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Methane Emission from Municipal Solid Waste Treatments in China

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Abstract: The greenhouse effect of methane (CH_4) is only inferior to that of carbon dioxide (CO_2). As an important anthropogenic emission source, the calculation of the emission amount of CH_4 from waste treatment in landfills plays an important role in compiling greenhouse gases inventory and in estimating the climate change effects caused by increasing of greenhouse gases. Based on the previous work, and according to the sampling and analysis on municipal solid waste (MSW) in typical cities, the degradable organic carbon (DOC) percentile was identified in typical cities in recent years. According to the IPCC greenhouse gases inventory guideline and default method of CH_4 emission from MSW landfills, and in light of MSW managing situation in different regions, the amount of CH_4 emission was calculated. The results show that the amount of CH_4 emission decreases geographically from east to west and it increases temporally from 1994 to 2004 in China.

Key words: climate change; municipal solid waste; methane; emission

Introduction

Methane is an important anthropogenic greenhouse gas. Although its concentration in atmosphere is much lower than carbon dioxide, however, its global warming potential (GWP) is 21 times that of carbon dioxide. Organic substances will undergo anaerobic decomposition and CH_4 is produced by methane bacteria when municipal solid waste (MSW) is treated in landfills. Therefore, CH_4 emission from waste landfills is one of the major emission sources of greenhouse gases [1].

The global amount of CH_4 emission from MSW treatments is around 22−36 Mt every year [2]. Although the CH_4 emission from MSW landfills is ranked only with the third in anthropogenic CH_4 emissions sources, comparing with that from paddy fields and ruminants, the control of emission from landfills is the most feasible and effective measure to minimize the growth of total CH_4 amount. For example, CH_4 emission from landfills is about 2.2 Mt per year in Britain, accounting for about 20% of its total CH_4 emissions. In the United States, annual emission from landfills is 11.6 Mt, accounting for 37% of its total CH_4 emissions. The emission contribution rate is 21.8%−34.4% in 1995 in Japan [3−4]. The research and calculation of CH_4 emission from MSW landfills have an increasingly prominent role in estimating the global greenhouse gases emissions and in understanding the global climate change.

Since 1992, in the financial and technical support from relevant international organizations, Chinese government has organized separately the Institute of Atmospheric Physics (IAP) of Chinese Academy of Sciences (CAS), the Energy Research Institute (ERI) of the National

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Development and Reform Commission (NDRC), the Environmental Engineering Department of Tsinghua University (TU), the Institute of Agricultural Environment and Sustainable Development (IAESD)of the Chinese Academy of Agricultural Sciences (CAAS), and other research departments to carry out a series of researches related to estimating CH_4 emissions [5]. For example, Chinese Ministry of Science and Technology (MOST) and the Asian Development Bank (ADB) have completed the report of *China's National Countermeasures to Global Climate Change Research* [6]; State Environmental Protection Administration (SEPA) and the World Bank (WB) have finished a report of *Problems and Countermeasures of Chinese Greenhouse Gases Control* [7]; The sub-report of Global Environment Facility (GEF) — Estimations of Sources and Sinks of China's Greenhouse Gases Control in 1990 [8]; *The People's Republic of China-Initial National Communication on Climate Change* [9], and "UNDP/GEF - China Initial National Communication" item 5 — Chinese Greenhouse Gas Emission Inventory from Municipal Waste [10], etc.

Currently, the CH_4 emission of MSW treatment models developed mostly by foreign researchers based on their situations can be divided into two types, namely dynamic model and statistical model [4]. The statistical model includes IPCC default model and chemical computation model; and the dynamic model includes Gardner dynamic model and Marticorena dynamic model [4]. In order to evaluate objectively practical contribution of CH_4 emission from landfills to the global greenhouse effect and to make it being used effectively, researching and developing CH_4 dynamic model, which suits for specific MSW properties and actual landfills situations in different regions, will be one of future significant development issues in the future.

Based on the analysis of IPCC methodology of CH_4 emission from landfills and Chinese actual situation of MSW treatment, the IPCC default method was used in this study to estimate the CH_4 net emission in 2004, including provincial and national total emissions. The spatial distribution and temporal trends of CH_4 net emission from MSW treatments in China were analyzed.

