Comparison of Different Methods for Determining Methane Emission from Waste Disposal Sites in Thailand

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Abstract: This study is primarily focused on the estimation of total methane emission potential from waste disposal sites in Thailand. The results from two estimation methods, i.e. default method proposed by the Intergovernmental Panel on Climate Change (IPCC) and Landfill Gas Emission Model (LandGEM) proposed by United States Environmental Protection Agency (EPA), are compared with the measurement result obtained from actual waste disposal sites. From the information of waste

generation rate and total disposed waste amounts at 142 waste disposal sites in Thailand, total methane emission potential from these waste sources was estimated to be 138.9 Gg/year by IPCC method, considerably higher than 94.7 Gg/year predicted by LandGEM of the EPA. Meanwhile, actual measurement from representative landfill and open dumpsites by close flux chamber technique gave an average methane emission rate of 23.95 and 1.98 $g/m^2.d$ respectively during the dry season. The emission rate was found to vary widely as a result of the variations in local climatic conditions, waste characteristics, waste disposal methods, the presence of cover soil and gas migration in the waste disposal site. Total emissions from all waste disposal sites was then estimated based on these average values estimated to be 64.3 Gg/year.

Keywords: Close flux chamber, first order model, IPCC, Land GEM, methane emission.

Introduction

Urbanization and the continuous increase of the urban population yields increasing amount of waste to be disposed. Before 1990's, most of the wastes collected from urban areas in Thailand were dumped in open areas resulting in unsanitary and nuisance conditions that affect the people living nearby the site. During the past decade, there is a gradual improvement of waste disposal practice from open dumping to sanitary landfill to cope with the increasing amount of waste, while minimizing

environmental impact from waste disposal. At present, about 34% of wastes are being disposed of by landfill, 1% by incineration and the others by open dump practice [PCD, 2003]. One of the major impacts from waste disposal either by sanitary landfill or open dumping is the release of greenhouse gases, mainly methane and carbon dioxide, to the atmosphere. These greenhouse gases are produced from the biodegradation of wastes under anaerobic conditions through microbial activities. These waste disposal sites are considered as one of the most important anthropogenic sources of greenhouse gases, especially methane gas, which has global warming potential 21 times that of carbon dioxide [IPCC, 1997].

The objective of this study was to evaluate the methane emission potential from waste disposal sites, i.e. sanitary landfills and open dumpsites in Thailand. The results can be used as primary information for the development of mitigation plans for this greenhouse gas emission at national level.

Methodology

The methane emission potential was evaluated by two different methods, i.e. default method proposed by the Intergovernmental Panel on Climate Change (IPCC) and Landfill Gas Emission Model (LandGEM) proposed by United States Environmental Protection Agency (EPA). They were compared with the measurement results obtained from actual waste

disposal sites by close flux chamber technique. The details of each estimation method are presented as follows.

1. Determination of Methane Emission Potential by IPCC Method

IPCC has proposed the method for estimation of methane emission from waste disposal sites by default method as per the following equation.[1]

$$\text{Methane Emissions} = (MSW_T * MSW_F * MCF * DOC * DOC_F * F * 16/12 - R) * (1 - OX) \quad (1)$$

Where MSW_T = Total amount of waste generated (Gg/year)

MSW_F = Fraction of waste being disposed

MCF = Correction factor of waste fraction that generates methane gas for sanitary landfill and 0.5 for open dumping)

DOC = Fraction of biodegradable organic carbon

DOC_F = Fraction of biodegradable organic carbon that is readily available for degradation

F = Fraction of methane in biogas

OX = Fraction of methane gas that is oxidized to carbon dioxide

2. Determination of Methane Emission by Landfill Gas Emission Model (LandGEM)

The United State Environmental Protection Agency (EPA) has developed a program called Landfill Gas Emission

Model (LandGEM) for the estimation of methane from degradation of solid wastes in the waste disposal site with time [EPA, 1998]. The model is based on first-order decay reaction in waste biodegradation and methane generation as shown in Equation 2.

$$Q = L_o R (e^{-kc} - e^{-kt}) \quad (2)$$

Where Q = Volume of methane gas produced in current year (m^3/year)

L_o = Potential of methane production from solid wastes (m^3/ton)

R = Receiving rate of solid wastes during site operation (ton/year)

k = first-order decay rate constant ($year^{-1}$)

c = Time period from the closure of waste disposal site to present year (year)

t = Time period from the opening of waste disposal site to present year (year)

