Chapter 6
Pulp and Paper Making Process

Abstract Pulp and paper mills are highly complex and integrate many different process areas including Raw material preparation (wood debarking and chips preparation); Pulping (including cooking or refining, washing, screening and cleaning and thickening); Pulp bleaching (if required) and Paper making. The major unit operations are pulping, bleaching and paper making. Brief description of pulp and paper making process is presented in this chapter.

Keywords Pulp and paper mills · Raw material preparation · Wood debarking · Chips preparation · Pulping · Cooking · Refining · Washing · Screening · Cleaning · Thickening · Pulp bleaching · Paper making

Pulp and Paper industry is a highly water-dependent industry when compared with many other industries. Due to the severe environmental regulations, the industry is responsible for the management of the water resources they use. Such resources are usually obtained from the surface and ground waters and after being used in almost all the main process stages (Fig. 6.1), and also for cleaning the equipment, cooling the machines, etc. form the main part of the liquid reject from the pulp and paper industry (Kamali et al. 2016). Due to the increasing concerns on the scarcity of water resources, the water management in water intensive industry is of high importance and therefore strict environmental regulations have been developed for ensuring the sustainable use of the water resources in industrial water users. At the beginning of the last century the manufacturing processes in addition to other internal use required high amount of water (200–500 m^3/tonne paper). But now, this amount has been significantly reduced due to the technological advances in the pulp and paper production processes. Furthermore, in many developed countries, the use of recovered paper produced has significantly increased in the last two decades resulting in a decrease in the amount of the wastewater generated for the production of pulp and paper, due to the recycled fiber mills being less water intensive as compared to virgin mills (Hong and Li 2012). Although the industry is a large user of water, only a small part of the water used is utilized during the manufacturing activities in a typical pulp and paper mill. Wiegand et al. (2011)

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have reported that in United States, about 88% of the intake water is returned to the surface waters after being treated, whereas only 11% of it is evaporated and 1% is embedded in products or in solid wastes. Therefore, advanced treatment processes can significantly aid the mills to improve the quality of the effluents satisfying the environmental regulations. Furthermore, some internal treatment processes can be provided in order to re-use the water during the manufacturing processes.

Pulp and paper manufacture is a complex process. The basic unit operations are (Fig. 6.1):

- Raw material preparation (wood debarking and chips preparation).
- Pulping (including cooking or refining, washing, screening and cleaning and thickening).
- Pulp bleaching (if required).
- Paper making.

The three major unit operations are pulping, bleaching and paper making. A large amount of water is used in these processes. A mill may have one, two or all three of these basic operations and often more than one of a given operation. The major sources of water effluents are shown in Table 6.1.

Wood pulp is produced by three main processes: Mechanical forces in the presence of water (mechanical pulping). The process involves passing a block of wood, usually debarked, through a rotating grindstone where the fibres are stripped of and suspended in water; Chemical pulping utilises significantly large amounts of chemicals to break down the wood in the presence of heat and pressure. The spent liquor is then either recycled or disposed of by burning for heat recovery; Chemical thermo-mechanical pulping is the combination of chemical and mechanical pulping. The wood is first partially softened by chemicals and the remainder of the pulping proceeds with mechanical force (Bajpai 2012; Thompson et al. 2001).

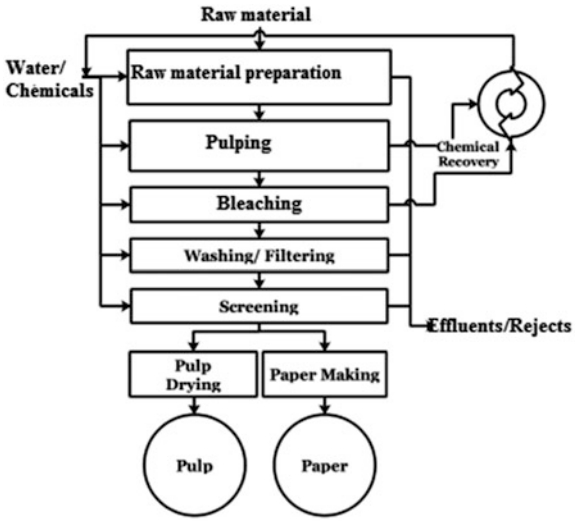

Fig. 6.1 Schematic of pulp and paper production process

Table 6.1 Major sources of water effluents

Waste water from material preparation
Spent pulping liquor from pulp washing
Digester and evaporator condensates (chemical pulping only)
White waters from screening, cleaning and thickening systems
Bleach plant washers filtrates
Paper machine white water