1 Calculation method

There are many methods to calculate the MSW methane emission from landfills, including theoretic gases generation method, IPCC default method, and one order dynamic method etc., which have considerable differences not only in their assumptions but also in their complexity and input data required. *IPCC 1996 Revised Guidance for National Greenhouse Gas Inventories* (hereinafter referred to as "IPCC 1996 Guidance") is a method recommended by relevant United Nations organizations. Based on China's actual situation, and using the default method provided by "IPCC 1996 Guidance", we calculated and analyzed the methane emission from MSW treatment in China.

1.1 *IPCC 1996 guidance*

Two CH_4 emission calculation methods are introduced in "IPCC 1996 Guidance", and they are "Default Method" (Tier 1) and "First Order Decay (FOD) Method" (Tier 2).

1.1.1 *Default Method*

Default Method is based on the mass balance equation, including the estimation of organic carbon degradation process and the calculation of CH_4 emission amount generated from MSW treatment. By using this method, the world is divided into four different regions according to their economic development levels, and their MSW generating amoun is evaluated by using different DOC parameters in different regions, and then the CH_4 emission amount from MSW treatment in a country can be calculated. This method requires a little data and can be further revised and improved when the new and detail data are available in a specific country.

1.1.2 *First Order Decay Method*

First Order Decay (FOD) Method estimates the change of methane emission with time. This method assumes that the degradable organic carbon (DOC) in waste decays slowly throughout a few decades, when CH_4 and CO_2 are formed. The estimation shows a good result of MSW degradation process with time. But "IPCC1996 Guidance" does not provide the default values or recommended values for main parameters of FOD method, and there is not enough reliable information to provide default values or recommended values at present, thus the comparability of CH_4 emissions in different regions is reduced.

Considering China's actual situation, and referring to *IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* [1], the IPCC recommended methodology (Tier 1) was used in this study, and more attention was paid to the IPCC default values for several parameters. According to the survey results of MSW generation amount and its disposal situation, and using the statistical data, and the actual sampling and analysis information, more actual parameters for calculating CH_4 emission were obtained. The basic data used in this study were collected from *China Urban Construction Statistics Yearbook, the Annual Statistics*

Bulletin which is published by National Bureau of Statistic of China, and the investigation reports and research results of different research teams, including "the Study on Greenhouse Gas Emission of Chinese Municipal Solid Waste", and so on.

1.2 *Choosing of parameters*

According to the literatures and statistical data [11], the ratio of MSW treated in landfills was about 95%. CH_4 emission factors were decided by the regional waste management levels and the default values of methane correction factors for various landfills supplied by "IPCC 1996 Guidance" (Table 1). The regional waste management levels were gained by investigating the typical MSW landfills, and the surveying statistics tables also used [10]. Meanwhile, referring to the literatures [10, 12] and considering the actual situation, the weight percentage of total DOC in MSW was about 6.55% in 2000, it is slightly larger than 6.2% in 1994 [10]. Since the organic matter content has decreased slightly and tended to be more stable in recent years [13], in this study the 6.5% DOC ratio was used when we calculated the methane emission inventory for 2004. Besides, part of generated methane will be oxidized by soil or other coverage materials when it emits into the atmosphere, the real methane emission amount will reduce. The methane emission is called net emission after it has passed through the coverage materials and part of it has been oxidized, and 0.1 was used as net oxidation factor in calculating methane net emission in this study [1]. At present, since there are not so many methane recovery and utilization facilities in China, default value 0 was used for CH_4 recycling parameter according to "IPCC 1996 Guidance".

Table 1 Classification of MSW treatment sites and methane correction factor (MCF)

Type of landfills	Default value of MCF
Managed landfills	1.0
No-managed and deep landfills (> 5 m)	0.8
No-managed and shallow landfills (< 5 m)	0.4
No-classified MSW landfills	0.6

The source of data: *IPCC 1996 Revised Guidance for National Greenhouse Gas Inventories*

There are some ranges for several parameters provided by "IPCC 1996 Guidance", therefore their upper and lower limit values were respectively used in calculating the maximum and minimum CH_4 net emissions. In the calculation of the minimum emission, the ratio of DOC was 0.5 and the ratio of CH_4 in landfill gases was 0.4; the ratio of DOC was 0.6 and the ratio of CH_4 in landfill gases was 0.6 in calculating the maximum emission.

During calculating the net CH_4 emission from MSW treatment, by using the IPCC recommended methodology, some default values suggested by "IPCC 1996 Guidance" were adopted, namely, the ratio of DOC was 0.77 and the ratio of CH_4 in landfill gases was 0.5.

It can be seen that the ratio of DOC (0.77) is significantly higher in IPCC recommended methodology for methane net emission calculation.

