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GREENHOUSE GAS EMISSIONS

Estimation of Methane Emissions from Municipal Solid Waste Landfills in China Based on Point Emission Sources

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Abstract

The methane (CH_4) emissions from municipal solid waste (MSW) landfills in China in 2007 were estimated based on database of the three-dimensional emission factors matrix and point sources, by an IPCC recommended FOD (first-order decay) model. The location, capacity and age of landfills constitute the three dimensions of the emission factors matrix, which were obtained by laboratory analysis and in situ investigation. Key parameters such as waste composition, degradable organic carbon ratio, CH_4 correction factor, oxidation factor and recovery rate, were carefully analyzed in terms of these three dimensions. The point sources database consists of 2,107 MSW landfills in cities and towns of China in 2007. The results show that the CH_4 emissions from MSW landfills were 1.186 Mt in 2007. Compared with the CH_4 emissions of 2.20 Mt in 2005, the significant discrepancy mainly comes from statistical data of landfills, e.g., number of landfills and amount of waste disposed in landfills. CH_4 emissions were lower than 700 t for most of the landfills, whereas there were 279 landfills with emissions larger than 1,000 t, and only 10 landfills with emissions larger than 10,000 t. Jiangsu province ranks the largest emitter with 98,700 t while Tibet is the smallest emitter with 2,100 t. In general, the emissions from eastern provinces, such as Jiangsu, Guangdong and Zhejiang, were larger than those from western provinces, such as Ningxia, Tibet and Qinghai.

Keywords: municipal solid waste landfill; CH_4 emissions; point emission sources

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1 Introduction

Methane (CH_4) is the second largest driver of climate change behind carbon dioxide and one of the six greenhouse gases (GHGs) listed in the Kyoto Protocol, with global warming potential of 25 over 100 years (IPCC, 2007a). CH_4 is also a short-lived climate pollutant with an average life-time around 12 years in the atmosphere. According to the IPCC Fourth Assessment Report (IPCC, 2007b), the total CH_4 emissions and those from waste management accounted for 14.3% and 2.8% respectively, of the global GHG emissions in 2004. The CH_4 emissions from waste management shared 4% of the global total GHG emissions

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in 2010 (UNEP, 2012), with about half both from municipal solid waste (MSW) landfill and waste water treatment (JRC and PBL, 2012). The CH_4 emissions from MSW landfill rose fast from 16.50 Mt in 1970 to 29.50 Mt in 2008, with the total growth of 78.79% (JRC and PBL, 2012). About 73% of safely disposed MSW in China was landfilled in 2012 (NBSC, 2013). Landfill is the dominant treatment of MSW disposal at present and will continue to be the dominant and most economically viable MSW management in the mid-term future of China.

With the development of economy, advance of urbanization and improvement of people's living standards, both the waste generation and landfill are substantially increasing. Comprehensive and accurate estimation of the CH_4 emissions from landfills is increasingly important in waste recycling and CH_4 emission reduction in China. The regional specific emission factors and detailed inventory for CH_4 emissions are essential to regional GHG inventories and climate change programs at provincial level.

Waste decomposition does not begin immediately after the disposal but typically with a time delay. Therefore, the CH_4 emissions by the waste decomposition will last a period of time (roughly 50 years) after the MSW landfilled (IPCC, 2006). The annual emissions vary significantly due to variation of landfill capacity, management level and operation time. Research has identified that the regional specific and finer classified emission factors and landfill specific activity data are essential to the CH_4 emission estimation due to the notable impacts of capacity and management level on the emissions (Börjesson et al., 2009; Ishigaki et al., 2008; Kumar et al., 2004; Wangyao et al., 2010). However, studies on landfill CH_4 emissions in China were mostly based on nationwide emission factors and national or regional waste disposal data (Jiang et al., 2004; Xu, 1997; Gao et al., 2006, 2007; Qu and Yang, 2011; Luo et al., 2009; Gong et al., 2007). The uncertainty of estimation of CH_4 emissions from landfills in China based on the general emission factors and regional activity data is relatively high due to the special emission process of landfills.

In this paper, the region specific emission factors and detailed information on each landfill in China were used to calculate the landfill CH_4 emissions in 2007. The emissions at provincial and national levels were aggregated from individual landfills. This bottom-up method reduces the uncertainties associated with emission factors and activity data, and therefore significantly improves the estimation quality.

2 Methodology

The FOD (first-order decay) model recommended by IPCC guidelines (IPCC, 2006), is applied in calculation in this paper. It is currently the mainstream approach and utilized by EPA (2013) for landfill CH_4 emissions. The advantage of this model is that it incorporates time parameters to reflect the decay process of carbon in waste. The FOD model involves relatively more parameters than other methods, e.g., mass balance method. The FOD model can be presented as:

$$E_{\mathrm{CH_4}} = M \cdot \sum_{i=1}^{4} C \cdot f_i \cdot D_i \cdot D_F (\mathrm{e}^{-(T-1)\cdot k_i} - \mathrm{e}^{-T\cdot k_i}) \cdot F \cdot 16/12 \cdot (1-R) \times (1-O), \quad (1)$$

where $E_{\mathrm{CH_4}}$ is the CH_4 emitted in inventory year T; M is the mass of MSW landfilled at time 0, when the reaction starts; C is the correction factor; f_i is the fraction of waste type i (kitchen waste, paper, textile, and wood); D_i is the fraction of degradable organic carbon in waste type i; D_F is the fraction of degradable organic carbon which decomposes; k_i is reaction constant; F is the fraction of CH_4, by volume, in generated landfill gas; R is the CH_4 recovery rate; O is the oxidation factor.

Because the waste composition in China is different from that in developed countries, the IPCC default emission factors for FOD, most of which are derived from studies of developed countries, are not appropriate in our estimation. We developed a China landfill emission factors matrix by field investigation and laboratory analysis. The activity data, i.e., mass of MSW in each landfill, time of landfill operation are all from landfill-level survey.

The estimation does not include Taiwan, Hong Kong and Macao. The scope of survey covers all the landfills including sanitary landfill and simple landfill