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Characterization, quantification and management of China's municipal solid waste in spatiotemporal distributions: A review

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ABSTRACT

Municipal Solid Waste (MSW) is a heterogeneous waste stream, which is harmful for human health and the ecological environment if it is not well managed. Based on results from different authors by analyzing the generation, physical components and management of MSW from different cities, this paper presents an overview of the temporal trends and spatial variation characterization of MSW generation and its physical components in China. Total MSW generation has increased from 31,320 thousand tons in 1980 to 178,602 thousand tons in 2014, and MSW generation per capita has also increased from 448.3 g to 653.2 g. The distribution of MSW generation is mostly concentrated in the coastal southeastern region, as well as large point sources of more than 200 thousand tons per year are mostly distributed in Jiangsu, Zhejiang, Shandong, Hebei and Guangdong provinces. The review shows that the largest proportion of food waste, plastics and paper is 61.2% (54.2–65.9%, 95% CI), 9.8% (7.2–14.0%, 95% CI), 9.6% (6.7–12.3%, 95% CI), respectively, in 2014; the best estimates of other waste were as follows: 3.1% textile, 2.1% glass, 1.1% metal, 1.8% wood and grass, 1.3% rubber and leather, 1.8% ceramic, 2.5% ash, 1.2% hazardous waste, and 4.5% miscellaneous. To better manage China's MSW, several possible and appropriate solutions (e.g., concentrating on key regions, intensifying source separation, promoting green lifestyle, and establishing specialized regulations and policies) should be adopted, which might facilitate the application of China's 13th Five, and identify gaps in our knowledge of MSW management subject.

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1. Introduction

Municipal solid waste (MSW, as well as the list of all the abbreviations in this paper is in Table S1) is a heterogeneous waste stream that is an inevitable part of daily life (Hering, 2012). Compared with industrial solid waste, medical waste and construction waste, MSW has the characteristics of non-point source pollution (Hou et al., 2012; Tian et al., 2012). In other words, MSW "tracks" the whereabouts of humans and scatters in every corner of the city, which can harm human health and the ecological environment anytime and anywhere if it is not well managed (Funari et al., 2016; Laner et al., 2009; Vergara and Tchobanoglous, 2012). Moreover, the important physical components (PCs) of MSW, such as plastics and chemical fibers, may be harmful in some contexts (Delgado et al., 2007) (either they are themselves potentially toxic or they absorb other pollutants) and are suspected of being carcinogenic to humans (Rochman et al., 2013).

As the largest developing country, China deserves special attention. According to the previous studies (Hoornweg and Bhada-Tata, 2012), China produced approximately 30% of the world's MSW in 2012, and this MSW is an increasing concern. Facing this pressure, China has devoted considerable effort to managing its MSW. For instance, MSW harmless treatment capacity increased by 252 times (from 2107 tons/day in 1980 to 533,455 tons/day in 2014), and non-polluting disposal plants increased by 47 times (in 1980: 17 units; in 2014: 818 units). New regulations and measures (e.g., the Cleaner Production Promotion Law (PRC, 2002), MSW Management Measures (PRC, 2004) and the Circular Economy Promotion Law (PRC, 2008)) have also been implemented in the past few years. However, the efforts of MSW management (MSWM) have fallen far behind the increase in MSW generation, and its more complex challenges remain. Managing China's MSW has become a global challenge, both currently and in the future (Chen et al., 2010; Vergara and Tchobanoglous, 2012; Zhang et al., 2010).

A historic transformation occurred with China's 13th Five-Year Plan (13th Five), which was released on March 17th 2016, and its promotion of several missions of MSWM, including waste reduction, recycling and composting, treatment technology, equipment and infrastructure, and monitoring systems. The improvement of the MSWM strategies is an important goal for the Chinese government in the years to come, and all aspects of China's MSWM will have to undergo great reform to achieve this goal. Establishing a realistic national reform strategy requires greater knowledge of MSW as well as its generation and physical components (GAPC) (Burnley, 2007; Chang and Davila, 2008; Chang et al., 2011; Gu et al., 2015). GAPC could provide supporting database and/or initial value for predicting the disposal pattern, changes and trends of MSW generation, developing 3Rs approach, assessing the possibility of composting organic solid waste, estimating the recovery potential and the greenhouse gases emissions, which are the initial steps that needed for the successful implementation of an integrated MSWM system of national strategy.

A number of published papers have reviewed the variation tendencies of MSW-GAPC (MSWGAPC) (Chen et al., 2010; Chung and Poon, 1998a,b; Gu et al., 2015; Li et al., 2009; Yuan et al., 2006; Zhang et al., 2010; Zhao et al., 2009b; Zhu et al., 2009) and MSWM, including waste collection, transportation, recycling and disposal, at both the national (Chen et al., 2010; Chung and Lo, 2008; Zhang et al., 2010) and regional levels (Chu et al., 2013; Hong et al., 2006; Li et al., 2009; Mo et al., 2009; Xiao et al., 2007; Yuan et al., 2006; Zhao et al., 2009a; Zhuang et al., 2008). Some of the field survey results have been published in Chinese journals (Cao and Lin, 2010; Gao and Gu, 2003; Gao and Qi, 2008; Gou et al., 2012; Guo et al., 2006; He et al., 2008; Jiang and Zhou, 2007; Li et al., 2004; Li, 2011; Liang et al., 2008; Liu and Chen, 2002; Peng, 2011; Rong et al., 2004; Shao et al., 2009; Tan and Zhong, 2013; Wang et al., 2003; Wang, 2013; Xiang, 2010; Xu and Guo, 2005; Xu et al., 2008; Zeng et al., 2004; Zhang, 2003; Zhao et al., 2005; Zheng and Li, 2008) and/or academic dissertations (Lu, 2004; Mohammed and Masri, 2004; Qu, 2007; Zhang, 2003), while others have not yet been published. This fragmented information on MSWGAPC is not conducive to achieving the national reform goals of the 13th Five regarding MSWM.

Considering the urgency of MSWM system of national strategy, this paper presents an overview of comprehensive multi-year generation inventory of MSWGAPC for the period between 1980 and 2014 in China. Temporal variation trends and spatial distribution characteristics of MSWGAPC by nation, region and province are analyzed in detail. We also compared our results with those of previous reviews and/or studies. Section 2 introduces the methods and data, and Section 3 reviews the MSW characterization and quantification in spatiotemporal distributions. Some possible management countermeasures are presented in Section 4, and conclusions are summarized in Section 5. The present review implicates several possible and appropriate solutions that might facilitate the application of China's 13th Five, and identifies gaps in our knowledge of MSWM subject.

2. Methods and data

2.1. MSWGAPC generation and uncertainties

Data sources in this review can be classified into four categories. First, data on MSW generation in China in its entirety (excluding Hong Kong, Macao and Taiwan) and 31 provinces were derived from the provincial collection, transport and disposal of MSW tables in the China Statistical Yearbook (NBSC, 1981–2015); data on MSW generation in 658 urban sources were derived from the China Urban-Rural Construction Statistical Yearbook (NBSC, 2006–2014). Second, data on MSW PC (MSWPC) from 78 Chinese cities were acquired through published papers, ad hoc interviews with local officials, and the authors' personal survey of MSW. These MSWPC data were mainly gathered during the period between 1989 and 2014, as such, the data (e.g., Shanghai, Beijing) spanned

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