Chapter 2
Generation of Waste in Pulp and Paper Mills

Abstract In the Pulp and Paper Industry several types of solid wastes and sludge are generated. Solid waste is mainly produced from pulping, deinking processes and wastewater treatment. The waste generation is strongly affected by the production process and wastewater treatment technologies. About 40–50 kg of sludge (dry) is generated in the production of 1 tonne of paper at a paper mill and of that approximately 70 % is primary sludge and 30 % secondary sludge. The amount of sludge on a dry mass basis may vary from 20 % in a newsprint mill to 40 % in a tissue mill. The data on waste generated in pulp and paper mills and deinking mills are presented in this chapter. Waste generated through production of different paper grades from recycled fibre are also presented.

Keywords Waste generation • Pulp and paper mill industry • Solid waste • Recycled fibre • Wastewater treatment • Primary sludge • Secondary sludge

Different types of solid wastes and sludge are generated in the Pulp and Paper Industry at different production processes (Monte et al. 2009; Gavrilescu 2004, 2005; Abubakr et al. 1995). Treatment of wastewater generated at pulping, paper-making, and deinking processes is the main source of wastewater treatment sludge and deinking sludge. Tables 2.1 and 2.2 show solid waste generated in pulp and paper mills (Monte et al. 2009; IPPC 2001; CANMET 2005). Overall view of the solid waste rates in the Kraft pulp mill are presented in Table 2.3 (Gavrilescu 2004).

Balwaik and Raut (2011) have reported that about 300 kg of sludge is produced for each 1 ton of recycled paper. The amount of waste generated in paper production varies greatly within different regions, because of different recycling rates. In Finland, the ratio of recycled fiber production to paper production can be expected to be smaller than example in central Europe (Kujala 2012). This is due to the reason that most of the paper produced in Finland is exported to other countries and so the amount of recovered paper is relatively low. According to WRAP (2010), over 5 million tons of paper and board was produced in 2007. At the same time, the production of paper mill sludge from Recycled fiber production was approximately 1 million tons (Rothwell and Éclair-Heath 2007).

The generation of wastewater treatment sludge vary widely among mills (Lynde-Maas et al. 1997; Reid 1998; Elliott and Mahmood 2005, 2006;

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Table 2.1 Solid waste generated in pulp mills

Rejects
The rejects from virgin pulps consist of sand, bark and wood residues from wood handling, which are undesirable for papermaking. Rejects typically have a relatively low moisture content, significant heating values, are easily dewatered and are, generally, burned in the mill's bark boiler for energy recovery
Green liquor sludge, dregs and lime mud
These are inorganic sludges separated from the chemical recovery cycle. These sludges are normally landfilled, after dewatering and drying
Wastewater treatment sludge
It comes from two sources: primary sludge and biological sludge generated in the second clarifier. These sludges are generally blended together, a polymer added and dewatered together to a 25–40 % dry solid content
Chemical flocculation sludge
It arises from water treatment and is often transported to the landfill site due to the high content of inorganic matter and water

Based on Monte et al. (2009), IPPC (2001), CANMET (2005)