3. Determination of Methane Emission Rate by Close Flux Chamber Method

Actual methane emission rate from waste disposal sites was measured in the field using close flux chamber method. The chamber is made of stainless steel with a diameter of 50.5-cm and 25-cm height (Fig.1). It was covered with heat insulator and acrylic sheet at the top where a thermometer and an incline manometer for temperature and pressure measurement inside the

chamber were installed. A gas sampling port is also attached to the top cover of the chamber so that an increasing rate of methane gas composition in the chamber can be determined. The methane flux can then be computed using the following equation.

$$J = (V/A)dC/dt \quad (3)$$

Where J = Methane Flux from the waste disposal site ($mol/m^2.h$)

V = Volume of chamber (m^3)

A = Covered area of chamber (m^2)

dC/dt = Increasing rate of methane gas in chamber ($mol/m^3.h$)

Two waste disposal sites in Thailand, i.e. Nakorn Prathom municipality landfill and Nonthaburi dumpsite, were selected as the representative study areas. The sites have been operating for about 5 and 10 years, which can be considered as the average operating period for sanitary landfills and open dumpsites in Thailand. The methane emission rate from these sites was determined at 4 different locations during January 2002 to October 2002. The average emission rates from these measurement locations were employed for the estimation of total emission rate from all waste disposal sites within the country.

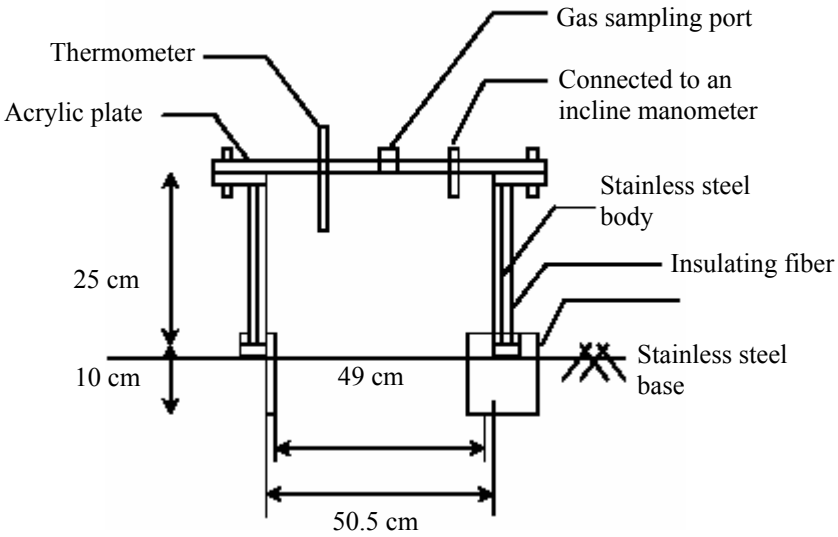

Figure 1. Schematic of close flux chamber.

Results and Discussion

1. Municipal Solid Waste Generation and Availability of Disposal Sites in Thailand

A survey of waste disposal sites in Thailand through a questionnaire and field visits revealed that in the year 2002, there were currently 142 waste disposal sites in operation (Fig.2). As of 2002, the total amount of municipal solid wastes being disposed in the country as reported to be about 26,878 ton/day, of which 15,210 ton/day or about 56.59% was handled in these 142 disposal facilities. The remainder was disposed of in abandoned land, which is not identified as waste disposal site. The waste disposal sites are located in various regions all over Thailand, as summarized in Table 1. Two major methods are

being employed for the disposal of wastes in these sites, i.e. landfill and open dumping. The landfill operation normally varied widely from the minimum requirement of having only daily cover and waste compaction to fully equipped sanitary landfill with standard liner, cover soil, leachate collection/treatment system, gas collection and ventilation system and groundwater monitoring wells. The fraction of wastes being disposed of by landfill and open dumping was found to be 73.45% and 26.55% respectively. The majority of those waste disposal sites are small with a capacity of less than 25 ton/day (Fig.3).

Table 1. Number of solid waste disposal sites and amount of wastes as classified by region.