2 CH_4 emission characters

2.1 *Spatial distribution characters*

Figure 1 shows the spatial distribution of the minimum and maximum CH_4 emissions as well as the CH_4 emission from IPCC recommended methodology for 2004. The CH_4 emission values for each province were calculated by using the IPCC calculation equations.

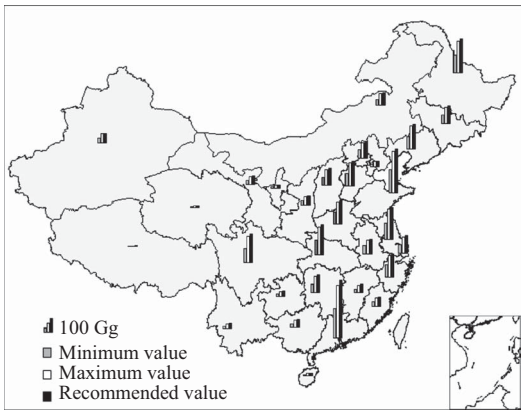

Fig. 1 Distribution of CH_4 net emissions in 2004 over China (unit: Gg)

Seen from Fig. 1, larger CH_4 net emissions occured in 2004 in the regions more flourishing in economy and heavier populated. The CH_4 net emission was the largest in the eastern regions, the next in the central regions, and the least in the western regions. Particularly, the CH_4 net emission from MSW treatment was significantly higher in Guangdong and Shandong Provinces, but lower in Tibet, Qinghai, Hainan Provinces of China in comparison with other regions.

Table 2 shows the CH_4 net emissions in 7 different regions of China. It can be seen that the emission in East China was much higher than that in other regions in 2004, and then followed by North China and Northeast China.

Table 2 CH_4 net emissions from MSW in different regions in 2004

Region	CH_4 net emission / Gg		
	The minimum value	The maximum value	The IPCC recommended value
North China	282.77	509.01	544.35
Northeast China	275.06	495.12	529.50
East China	538.24	968.89	1036.17
Central China	254.44	458.01	489.82
South China	241.15	434.08	464.22
Southwest China	152.00	273.64	292.64
Northwest China	128.72	231.73	247.82
Total	1872.38	3370.48	3604.52

The CH_4 emissions were relatively lower in Northwest China and Southwest China due to the relatively less number and smaller scale of cities.

2.2 *Temporal trend characters*

Base on the CH_4 net emission in 2004, making use of MSW generation data from 1994 to 2003 and the calculation method mentioned above, the national CH_4 net emissions from 1994 to 2003 were also calculated, and its long term trend was shown in Fig. 2.

It can be found that the CH_4 emission values recommended by IPCC were slightly larger than the maximum emission values in Fig. 2 due to the higher ratio of DOC recommended. In addition, the CH_4 net emissions gradually increased from 1994 to 2004. The net emission in 2004 was about 1.7 times higher than that in 1994; the growth rate was smaller in 1995−2000, however it has become noticeably larger in recent years. This trend is in line with the increase of the MSW generated amount from landfills.

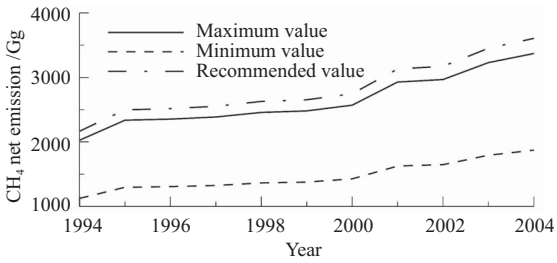

Fig. 2 CH_4 net emissions from MSW during 1994−2004 in China

3 Conclusions

From the above analyses, several conclusions can be obtained, as follows:

(1) Using the IPCC recommended methodology, the DOC ratio more pertinent to China's situation, and according to different MSW management level in different regions, the CH_4 net emission from MSW treatment over the whole country was calculated, and its spatial distribution, i.e. the gradual decrease trend from east to west ,was also revealed.

(2) The minimum, maximum and recommended values of CH_4 net emissions in 2004 were 1872.38 Gg, 3370.48 Gg, and 3604.52 Gg, respectively. The IPCC recommended value is slightly larger than the maximum value due to the higher ratio of DOC used.

(3) According to the calculation and analysis of CH_4 net emissions from 1994 to 2004, we can find that the emission increased gradually from 1994 to 2004, the increase slowed down between 1995 and 2000, but has accelerated significantly in recent years, and the emission in 2004 reached nearly 1.7 times as large as the emission in 1994.

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