Table 2.2 Solid waste generated in paper mills

Rejects
The rejects from recovered paper are impurities and consist of lumps of fibres, staples and metals from ring binders, sand, glass and plastics and paper constituents as fillers, sizing agents and other chemicals. Rejects also have a relatively low moisture content, significant heating values, are easily dewatered and are, generally, incinerated or disposed of in landfills. Screen rejects are produced during filtration steps with screens with very small slots to remove pulp possibly containing stickies that might disturb the production process and quality of end product. Screen rejects have a high content of cellulose fibre
Deinking sludge
This residue contains mainly short fibres or fines, coatings, fillers, ink particles (a potential source of heavy metals), extractive substances and deinking additives. It is normally reused in other industries (e.g. cement, ceramics), or is incinerated, even though it has a poor heating value. Deinking sludge is generated during recycling of paper (except for packaging production). Separation between ink and fibres is driven by "flotation" process, where foam is collected on the surface of flotation cells. The generated deinking sludge contains minerals, ink and cellulose fibres (that are too small to be withhold by filters)
Primary sludge
This sludge is generated in the clarification of process water by kidney treatments, e.g. dissolved air flotation. The sludge consists of mostly fines and fillers depending on the recovered paper being processed and it is relatively easy to dewater. This sludge can be reincorporated into the process for board industry, but for high grade products can be incinerated, dumped or, otherwise, mixed with deinking or secondary sludge
Secondary or biological sludge
This sludge is generated in the clarifier of the biological units of the wastewater treatment, and it is either recycled to the product (board industry) or thickened, dewatered and then incinerated or disposed of in landfill. Secondary sludge volumes are lower than those corresponding to the primary sludge, since most of the heavy, fibrous or inorganic solids are removed in the primary clarifier. Secondary sludges are often difficult to handle (due to a high microbial protein content), and such solids need to be mixed with primary sludge to permit adequate dewatering

Based on Monte et al. (2009), IPPC (2001), CANMET (2005)

Table 2.3 Generation of waste in a Kraft mill

Waste	Yield (kg/t o.d. pulp)
Wood wastes:	
Sawdust coming from the slasher deck	10–30
Bark falling from the debarking drum	100–300
Pins and fines from chip screening	50–100
Wood waste from woodyard	0–20
Knots from pulp deknotting	25–70
Sodium salts from recovery boiler	5–15
Dregs and grit from causticizing:	5–10
Dregs	10–30
Grit	15–40
Total:	220–615

Based on Gavrilescu (2004)

Table 2.4 Generation of waste from few European pulp and paper mills

	SCA	Norske Skog	Stora Enso	Holmen
Mill production (millions of tonnes)	9,9	4,8	15,1	2,3
Total waste generated (kg/ton product)	163	163	155 (dry)	160
Recovered waste (kg/ton product)	115	138	–	136
Waste sent to landfill (kg/ton product)	47	16	22	23 (wet)
Hazardous waste (kg/ton product)	0,3	1,5	0,3	0,2

Based on Monte et al. (2009)

Table 2.5 Generation of waste in different processes in Europe

Process	Kraft	Sulphite	Mechanical semi-chemical	Recycled fibre
Specific waste (kg/Adt)	100	80	60	185
Waste generated through paper production (million tonnes)	2,1	0,2	0,8	7,7

Based on IPPC (2001), Monte et al. (2009)

Krigstin and Sain 2005, 2006; Monte et al. 2009; Abubakr et al. 1995). Not much data is available on total waste generation. This is due to the fact that most of the pulp and paper mills already have processes applied to internally treat the wastes which reduce the generation of solid waste. This applies to bark residues from debarking which are incinerated in the bark boiler and, as a result, only ashes remain as waste. The same can apply to sludge incineration. Data on generation of waste from few European pulp and paper mills – Holmen, SCA, Norske Skog, Stora Enso are presented in Table 2.4 (Monte et al. 2009).

The amount of waste generated when virgin fibres are used as raw material depends mainly on the pulping process used (Table 2.5) (IPPC 2001; Monte et al. 2009). IPPC (2001) reports that in Europe, 65 % of total pulp production is kraft pulp which produces about 100 kg/Adt of wastes. Semi-chemical and mechanical processes produce about 60 kg/Adt.

CEPI (2006) has reported that in 2005, the total production of paper in Europe was 99.3 million tones. This generated 11 million tonnes of waste, representing about 11 % in relation to the total paper production. The production of recycled paper, during the same period, was 47.3 million tonnes generating 7.7 million tonnes of solid waste (about 70 % of total generated waste in papermaking) which represents 16 % of the total production from this raw material.