Region	Number of sites		Amount of waste disposed (Tons/day)	
	Landfill	Open dumps	Landfill	Open dumps
North	10	14	754	389
North-eastern	14	14	835	526
Central (excluding Bangkok Metropolitan)	5	25	253	1,168
East	5	15	206	739
West	1	9	65	286
South	7	21	358	943
Bangkok Metropolitan	2	-	8,700	-
Total	**44**	**98**	**11,171**	**4,039**

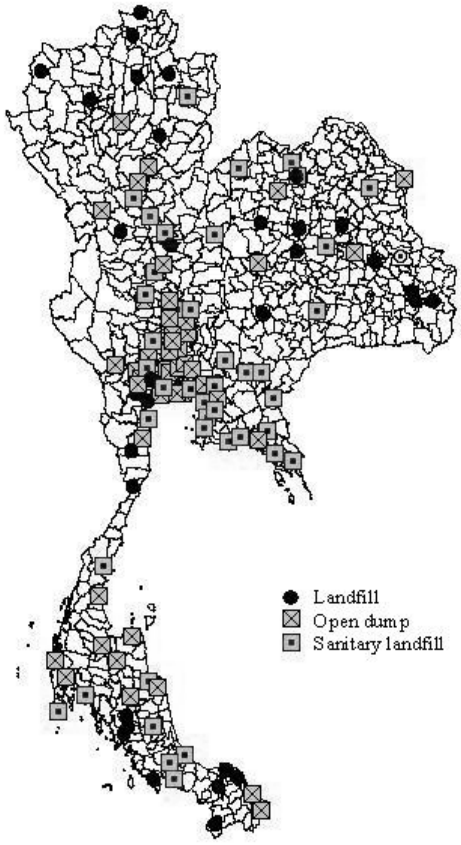

Figure 2. Location of Waste Disposal Sites in Thailand.

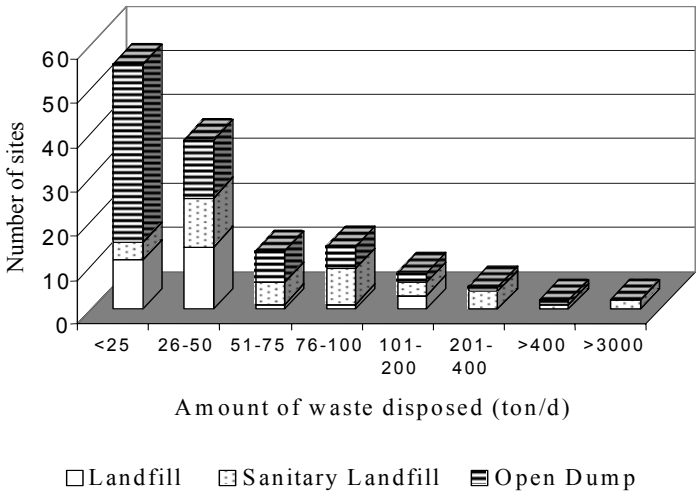

Figure 3. Number of disposal sites according to the amount of waste disposed.

2. Determination of Total Methane Emission Potential by IPCC Method

In the estimation of methane emission potential from waste disposal sites in Thailand by IPCC default method, the fraction of biodegradable organic carbon and biodegradable organic carbon that is readily available for degradation was set at 0.12 and 0.77. Methane content in landfill gas was assumed at 0.55. These figures were the typical values for municipal solid wastes in Thailand. [Towprayoon, 1996]. The fraction of methane gas that is oxidized to carbon dioxide was not taken into account, or in other words OX was assumed to be 0. The amount of solid wastes that is available for anaerobic degradation and methane generation was assumed 100% and 50% of total waste amount for landfill and open dump respectively. The results show that there was about 138.9 Gg/year of methane emission potential in those sites in the Year 2002. The contribution from landfill and open dumpsites accounts for 69.01% and 30.99% respectively. On a regional basis, the major contribution came from Bangkok Metropolitan with total amount of 59.12 Gg/year, followed by Northeastern and Northern regions as shown in Table 2.

Table 2. Estimated methane emission rate by IPCC method as classified by region.

Region	Methane Emission Rate (Mg/year)		
	Landfill	Open dumpsite	Total
North	6.89	3.43	10.33
North-eastern	7.63	4.79	12.42
Central (excluding Bangkok Metropolitan)	2.31	10.64	12.95
East	1.88	6.73	8.62
West	0.59	2.61	3.20
South	3.27	8.59	11.86
Bangkok Metropolitan	79.52	-	79.52
Total	**102.10**	**36.80**	**138.90**

3. Determination of Methane Emission by Landfill Gas Emission Model (LandGEM*)*

In contrast to the IPCC method in which methane emission potential is calculated based on the amount of wastes being disposed each year, landfill gas emission model proposed by EPA determines the methane emission based on first-order decay reaction in which annual methane emission depends on the amount of remaining organic wastes in that year. From the input of waste received rate of each landfill, methane emission can be estimated by assuming methane production potential (L_0) of 170 m^3/ton and first-order decay rate constant (k) of 0.05 $year^{-1}$. These values are recommended as the typical figures for developing countries which usually have a high amount of readily biodegradable wastes [USEPA, 1998]. For open dumpsites, methane emission potential was assumed to be 50% of landfill or 85 m^3/ton.

