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Preface

The management of wastes, in particular of industrial waste, in an economically and environmentally acceptable manner is one of the most critical issues facing modern industry, mainly due to the increased difficulties in properly locating disposal works and complying with even more stringent environmental quality requirements imposed by legislation. The development of innovative systems to maximize recovery of useful materials and/or energy in a sustainable way has become necessary. The significant residual waste streams from pulp and paper mills include wastewater treatment sludges, lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludges and wood processing residuals. Pulp and paper mill industries are always associated with disposal problem of highly contaminated sludge or bio-solids. In countries with large scale Pulp and paper production, the huge amount of waste generated has prompted the government and industries to find new use of these bio-solids. Paper mill sludges have a net environmental advantage over sewage sludges in that they are nearly pathogen free; handling and use pose lower health risks. Land filling, land application, composting, land-spreading to improve soil fertility, production of ethanol and animal feed, pelletization of sludge, manufacture of building and ceramic materials and lightweight aggregate, landfill cover barrier are among the waste management options studied. The challenge to find efficient methods for firing sludge still exists today and is becoming increasingly important as pulp and paper mill strive to be competitive. So far, incineration has been the primary alternative to landfill. However, incineration is associated with environmental pollution problems. The emission of gaseous NO_x and SO_2 are the major precursors of acid rain. The residue ash contains various toxic metals which need to be landfilled and hence result in ground water contamination. The plastics and glue found in the sludge are the sources of chlorinated compounds such as HCl, dioxins and furans which are major threat to the environment. This book presents general introduction on waste management in pulp and paper industry, generation of waste in pulp and paper mills, waste composition, methods of sludge pretreatment, processes and technologies for conversion of pulp and paper mill waste into valuable products, state-of the-art waste reduction techniques employed in the pulp and paper industry worldwide and future trends.

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Abbreviations

AOX	Adsorbable organic halides
BOD	Biochemical oxygen demand
CCPs	Coal combustion products
CDs	Cyclodextrins
CEC	Cation exchange capacity
COD	Chemical oxygen demand
CTMP	Chemithermomechanical pulp
DIP	Deinked pulp
DS	Dry solids
DSC	Dry solids content
EPA	Environment Protection Agency
ESP	Electrostatic precipitator
FRCA	Fine recycled concrete aggregate
GHG	Greenhouse gas
HPSEC	High pressure size exclusion chromatography
IPPC	Integrated pollution prevention and control
LHL	Low-high-low temperature
MDF	Medium density fiberboard
MDI	Methylene diphenyl diisocyanate
MTCI	Manufacturing and Technology Conversion International
NSSC	Neutral sulfite semi-chemical
OFS	Oil-from-sludge
PPMB	Pulp and paper mill biosolids
RPS	Recycled paper sludge
RTP	Rapid thermal processing
SCWG	Supercritical water gasification
SCWO	Supercritical water oxidation
SHF	Separate hydrolysis and fermentation
SSCF	Simultaneous saccharification and co-fermentation

SSF	Simultaneous saccharification and fermentation
UFA	Unsaturated fatty acids
WAO	Wet air oxidation
WPSA	Waste paper sludge ash
WWTP	Wastewater treatment plant
WWTS	Wastewater treatment sludge

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Chapter 1
General Introduction

Abstract The production of paper consumes high quantities of energy, chemicals and wood pulp. Consequently, the paper production industry produces high environmental emission levels mainly as carbon dioxide due to energy consumption, or solid waste streams which include wastewater treatment sludges, lime mud, lime slaker grits, green liquor dregs, boiler and furnace ash, scrubber sludges and wood processing residuals. In terms of volume, most solids or liquids are those from the treatment of effluents, although waste from wood is also produced in large quantities. Wastewater treatment plant residuals are the largest volume residual waste stream generated by the pulp and paper industry. The general background of waste management in pulp and paper industry are presented.

