suitable for production of high quality paper. It could be added to slurries to produce coarser products, i.e. cardboard.

Semi-chemical pulping is used in 5 per cent of the pulp producing facilities.

Chemical processes: The difference between the semi-chemical and the chemical pulping consists in the fact, that chemical pulping is deep and therefore leads to almost complete dissolution of lignin.

Chemical pulping is carried out at much higher or much lower pH values and higher chemicals: wood mass ratios. It is designated for high quality white paper pulps under conditions that allow small amounts of lignin to remain.

3. Chemical Pulping

3.1. Acid Chemical Pulping

The acid chemical pulping is carried out by the sulfite method. The liquor consists of aqueous solution of sodium sulfite. It is produced by combustion of sulfur or pyrites and to the solution some lime is added (by passing the sulfite solution through a column, packed with limestone pieces.Sulfite pulping is carried out at 110-145^{0}C, for 8-10 hours. Heating and the liquor acidity lead to hydrolysis and sulfonation of lignin, as well as to the formation of sulfonic and aldonic acids.

Presence of sulfuric acid is not desired, because of the possible deeper cellulose degradation.

The acid sulfite digestion leads to product, which is light in color and easily bleachable. This method is applied for production of paper good for napkins, packaging, etc.

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Biographical Sketch

Venko N. Beschkov was born in 1946 in Sofia, Bulgaria. He obtained his M. Sc. degree in inorganic and physical chemistry in the University of Sofia "St. Clement Ohridski" (1969). He obtained his Ph.D. degree in the Central Laboratory of Chemical Engineering at the Bulgarian Academy of Sciences in Sofia Bulgaria (1978), and his D.Sc. degree in 1996. He was promoted as associate professor in 1984 and as a full professor in 1997. Venko Beschkov is Director of Institute of Chemical Engineering at the Bulgarian Academy of Sciences (since 1993).

The scope of his scientific activity is on mass transfer operations in chemical and biochemical engineering, bioprocess engineering and environment protection (fine chemicals production, waste water treatment, gas pollution removal, etc.). He has over 60 scientific papers and 1 monograph (*Boyadjiev Chr., V.Beschkov, Mass Transfer in Liquid Film Flow, Publishing House of the Bulgarian Academy of Sciences, Sofia, 1984*) published. He is an editor-in-chief of the scientific journal *Bulgarian Chemical Communications* (since 1996). He was also an editor of textbooks on chemical technology in Bulgarian (1986).

His teaching activity consisted in delivering courses in hydrodynamics in the Faculty of Chemistry, University of Sofia “Climent Ohridski" as a assistant professor and a reader (1976-1984); in biochemical engineering in the Faculty of Biology, University of Sofia “Climent Ohridski" as a reader (1987-1989); in technology in bioconversion as a reader in the University of Chemical Technology & Metallurgy, Sofia, Bulgaria (since 1999).

He was Deputy-minister of The Ministry of Environment Protection in the Government of The Republic of Bulgaria (1991/92), consultant and trainer in different international projects on environment protection (since 1993).