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Views & Comments

Hazardous Waste Management in the Guangdong–Hong Kong–Macao Greater Bay Area

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1. Introduction

Coordinated regional development is one of the national strategies in the new era [1]. The fifth plenary session of the 19th Central Committee of the Communist Party of China (CPC) proposed to "promote coordinated regional development," "persist in implementing a coordinated regional development strategy," and "improve the coordinated regional development system and mechanism" [2]. The Guangdong–Hong Kong–Macao Greater Bay Area (referred to herein as the "Greater Bay Area") is one of the most economic and open regions in China [3,4]. It includes Guangzhou, Shenzhen, Zhuhai, Foshan, Zhongshan, Dongguan, Huizhou, Jiangmen, Zhaoqing, Hong Kong, and Macao. In 2019, the permanent population of the Greater Bay Area reached 76.5 million, with a total gross domestic product (GDP) of 11.6 trillion CNY. To further promote the high-quality development of this region, the General Office of the CPC Central Committee issued the *Outline Development Plan for the Guangdong–Hong Kong–Macao Greater Bay Area* in 2019. However, a large gap remains between the Greater Bay Area and other world-class bay areas in terms of the quality of the ecological environment, particularly regarding the high-quality resource-utilization rate of solid waste [5]. Levels of particulate matter (e.g., $PM_{2.5}$) in the Greater Bay Area are two to three times greater than those in Tokyo Bay, New York Bay, or San Francisco Bay. At the same time, nearly 100 discolored and smelly rivers in the bay area affect the water quality. The most important difference between the Greater Bay Area and other world-class bay areas is that the annual generation intensity of solid waste is higher in the Greater Bay Area. The solid waste generated per unit of GDP in Shenzhen and Guangzhou are 5880 and 7690 tonnes per billion CNY, respectively. Meanwhile, the solid waste per unit of GDP generated in Huizhou and Zhuhai is as high as 14 280 tonnes per billion CNY. These values are much higher than the 1800 tonnes per billion CNY generated in the United States [6]. Hazardous wastes are usually highly toxic, explosive, flammable, and even radioactive in comparison with domestic waste, straw, and other solid waste [7]. Due to the large scale and the diverse types of industries in the region, the total pollution and the variety of medical waste and industrial hazardous waste are extremely complicated and add up to an enormous amount. According to incomplete statistics, the amount of hazardous waste generation in the Greater Bay Area reached at least 3.65 million tonnes in 2019 [8–19]. Based on the data, it has been predicted that this number will increase to 11.6 million tonnes in 2025. This paper presents a policy proposal for the integrated management and control of hazardous waste that could help in developing the management and social economy of hazardous waste in the Greater Bay Area.

2. Current status of and problems with hazardous waste management in the Greater Bay Area

The data presented in Fig. 1 shows a linear upward trend in the generation of hazardous waste in the Greater Bay Area. From 2015 to 2019, the amount of hazardous waste generated in the Greater Bay Area increased from 1 757 600 to 3 653 300 t. A fitting equation can be used to show that the overall trend is linear. However, there was an uneven distribution in terms of the amount of hazardous waste generated (Fig. 2). The sources of hazardous waste were mainly distributed in Shenzhen, Guangzhou, and Foshan, which accounted for 18.8%, 17.3%, and 10.9%, respectively.

The prediction of hazardous waste production can provide a basis for establishing a waste-disposal scale and putting forward countermeasures for optimal waste management in a region. At present, the quantitative prediction model for waste in this region is mainly based on socioeconomic characteristics (e.g., population and economic development) and statistical methods (e.g., the grey model (GM), regression analysis, and time-series models). Due to the small sample size and the monotonous growth of the data, the grey prediction model is suitable for use in this context [20]. This model, which processes a known time series and seeks to identify the underlying principle by continuing the series, has been widely used in agriculture and the environment, among other fields. Based on the amount of hazardous waste generated in the Greater Bay Area from 2015 to 2019, a GM (1,1) model of hazardous waste was established to predict the generation of hazardous waste in the next few years. The prediction results are shown in Table 1.

As mentioned earlier, various types of hazardous waste are generated in the Greater Bay Area. From 2015 to 2019, the types

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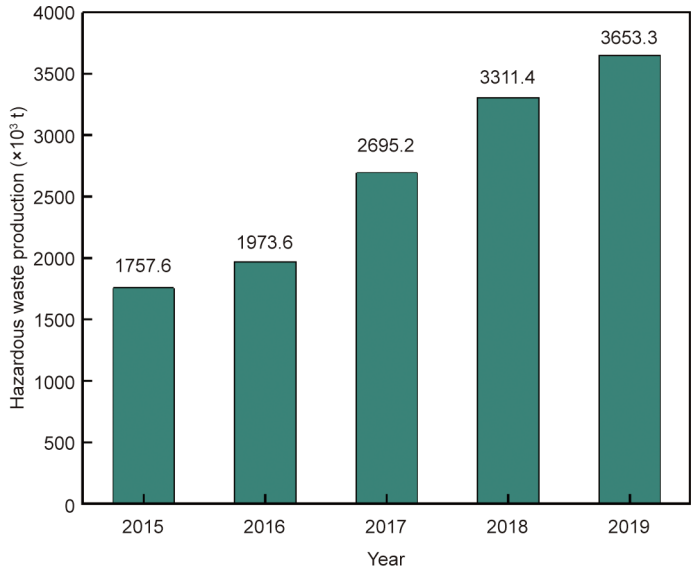

Fig. 1. Total hazardous waste generation in the Greater Bay Area in 2015–2019.

