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Qualitative and quantitative analysis of gaseous pollutants for cleaner production in pulp and paper mills

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ABSTRACT

To reduce pollution emissions and achieve a cleaner production in paper industry, it is essential to understand the inner links between concentrations of gaseous pollutants, types of final products and production techniques. In this study, the concentrations of four potential gaseous pollutants, total volatile organic compounds (TVOC), formaldehyde (HCHO), hydrogen sulfide (H_2S), and hydrocarbon compounds (C_xH_y), in the ambient air on thirty sampling points of five pulp and paper mills were detected and analyzed. The results were summarized with respect to the following aspects: (1) Levels of four gaseous pollutants on all the sampling points in five mills. It was obvious that the situation of gaseous pollution from pulp mill was much more serious than those from paper mills. (2) Gaseous pollutant distinctions due to different production processes. The levels of gaseous pollutants from five mills were greatly influenced by the utilized raw materials and the applied paper chemical agents (flavor, coating materials and additives) in mills. (3) Gaseous pollution comparisons at common points. At the two common points in five mills, i.e. the wet end of paper machine and the wastewater treatment process, TVOC and HCHO, C_xH_y and H_2S were the main gaseous pollutants, respectively. In addition, some feasible measures to realize a cleaner production in pulping and papermaking process were also put forward in the article.

1. Introduction

As one of the largest industries in the world, the global total paper production amounted to 403 Mt in 2013 (Bajpai, 2015a), wherein on account of the growing retail market and coupling with the expansion of paper industry, Asia Pacific has been expected to be the fastest growing market. As one of the major developing markets, in 2015, the capacities of 2900 paper mills in China and the public consumption reached 107.1 and 103.5 Mt, which increased by 2.3% and 2.8% from the previous year. From 2006 to 2015, the Chinese average production volume and consumption of paper had increased by 5.7% and 5.1% on an annual basis (China Technical Association of Paper Industry, 2016).

However, the rapid development of Chinese paper industry has brought a lot of challenges for environmental hazards as well as the profits, as a mass of gaseous, liquid, and solid compounds have been discharged to the environment (Avsar and Demirer, 2008; Chandra and Sankhwar, 2011; Kinnarinen et al., 2016). Compared with most concerns about wastewater and solid pollutants (Kamali and Khodaparast, 2015; Wen et al., 2016; Meyer and Edwards, 2014), few researches on the analysis and treatments of gaseous pollutants in paper industry have been reported. However, compared with water pollution and solid waste, the harm of gaseous pollutant to humans is more invisible, direct and deadly. In 2015, the total discharge of VOCs was 25 Mt in China, in which the VOCs from industrial sources accounted for 43% of the total, which far exceeded by the transportation, life and agricultural sources (Zhang, 2017). As a traditional and important chemical industry, not only VOCs but also the research of the whole emission situations of gaseous pollution in pulping and papermaking industry is important and urgent.

The situation of industrial pollutant emission tends to be complex due to numerous factors. The choices of raw material, pulping and papermaking technology mainly depend on the types of final paper products. In 2015, there were about 10 kinds of paper products on the Chinese market (China Technical Association of Paper Industry, 2016). The raw materials are diverse, in addition to natural fiber resources, commercial pulp and recycled fiber, the domestic and imported waste paper are also common choices for

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paper mills (Szabó et al., 2009).

In our previous research on the gaseous pollutants in one paper mill, the levels of total volatile organic compounds (TVOC), hydrocarbon (C_xH_y), formaldehyde (HCHO) and hydrogen sulfide (H_2S) were detected in the emissions from 6 points (waste paper sorting room, deinking section, wet end of paper machine, vacuum pump outlet, wastewater treatment plant and office area) in a paper mill (Tong et al., 2015, 2016). To study the relationships existing among various pollutants concentrations, types of final products and production techniques, the gaseous pollution in four supplementary pulp and paper mills were further detected and analyzed in the study. Five pulp and paper mills, six sampling points in each mill, the concentrations of four compositions, C_xH_y, TVOC, HCHO, and H_2S in the emission on each point were analyzed.

2. Materials and methods

2.1. Pulping & papermaking processes

To better understand the distinctions between the different sampling points in various mills, a brief description of pulping and papermaking processes is provided, and the process diagram is shown in Fig. 1. The market pulp with chemical pulping process and the deink pulp with waste paper are fed into the paper machine for the final paper production. According to the different quality indexes requirements from customers, some post-processing processes, such as coating and plastic coating, are conducted after the paper production (Lindberg, 2000).