The amount of waste sludges generated from a mill using secondary fiber differ from a mill using virgin materials. Also, the composition is different. A greater amount of rejects is produced when processing recycled fiber, because of the unrecyclable filler proportion in the raw material. This problem is especially conspicuous in mills producing recycled paper from office waste, using highly filled grades as the raw material. Deinking mill sludge generally has a higher ash content; the kraft pulp mill sludge is found to be high on sulfur. Obviously, great variations occur within both plant types, depending on the processes and raw materials (Glenn 1997). The amount of wastes produced in paper mills based on recycled fibre depends mainly on the quality of recovered paper used as raw material. It also depends on the effort and expenses made in preparation of secondary fibres for certain product and process requirements. The average quantities of waste generated through production of different paper grades from recycled fibre are presented in Tables 2.6 and 2.7 (Kay 2002; Scott and Smith 1995; Gavrilescu 2008).

2.1 Generation of Wastewater Treatment Sludge

Joyce et al. (1979) have reported that about 40–50 kg of sludge (dry) is generated in the production of 1 tonne of paper at a paper mill in North America. Of that approximately 70 % is primary sludge and 30 % is secondary sludge (Elliot and Mahmood 2005, 2006). The primary sludge can be dewatered relatively easier. Compared with the primary sludge, the secondary sludge is very difficult to dewater. The secondary sludge consists mostly of excess biomass produced during the biological process (Ramalho 1983). About half of the incoming organic pollution load is converted into secondary sludge. The solid content is 0.5–2 % solids (Winkler 1993). Generally, a treatment plant includes both primary and secondary treatment stages installed one after another. Primary treatment stage is based on the sedimentation process mainly, but also can be implemented by a flotation method.

Table 2.6 Waste generated through production of different paper grades from recycled fibre

Paper grade	Solid waste (dry basis, kg/Adt)
Packaging paper	50–100
Newsprint	170–190
Light-weight coated paper/super-calendered paper	450–550
Tissue and market pulp	500–600

Based on Kay (2002)

Table 2.7 Rejects and sludge generation from different recovered paper grades and papers

Paper grade	Recovered paper grade	Total waste	Rejects		Sludges	
		Rejects and sludges	Heavy-mass and coarse	Light-mass and fine	Flotation de-inking	White water clarification
Market DIP	Office paper	32–46	<1	1 4–5	12–15	15–25
Graphic paper	News, magazines	15–20	1–2	3–5	8–13	3–5
	High grades	10–25	<1	≤3	7–16	1–5
Sanitary paper	News, magazines, office paper, medium grades	27–45	1–2	3–5	8–13	15–25
Liner, fluting	Old corrugated containers, Kraft papers	4–9	1–2	3–6	–	0–1
Board	Sorted mixed recovered paper, old corrugated containers	4–9	1–2	3–6	–	0–1

Based on Scott and Smith (1995), Gavrilescu (2008)

The secondary treatment stage, is based on biological treatment preformed in either aerobic lagoons, activated sludge systems, anaerobic treatment or sequential biological treatment (aerobic-anaerobic or anaerobic-aerobic) systems. Moreover, tertiary treatment can take place in addition to the above mentioned treatment stages in countries with tight environmental regulations (Bajpai 2000; Bahar 2009; Abubakr et al. 1995). About 80 % of total suspended solids contained in wastewater entering the treatment process are transferred to wastewater treatment sludge during the primary process (Monte et al. 2009). Inorganic part of wastewater treatment sludge is mostly present in the form of sand, while organic part is present as bark, fibre or other wood residuals. During the biological treatment, soluble organic materials are converted to carbon dioxide, water and biomass by microorganisms present in active sludge and required for successful process implementation. The excess biomass is settled in the secondary clarifier where secondary sludge also known as biological sludge, biosolids or activated sludge, is produced (Bahar 2009; Abubakr et al. 1995). Depending on a certain treatment scheme applied at a certain mill, primary sludge and secondary could be also either mixed together or collected separately. Basically, primary sludge consists of both organic and inorganic matter, while secondary wastewater treatment sludge consists mainly organic materials.