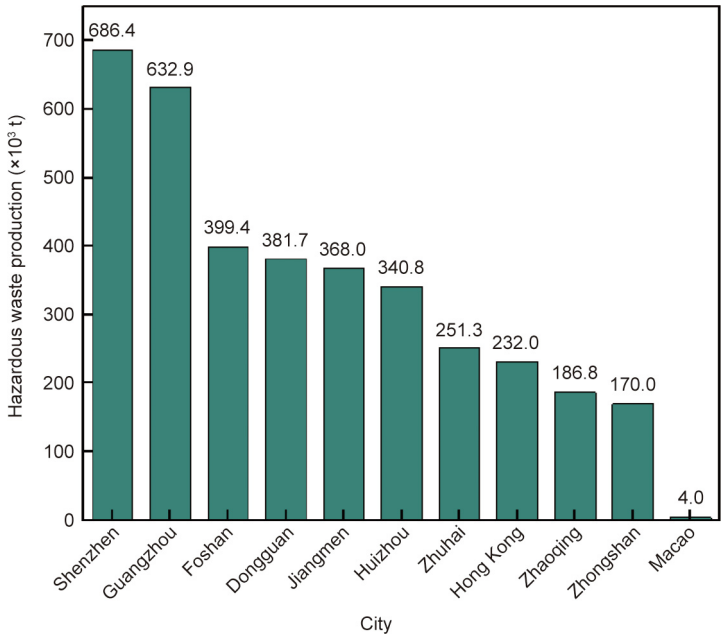

Fig. 2. Regional distribution of hazardous waste production in the Greater Bay Area in 2019.

Table 1
Near-term forecasting of hazardous waste production in the Greater Bay Area.

Item	2020	2021	2022	2023	2024	2025
Predictive value ($\times 10^3$ t)	4 545.8	5 486.2	6 621.1	7 990.9	9 644.0	11 639.1

of hazardous waste in the Greater Bay Area included 41 out of the 50 categories in the *National Catalogue of Hazardous Waste*. Furthermore, differences exist in the types of hazardous waste from Shenzhen, Guangzhou, Zhuhai, Zhaoqing, and Jiangmen, which respectively generate 41, 34, 28, 28, and 27 types of hazardous waste. In comparison, Zhongshan, Dongguan, Huizhou, and Foshan only generate 17, 16, 12, and 9 types of hazardous waste, respectively.

Moreover, several problems exist in the treatment and disposal of hazardous waste in the Greater Bay Area. First, the complex utilization of hazardous waste is less than 50%, which is lower than the national average of 51% in large and medium cities [21]. The second problem is that the cities' capacity for waste treatment and disposal is insufficient to meet the amount of waste production. The scale of hazardous waste disposal in Foshan, Dongguan, and Jiangmen is only 50% of hazardous waste production. In particular, the gap between the disposal capacity and the generation of waste incineration residue, surface treatment wastes, and copper-containing wastes has been increasing. In contrast, the treatment capacity of Shenzhen, Guangzhou,

Zhaoqing, and Zhongshan has exceeded the actual production of waste; in particular, Zhongshan's waste treatment capacity is more than double its waste production. The third problem is that the waste disposal capacity and type of disposal are weak. The majority of waste-disposal enterprises are small in scale (with a disposal capacity below 20 000 t). The fourth problem is that the types of hazardous waste that can be disposed of by local hazardous waste disposal enterprises are inconsistent with the actual waste categories generated in the region. For example, there are 11 categories of hazardous wastes approved for disposal in Foshan; however, more than 14 types of hazardous wastes are generated in this region, and the top three industrial hazardous wastes output need to be disposed of in another city [10].