2.2. Case studies

In the study, five pulp and paper mills (Mills A-E) located in Guangdong province, which is one of the main provinces of papermaking industry in China, were investigated, and their process schematics are presented in Fig. 2. Their main characteristics are listed as follows:

(1) Mill A: A pulp and paper mill whose main product is offset newsprint, which is made from 100% deinked pulp (DIP) pulping with waste paper. Its annual output was 550 Kt in 2015.
(2) Mill B: A pulp mill whose final product is market pulp board, which includes mixed bleached Kraft pulp (MBKP) and bleached eucalyptus Kraft pulp (BEKP). Its annual output was 250 Kt in 2015.
(3) Mill C: A household paper mill whose main products are toilet rolls and facial tissues whose raw materials are market pulp board. Its annual output was 120 Kt in 2015.
(4) Mills D and E: Two paper mills. Both of them use market pulp board as raw materials, but their products are coated ivory boards and digital paper, respectively. The main products of Mill D cover cigarette box, drug box, cosmetics packing box and book covers, and that of Mill E is mainly digital printing paper. Their annual outputs were 70 and 80 Kt in 2015.

Based on their production processes, the emission air samples from several points in each mill were collected for analysis. As plotted in Fig. 3, the comparisons and analysis of the detected results were discussed in the following aspects: (1) Levels of four gaseous pollutants at all the sampling points in five mills; (2) Gaseous pollution distinctions due to different production processes; (3) Gaseous pollution comparisons at the common points.

2.3. Sampling and determination methods

To guarantee the accuracy of experimental results, in the investigation, the concentrations of C_xH_y, TVOC, HCHO and H_2S in the emission air were collected and determined according to the

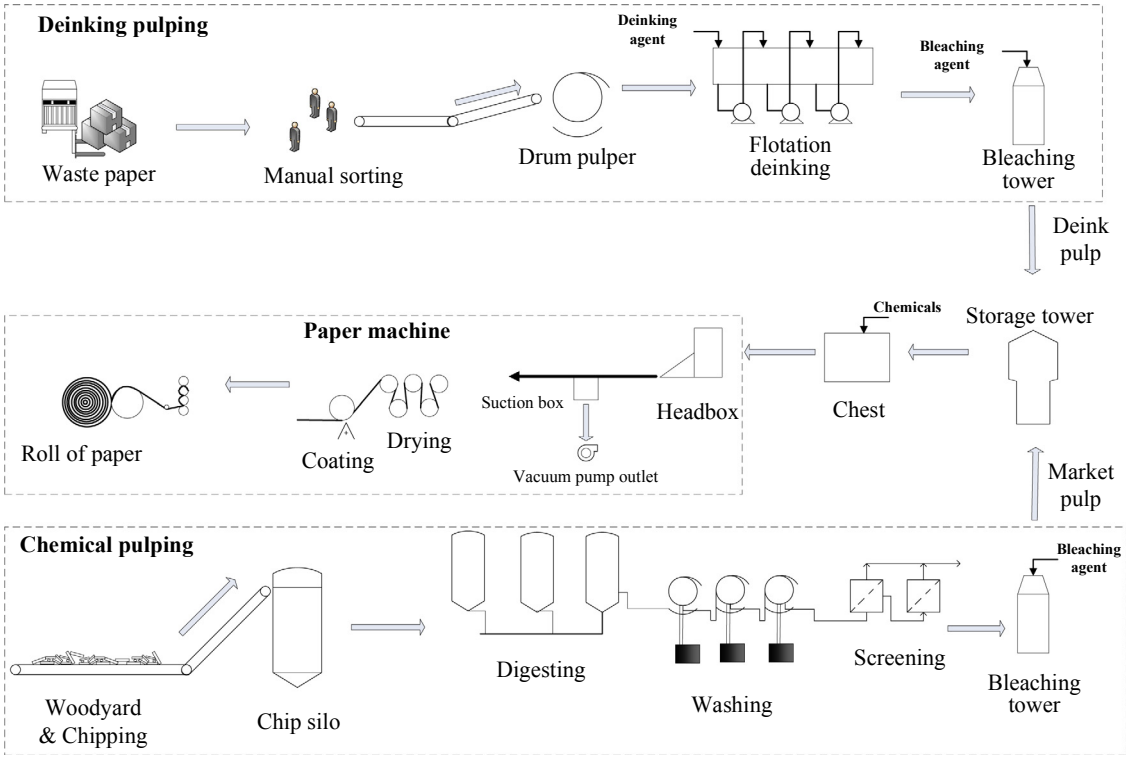

Fig. 1. Flowchart of pulping and papermaking process.