Keywords Waste management • Pulp and paper industry • Solid waste • Wastewater treatment sludges • Lime mud • Lime slaker grits • Green liquor dregs • Boiler ash • Furnace ash

1.1 The Paper and Paperboard Industry in the Global Market

The pulp and paper industry plays an integral role in the global economy. Approximately 400 million tonnes of paper and paperboard are produced globally (Bajpai 2013). Paper and paperboard consumption continues to grow in Asia, especially in China. Asia already accounts for well over a third of global paper and paperboard production. Meanwhile production in North America is shrinking. For the past 4 years, China has maintained the top spot for both demand and production of total paper and board, with the United States remaining in second place. China accounted for 25 % of world demand and 26 % of global production of total paper and board in 2012. In terms of pulp production, the United States remained the top producing country in the world with 50.4 million tonnes in 2012. China came in second producing 18.2 million tonnes. Estimates suggest that global paper consumption in 2025 will amount to 500 million tonnes, which means growth of about 1.6 % a year. Asia's share of global consumption is already 44 %. Europe and North America account for almost a third of consumption. Demand in Eastern Europe is also growing faster than in traditional markets. According to Confederation

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of European Paper Industries (CEPI) (2011), production of pulp in Europe was slightly increasing over the period of 1991–2011, while the production of paper and cardboard in European countries increased by 50 % over the same period. The production of pulp, paper and cardboard has grown in the Russian Federation as well (Deviatkin 2013). The production processes result in waste generation. According to Monte et al. (2009) in 2005 in Europe, 11 million tonnes of solid waste, including 7.7 million tonnes of waste from recycled fibre processing was generated during the production of 99.3 million tonnes of paper and in Russia in 2011, 15.2 million tonnes of pulp, paper, and board were produced (Deviatkin 2013). Meanwhile, about 25 % of all solid wastes generated in Pulp and Paper Industry and directed to landfills are wastewater treatment sludge and deinking sludge (Vuoristo 2012).

1.2 General Aspects of Waste Management

Solid waste is largely produced from pulping and deinking processes and wastewater treatment. Composition and amount of sludge are strongly affected by the raw materials used by the process, paper grade being produced, the production and wastewater treatment technologies and also the properties to be obtained (Monte et al. 2009; Abubakr et al. 1995). The important residual waste streams from pulp and paper mills include:

– Wastewater Treatment Sludges
– Lime Mud
– Lime Slaker Grits
– Green Liquor Dregs
– Boiler And Furnace Ash
– Scrubber Sludges
– Wood Processing Residuals

In terms of volume, most solids or liquids are those from the treatment of effluents, although waste from wood is also produced in huge quantities (Gavrilescu 2004, 2005; IPPC 2001; CANMET 2005; Battaglia et al. 2003; Geng et al. 2006; Suriyanarayanan et al. 2010; Krigstin and Sain 2005; Mladenov and Pelovski 2010; Springer 1993; Krogmann et al. 1997; Krogmann 1998; Charlie 1977; Hudson and Lowe 1996; Kay 2002, 2003; Reid 1997, 1998; Glenn 1997; Watson and Hoitink 1985; Nurmesniemi et al. 2007; Vehlow et al. 2007; Pickell and Wunderlich 1995). In countries with large scale Pulp and Paper production, the large amount of waste generated has prompted the government and industries to find new uses of these biosolids (Kay 2003; Glenn 1997; Watson and Hoitink 1985; Scott and Smith 1995; Abubakr et al. 1995; Vehlow et al. 2007; Young 1982; Turnbull 1982; Axegard and Backlund 2002; Ishimoto et al. 2000). In comparison to sewage sludges, paper mill sludges have a net environmental advantage in that they are almost free of pathogens; handling and use pose lower health risks.

Wastewater treatment plant residuals (WWTP) are the largest volume residual waste stream generated by the pulp and paper industry. In United States, about 5.5 million dry tons annually is produced (Bird and Talbert 2008; Thacker 2007). Wastewater treatment plant residuals are of four types:

– Primary including deinking residuals represents 40 % of WWTP residuals
– Secondary (waste activated sludge) sludge is 1 %
– Combined primary and secondary sludge is 54 %
– Dredged (5 %)

Mechanical dewatering is the norm of processing wastewater treatment plant residuals, with a solid content in the range of 30–40 % on average (Bird and Talbert 2008). When processed in this manner, the waste does not fall into the hazardous category as defined by the Resource Conservation and Recovery Act. This solid waste is low in metals, low in trace organics with low to medium nutrients. A small number of mills dry their residuals, which produce a 70–95 % solid waste rate (Thacker 2007).

Primary wastewater treatment plant residuals mostly consist of processed wood fiber and inorganic or mineral matter mainly kaolin clay, calcium carbonate, titanium dioxide. The ash (inorganic material) produced from this process ranges from less than 10 % up to 70 % (dry weight). Secondary wastewater treatment plant residuals consist mostly of non-pathogenic bacterial biomass.

