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Inland Vessels Emission Inventory and the emission characteristics of the Beijing-Hangzhou Grand Canal in Jiangsu province☆,☆☆

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ABSTRACT

Currently, air pollution from vessel exhaust emission is increasingly prominent. In particular, Jiangsu province, as a large inland waterway transportation province, has a large amount of ship emissions; however, the amount of such emissions remains unidentified. Considering the importance of the Beijing-Hangzhou Grand Canal for Jiangsu province and for the country, the inland vessel emission inventory of the Beijing-Hangzhou Grand Canal in Jiangsu province in 2014 was established using activity-based approach, the total annual emissions of particulate and gaseous pollutants were quantified, and the emission characteristics of vessels were also discussed. Dry cargo ships are the largest source of air pollutants, with ships whose gross tonnage is between 200 and 600 tons having the greatest contribution to exhaust emission. The order of the emission contribution for each vessel operation condition was as follows: normal navigation > passing through the shipping-lockage > berthing > mooring. Vessels running on the fairway made the greatest contribution in the aspect of the spatial distribution. Except in February, the monthly emissions not from ships presented a relatively steady trend.

1. Introduction

Fossil fuel consumption caused by ship activities involves the release of pollutants, such as NO_x, SO_2, CO, hydrocarbon (HC) and particulate matter (PM), to the atmosphere as well as the emission of greenhouse gases, such as CO_2. Currently, emissions from ship activities is the third largest source of air pollution in China, ranked after industrial exhaust and motor vehicle exhaust (Tan et al., 2014; Wan et al., 2013), and it is an important source of air pollution in port cities. In June 2015, the Hong Kong Environmental Protection Agency published the Hong Kong 2013 Air Pollutant Discharge Inventory Study (Hong Kong Environmental Protection Department (HKEPD), 2015). The report showed that ships remain the largest source of PM_{10}, NO_x and SO_2 in the whole city, accounting for 38.6%, 31.5% and 50.3% of the total emissions in the whole city. VOC and CO emissions from ships account for 11.4% and 19.2%, respectively.

However, studies on emission and control of air pollutants from ships are still at the initial stage in China. To date, only a few coastal cities or provinces, such as Hong Kong (Hong Kong Environmental Protection Department (HKEPD), 2012; Ng et al., 2013), Shanghai (Fu et al., 2012), Guangdong (Ye et al., 2014), Shenzhen (Yang et al., 2015), Tianjin (Jin et al., 2009), Dalian (Tan et al., 2014), and Qingdao (Liu et al., 2011), have conducted research studies on the emission inventory of ship air pollutants. Domestic studies on the emission of air pollutants from ships mainly focused on sea vessels rather than inland river ships. Some studies even neglected the air pollutant discharge of the

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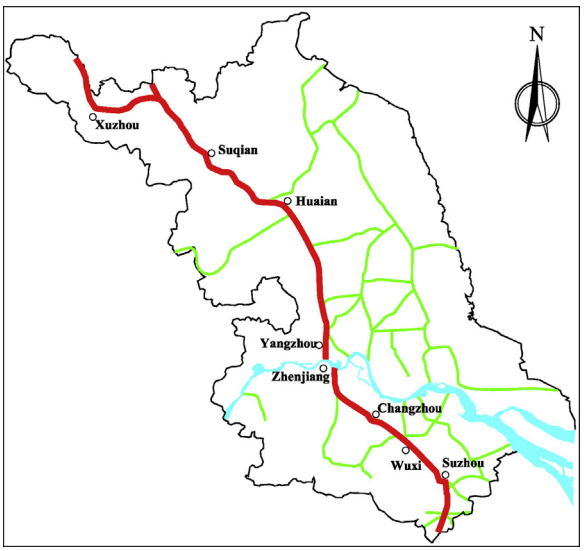

Fig. 1 – Overview of the Beijing-Hangzhou Grand Canal in Jiangsu province.

inland river ships directly. The study of air pollutant emissions from inland river ships is also relatively simple and crude. First, most of the emission inventories of inland river ships are compiled on the basis of simple corrections to foreign emission factors. Second, the basic information and activity level data are difficult to obtain. In addition, most emission studies of the inland river ships are based on the fuel consumption estimation method, without systematically analyzing the characteristics of emission characteristics of inland river ships. In fact, the air pollutants emitted from ships in river ports and waterways have a direct impact on the health of the local residents because of the lack of diffusion and the transfer of pollutants towards sea and often closer to the residents. Therefore, it is very important to refine the study of air pollutant discharge of inland river ships. Jiangsu province is a typical inland river province, in which the Beijing-Hangzhou Grand Canal in Jiangsu province is the most important part of the "two vertical and four horizontal" trunk network in Jiangsu province. It is the longest navigable route with the largest cargo density and the best transportation benefit in the Grand Canal. It is responsible for the transportation of large quantities of goods and materials in the Yangtze River Delta region and the strategic task of the power coal transportation from north to south. Booming ship activities have introduced serious environmental pollution problems while driving economic development.