In the 1970s and 1980s, there was concern over the release of chlorinated organic substances, such as dioxins and furans, from the use of chlorine in pulp bleaching. Facing market and environmental demands for "Elementary Chlorine Free" (ECF) and "Totally Chlorine Free" (TCF) bleached pulps, mills adopted bleaching processes which use chlorine dioxide (ECF pulp) or which use oxygen-containing compounds such as molecular oxygen, peroxide and ozone (TCP pulp) (Lovblad 1999).

In the production of paper, pulp is diluted to at least 99% with water and a mineral filler; china clay, titanium dioxide or chalk; and water-soluble substances such as optical brighteners and polyvinyl alcohol are added (Hentzschel et al. 1998). This is then pumped to a headbox and is distributed evenly along a moving wire cloth. This even distribution is facilitated by the constant side-to-side movement and vibration afforded by the headbox. The majority of the water drains through the wire leading to the formation of a wet paper sheet. This is then vacuum dried and pressed, to extract more water and form the paper sheet. Residual water is removed by passing it through a series of steam-heated cylinders.

Recycled paper is an important source of cellulose fibre for certain paper and board grades (corrugated paper, newsprint). For white grades, such as newsprint, the recycled fibre is de-inked using flotation, followed by washing and screening. Soluble components such as starch are removed in the wastewater.

In case of an integrated pulp and paper mill, most of white water from paper making operation is recycled to the pulp stock preparation and pulp washing in the pulping operation; thus the mill effluent is mainly from the spent pulping liquor, evaporator condensates and bleaching washer filtrates, although a small amount of effluent may be produced from some other operations, such as raw material preparation. Those mills which do not perform pulping and bleaching, the white water from papermaking is the only source of the mill effluent. The pollution loads from the pulp and paper industry mainly depends on pulping and bleaching methods used (Bajpai 2012).

For each tonne of manufactured pulp, the waste water discharge volume ranges from 30 to 180 m^3 whereas 20–70 m^3 is discharged per tonne of paper and paperboard (Gullichsen 1991; Miner and Unwin 1991). The quantities and characteristics of the generated pulp and paper waste waters are highly dependent on the type of raw material, the process conditions applied such as temperature, pH, pressure, chemical and mechanical treatments and the specific water consumption (Stemberg and Norberg 1977). Chemical addition and, to a lesser extent, high temperatures and pressure result in an increased release of organic matter into the

process water and extensive solubilization of lignin. Therefore, the pollution loads and the colour due to dissolved lignin compounds is very high for chemical as compared to mechanical pulping effluents (Corson and Lloyd 1978; Virkola and Honkanen 1985). The COD loads associated with the mechanical pulping processes range from 20 to 50 kg COD/tonne of pulp whereas in case of soda pulping processes the COD loads may be as high as 500–900 kg COD/tonne of pulp (Stemberg and Norberg 1977; Anonymous 1986). Nevertheless, the black liquors originating from Kraft and soda processes are usually burnt to recover the pulping chemicals and the calorific power from the organic components. This reduces to a great extent, the environmental impact associated with these pulping processes. Conventional recovery processes are not economically viable in small paper mills and in those mills using nonwoody raw materials with a high silica content. Black liquors represent a very important pollution source in several countries where small scale mills are common (Anonymous 1986; Velasco et al. 1985; Gonenc et al. 1990).

Pulp and paper industry waste waters may cause considerable damage to receiving waters if discharged untreated. The environmental impact associated with these wastewaters is not only restricted to the oxygen demand but also numerous effluents from the pulp and paper industry show acute or chronic toxicity to fish and other aquatic organisms (Roger 1973; Leach and Thakore 1976). Furthermore, these wastewaters streams often exert inhibitory effects on microorganisms, which can disturb biological treatment systems (Bajpai and Bajpai 1997; Bajpai 2013; Ferguson and Benjamin 1985; Welander 1988).

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