As chlorinated organic compounds have a tendency to partition from effluent to solids, wastewater treatment sludge is a significant environmental concern for the pulp and paper industry. But recent trends away from elemental chlorine bleaching have reduced these hazards (Bajpai et al. 1999). A continuing apprehension is the very high pH of more than 12.5 of most residual wastes. When these wastes are disposed of in an aqueous form, they may meet the Resource Conservation and Recovery Act's definition of a corrosive hazardous waste (Bird and Talbert 2008).

The generation of sludge vary widely among mills (Lynde-Maas et al. 1997; Reid 1998; Elliott and Mahmood 2005, 2006; Krigstin and Sain 2005, 2006). EPA investigated 104 bleached Kraft mills; the sludge generation ranged from 14 to 140 kg of sludge per ton of pulp. For these 104 mills, total sludge generation was 2.5 million dry metric tons per year, or an average of approximately 26,000 dry metric tons per year per plant. Pulp making operations are responsible for generating the bulk of sludge wastes, although treatment of papermaking effluents also produces significant sludge volumes. The majority of pulp and integrated mills operate their own wastewater treatment systems and generate sludges onsite. A much larger proportion of papermaking establishments and a small number of pulp mills discharge effluents to publicly-owned wastewater treatment works.

Significant number of mills dispose sludge through land application though landfill and surface impoundment disposal are most often used for wastewater treatment sludge (Rashid et al. 2006; Bajpai et al. 1999). U.S. Department of Energy and Environmental Protection Agency consider proper land application of sludge as a beneficial use. Paper mill sludges can consume large percentages of local landfill space each year. When disposed of by being spread on cropland, concerns are raised about trace contaminants building up in soil or running off into area lakes and streams. Some pulp and paper mills burn their sludge in incinerators for onsite energy generation (CWAC; Bird and Talbert 2008).

According to a 2002 study by the American Forestry and Paper Association, wastewater treatment plant residuals were managed in United States as shown in Table 1.1 (Bird and Talbert 2008). The Confederation of European Paper Industries (CEPI) reported in 2003 that waste water treatment residuals in member countries on average were managed as shown in Table 1.2. Boiler ash and causticizing residuals were managed in United States as presented in Tables 1.3 and 1.4 respectively (NCASI 2001, 2007; Bird and Talbert 2008).

Table 1.1 Wastewater treatment plant residuals management in USA

	Wastewater treatment plant residuals (%)
Land application	14.6
Lagoon or landfill	51.8
Incineration for energy production	21.9
Other beneficial use	11.7

Based on Bird and Talbert (2008)

Table 1.2 Waste water treatment residuals management in CEPI countries

	Waste water treatment residuals (%)
Land application	37
Energy recovery	33
Landfilling	11
Other industries	19

Based on Bird and Talbert (2008), CEPI (2003)

Table 1.3 Boiler ash management in USA

	Boiler ash (%)
Land application	9.3
Landfill/lagoon	65.4
Other beneficial use	25.3

Based on Bird and Talbert (2008), NCASI (2007)

Table 1.4 Causticizing residuals management in USA

	Lime mud (%)	Green liquor dregs (%)	Slaker grits (%)
Land application	9	3	5.5
Lagoon or landfill	70	95	91
Reuse in mill	1	0	3
Other beneficial use	21	2	1

Based on Bird and Talbert (2008), NCASI (2001)

Landfilling and incineration suffer from their inherent drawback of poor economics. The reasons are presented below (Canales et al. 1994):

– The high cost associated with dewatering the sludge to 20–40 % solids or higher so as to meet the requirements of landfilling or incineration,
– The significant energy loss in evaporating the sludge-containing water in incineration or combustion of the sludges in a recovery boiler. The sludge disposal/management costs can be as high as 60 % of the total wastewater treatment plant operating costs.

Due to rapidly reducing landfill space and the secondary pollution issues associated with the conventional sludge disposal approaches and also the increasingly stringent environmental regulations, the disposal of sludges continues to be one of the major challenges for the municipal wastewater plants and most pulp and paper mills (Mahmood and Elliott 2006). This together with record high oil prices have contributed to a need to investigate methods of converting sludge waste into energy (XU and Lancaster 2008, 2009). For example, the percentage of pulp/paper sludges disposed by landfills has constantly decreased in Europe in recent years, dropping 40 % in 1990 to 20 % in 2002. In the meantime, the percentage of pulp/paper sludge used as a raw material in other industries and other applications – agriculture as soil improvers, in road construction, land reconstruction and for energy recovery has gradually increased.

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