Based on the above, this paper takes the Beijing-Hangzhou Grand Canal in Jiangsu province as an example to study the emission inventory of inland river ships in Jiangsu province. The method to establish emission inventory of the inland river ships is considered, and the list of air pollutants emitted from ships sail on the Beijing-Hangzhou Grand Canal in Jiangsu province in 2014 is produced. The air pollutant emission characteristics of ships are systematically analyzed to provide data support for the decision-making of air pollution control on inland river ships in Jiangsu province.

2. Overview of the Beijing-Hangzhou Grand Canal in Jiangsu province

The Beijing-Hangzhou Grand Canal runs from north to south in Jiangsu province. The total length of the canal is 687 km, and it passes through Xuzhou, Suqian, Huaian, Yangzhou, Zhenjiang, Changzhou, Wuxi and Suzhou (Fig. 1). By the end of 2014, the waterway of the Grand Canal in northern Jiangsu reached the standard for the second class of national inland river channel, which allows for full navigation for 2000-ton ships; the parts in southern Jiangsu reached the standard for the third class of national inland river channel, which allows for full navigation for 1000-ton ships. A total of 455,704 ships arrive at the port along the waterway and the total number of the ships that pass through the twelve locks along the waterway is 1,401,999 in 2014. According to the Jiangsu Provincial Traffic Statistics Yearbook in 2014 (Jiangsu Provincial Department of Transport, 2015), the annual cargo throughput of the port along the waterway is 314.62 million tons, accounting for 57.186% of the province's inland river port throughput. This waterway plays the function of main waterway channel effectively.

3. Materials and methods

3.1. Scope and object of study

This paper takes 2014 as the base year and chooses the waterway of the Beijing-Hangzhou Grand Canal in Jiangsu province and the relevant port terminals as the research area. By taking as the study object the power-driven ships that sail into the waterway of the Grand Canal in Jiangsu province and arrive at the ports or cross the border, the annual emission of NO_x, SO_2, CO, HC, $PM_{2.5}$, PM_{10} and other major air pollutants and greenhouse gas emission of carbon dioxide are estimated and the air pollutant emissions inventory of the Grand Canal in Jiangsu province in 2014 is established.

In this paper, the ships are divided in two levels: first level of division is based on the functional use of the ship and the second level is based on gross tonnage. The first level is classified into six categories: dry cargo ships (including bulk carriers, general cargo ships, multi-purpose cargo ships), chemical tankers, container ships, oil tankers, tugboats/push boats and other vessels, according to the visa information of ships. In the second division, according to the gross tonnage, ships are divided into five grades; the specific distribution of the gross tonnage of the ship range is shown in Table 1.

3.2. Estimation method

Estimation methods of ship emissions can be roughly divided into two categories: fuel-based method and activity-based method. Based on the establishment of emission inventory of air pollutants of the Grand Canal in Jiangsu province, the goal of this study is to systematically analyze the emission characteristics of ships. In addition, this study seeks to ensure the high-value discharge area, the high-value discharge vessel type, the ship emission sharing rate under different operating conditions and the temporal variation of emission. The activity-based method is adopted by the research group; the method is given by Formula (1) (ICF International, 2009):

$$E = P \times LF \times T \times EF \times FCF \times 10^{-6} \quad (1)$$

In the formula, P is the engine rated power (kW); LF is the load factor; T is the ship's activity time (h); E is the ship's emissions (t/a); EF is the emission factor (g/kW h); FCF is the fuel correction factor.

When the ship's operating load is less than 20%, there is a problem that the emission intensity will increase because of the low output power. Therefore, it is necessary to implement a low load correction for the emission factor; details are shown in Formula (2) (ICF International, 2009):

$$EF = EF_{base} \times LLAM \quad (2)$$

LLAM denotes the low load correction for the emission factor in the formula.