Secondary sludges are often difficult to handle (due to a high microbial protein content). It needs to be mixed with primary sludge to allow adequate dewatering prior to landfilling (McKeown 1979). Secondary sludges can be incinerated in existing boilers, but due to their low solids content, the steam generation capacity of a boiler is often reduced. This results in operational problems. Secondary sludges may be landfilled, but leaching of soluble nutrients may lead to the contamination of ground water (Saunarnaki 1988). Secondary sludges can be also applied to land as a soil improving organic fertiliser, as long as the material does not contain chlorinated organic compounds (or adsorbable organo-halogens), as most of these are acutely toxic to fauna and flora (Walden and Howard 1981; Saunamaki 1988; Bajpai et al. 1999). Chlorinated organic substances are present in the solid and liquid effluent of pulp and paper mills that use elemental chlorine or chlorine dioxide for bleaching of pulp (Bajpai et al. 1999; Gullichsen 1991).

Wastewater treatment plant residuals are presented by several types and their shares within all wastewater treatment plant residuals are presented in Fig. 2.1 (Bird and Talberth 2008; Boni et al. 2003). The figure shows that there is no certain tendency on how to collect sludge. Moreover, not all mills conduct biological wastewater treatment on-site. So, they do not generate secondary sludge at all. Depending on the method of sludge treatment and utilization, separation of different sludge types, especially secondary sludge, could be beneficial. For instance, if sludge is proposed to be used in the production of construction materials then the highest content of inorganic content is beneficial. Moreover, primary and secondary sludge types are of different nature and in the case of necessary pretreatment, different sludge should be treated separately to achieve best possible results.

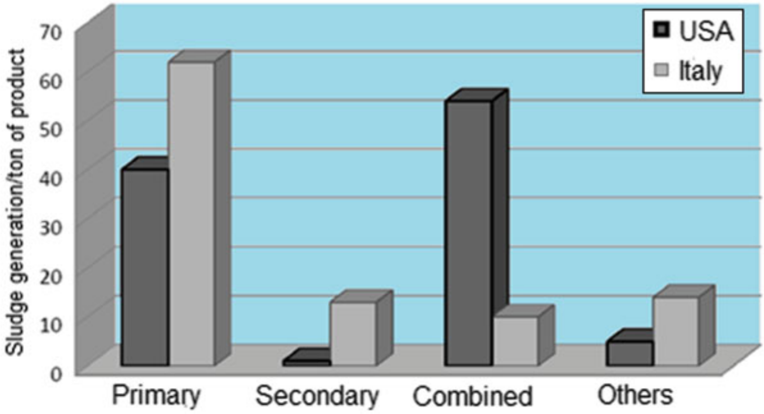

Fig. 2.1 Amount of different types of sludge generated by pulp and paper industry plants (Deviatkin 2013; Bird and Talberth 2008; Boni et al. 2003)

2.2 Generation of Deinking Sludge

Deinking sludge is generated in the mills producing recycled fibre from recycled paper (Bajpai 2006, 2013; Dash and Patel 1997; Seifert and Gilkey 1997). The amount of sludge on a dry mass basis can vary from 20 % in a newsprint mill to 40 % in a tissue mill. Deinking process enables increase of brightness and cleanliness of the material being produced so in many cases deinking process is included in the production scheme. Froth flotation deinking process is generally used in pulp and paper industry for selective deletion of ink particles only during recycled fibre processing. Wash deinking process is also used. This kind of deinking is aimed at removal of small particles, including fillers, coating materials, fines, and inks. However, froth flotation and wash deinking could be combined in the same production line so that the effect of unwanted materials removal is increased. In tissue paper production, in addition to deinking, de-ashing process is applied for better removal of fines and fillers (Kujala 2012; Deviatkin 2013). In case of deinking sludge, total suspended solids can be categorized into organic matter, such as bark and fiber, and inorganic matter, such as, kaolin, clay, calcium carbonate, titanium dioxide that are resulting from coating materials and other chemicals used for paper production.

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