In terms of its management system and mechanism, the Greater Bay Area is a heterogeneous city cluster with two systems, three customs areas, and three legal policies [22]. This situation has led to management heterogeneity in the current hazardous waste management. The Hong Kong and Macao Special Administrative Regions in the Greater Bay Area implement hazardous waste management following the *Chemical Waste Control Plan Guidelines*, while the Pearl River Delta in Guangdong follows the *Environmental Prevention and Control Law of the People's Republic of China on Solid Waste Pollution*. Moreover, there are differences in the classification of hazardous waste between Chinese mainland and Hong Kong and Macao. Chinese mainland classifies hazardous waste into 50 categories based on its corrosive, toxic, flammable, reactive, or infectious properties, according to the *National Catalogue of Hazardous Waste*. In comparison, Hong Kong and Macao does not systematically classify waste; waste is generally designated directly as *special waste types* according to the *Waste Disposal (Chemical Waste) (General) Regulation*, which includes abattoir waste, medical waste, stabilized residues, incineration ash treated at chemical waste treatment centers, chemical wastes, and so forth. The classification method in Hong Kong mainly categorizes two types of waste—namely, chemical waste and special wastes [23]—according to the waste sources and disposal methods [24]. At the same time, the Greater Bay Area has implemented different standards of management, control, construction, and treatment of hazardous waste in different areas, such as the *Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste*, *Waste Disposal Regulations* (Chapter 354), and the *Removal and Cleaning of Solid Waste*. In terms of the management system, an explicit classification management strategy is established in Hong Kong based on the classification of wastes by source [2], which could contribute to the identification, statistics, and management of the whole process, given improved management and control.

3. Policy implications

According to the generation, types, current treatment, and disposal methods of waste in the Greater Bay Area, as well as the comprehensive utilization of hazardous waste in comparison with other world-class bay areas, we make the following recommendations.

3.1. Coordinate, perform integrated planning and configure hazardous waste treatments with whole process precise control projects

First and foremost, based on an analysis of waste metabolism processes and the material flow in the economic circle of the Greater Bay Area, we suggest that a complete regional industrial chain be built and the precisely controlled management of key materials be clarified. Second, the top-level design of waste management in the Greater Bay Area should be strengthened. The types and distribution characteristics of hazardous waste in the Greater Bay Area should also be coordinated. This would assist in developing the planning and design of hazardous waste management, formulating supporting implementation plans for treatment and disposal projects, and promoting the coordinated planning and management of hazardous waste. Third, various modern management methods for hazardous waste should be implemented. Integrated monitoring technologies including remote sensing, geographical information systems, global positioning systems, drones, and the Internet of Things should be used to identify and address weaknesses in the generation, storage, transfer, utilization, and disposal of hazardous wastes in order to improve the level of management and control. Moreover, the illegal storage of hazardous wastes must be monitored in order to realize the systematic monitoring of waste sources and support the precisely controlled hazardous waste treatment.

3.2. Optimize the waste management layout and establish treatment and disposal projects that are compatible with the amount and type of hazardous waste

According to the types and quantities of hazardous wastes, geographical locations, and urban development planning in the Greater Bay Area, two or three centralized hazardous waste treatment zones should be selected scientifically. For example, disposal zones could be structured to make full use of uninhabited islands in the Greater Bay Area. Also, waste treatment and disposal projects should be planned and waste treatment plants should be constructed to deal with all types of hazardous waste. Wastes can then be disposed of in the same area they are generated in. Appropriate disposal projects to address the types and quantities of hazardous waste that are expected from emerging industries could be arranged ahead of schedule, which would reduce the environmental risk of improper disposal.

3.3. Build a technology and management system based on ecologically designed source reduction, waste classification, and quality classification

Based on the principle of industrial ecology, green designs can make it possible to reduce the generation of hazardous waste by replacing toxic and hazardous raw materials with environmentally friendly materials. Furthermore, it is necessary to strengthen the classification, collection, transportation, treatment, and disposal of hazardous wastes. An analysis of the urban industrial structure, layout, key substances, and resource metabolism paths could be helpful in establishing a classified collection and transportation system for hazardous waste in the Greater Bay Area. Moreover, a resource-based modular project consistent with classified collection and transportation can be established in the centralized industrial zone to support the classification, collection, and transportation of hazardous wastes. Next, it will be beneficial to promote the establishment of industrial symbiosis networks between upstream and downstream industrial ecosystems for the efficient cascade utilization of wastes. Finally, encouraging and supporting recycling, waste reduction, resource utilization, and safe disposal systems within the hazardous waste management system by formulating guiding preferential policies could stimulate market vitality. Subsidies can be provided to promote standardized hazardous waste disposal and the comprehensive utilization of renewable resources projects, renewable product research and development, and green product design. Meanwhile, equipment manufacturers that utilize hazardous wastes and recycling service companies can be provided with grant loans and tax incentives.

4. Conclusions

According to statistical data on hazardous waste in the Greater Bay Area from 2015 to 2019, the amount of hazardous waste reached 3.65 million tonnes in 2019 and included 41 of the categories listed in the *National Catalogue of Hazardous Waste*. A lack of overall planning for hazardous waste has resulted in limited waste management capability, including limited disposal capacity and types of treatment. Moreover, the comprehensive utilization rate of hazardous waste in the Greater Bay Area is less than 50%, which is lower than the national average of 51% in large and medium-sized cities. The problems discussed herein could be solved by planning a hazardous waste treatment and precision control project; optimizing the layout of the waste management system and establishing projects that are compatible with the amount and type of hazardous waste in the area; and building an ecologically designed technical processing system to manage hazardous waste. These initiatives will permit the safe control and disposal of hazardous waste in the Greater Bay Area.

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