As shown in Table 3, it was found that total methane emission of 94.70 Gg/year was estimated from all waste disposal sites in 2002. The contribution from landfills and open dumpsites were 69.64 and 25.05 Gg/year, accounting for 73.5% and 26.5% of total emission respectively. The majority of methane emission came from Bangkok Metropolitan followed by Northeastern and Southern region respectively. The estimated value is considerably less than that of IPCC method as they are calculated on different basis. Whereas the IPCC method estimates ultimate methane production based on the amount of waste disposed in 2002, the LandGEM model predicts methane emission based on the remaining deposited waste amount in the year 2002, assuming first-order decay rate from the start of site operation. As most of the landfill sites in Thailand are classified as young landfills (less than 10 years old), they are in the active phase of methane production and contribute a larger percentage in total methane emission from other waste disposal sites in the country.

Table 3. Estimated methane emission rate by Landfill Gas Emission model (LandGEM) as classified by region.

Region	Methane Emission Rate (Gg/year)		
	Landfill	Open dumpsite	Total
North	0.87	5.51	6.38
North-eastern	1.95	8.25	10.20
Central (excluding Bangko Metropolitan)	2.44	3.55	5.99
East	3.43	2.35	5.78
West	0.17	0.39	0.56
South	1.66	5.00	6.66
Bangkok Metropolitan	59.12	-	59.12
Total	**69.64**	**25.05**	**94.69**

4. Determination of Methane Emission Rate by Close Flux Chamber Method

The methane emission rate at representative waste disposal sites, Nakorn Prathom landfill and Nonthaburi dumpsite, was determined by close flux chamber method. The results are shown in Table 3. It was found that methane emission rate from landfill varied in a wide range from non-detectable level up to 94.0 $g/m^2.d$. The emission rates during dry period (January to June) was significantly higher than that of wet period (July to October) during the presence of cracks on the landfill surface with average emission rates of 23.95 and 1.17 $g/m^2.d$ during dry and wet season respectively. The emission rate during dry season in this study was in accordance with 20.3 and 35.4 $g/m^2.d$ reported in the literature [Chomsurin, 1997; Chiemchaisri and Puttimilinprateep, 2002] for the same and nearby landfills during 2000-2001.

The methane emission rates at 4 different locations in an open dumpsite at Nonthaburi province are also shown in Table 4. It was found that methane emission rate varied in a wide range among different locations and measured period. In accordance with the determination of methane emission rates at landfill sites, higher emission rates were detected during dry (January to June) period as compared to the rainy season. Average methane emission rate during this dry period was 1.98 $g/m^2.d$, significantly lower than that of the landfill site. The difference can be caused by the presence of oxygen and aerobic condition especially near the surface of the waste pile. Other

factors may include longer waste deposition in dumpsites (15 years as compared to 10 years in landfill), lower compaction density (no compaction in dumpsite) and different local climatic conditions. Nevertheless, this average emission rate is employed for the estimation of other dumpsites in the country for the prediction of total methane emission.

Table 4. Measured methane emission rates from waste disposal sites.

Site/Location	Methane emission rate ($g/m^2.d$)			
	January -June 2002		July -October 2002	
	Range	Avg.	Range	Avg.
Nakorn Prathom Landfill	0.09-10.69	2.52	ND	ND
- Location #1	0.53-83.12	14.92	0.82-1.21	1.02
- Location #2	0.02-94.04	55.00	2.72-4.39	3.65
- Location #3	0.09-69.79	23.34	ND-0.02	0.01
- Location #4				
Overall average	**23.95**		**1.17**	
Nonthaburi Dumpsite				
- Location #1	0.53-2.23	1.26	0.21-0.27	0.23
- Location #2	0.50-2.50	1.47	0.25-0.31	0.27
- Location #3	0.40-5.28	2.58	0.20-0.26	0.22
- Location #4	1.42-3.80	2.62	0.47-0.71	0.59
Overall average	**1.98**		**0.33**	

Remark: ND: not detected

Determined methane emission rates from these landfill and open dumpsites were then employed for the estimation of nationwide methane emission from 142 waste disposal sites. It was estimated that total methane emission in Year 2002 was 64.3 Gg/year which is closer to the predicted value from LandGEM, as compared to IPCC methodology. The contribution from landfill and open dumpsite was estimated to be 59.2 and 5.0 Gg/year or

92% and 8% of total methane emission respectively. It should be noted that this estimation was only the preliminary predicted value as the gas emission rate can vary in a wide range depending on waste characteristics, climatic condition, disposal method, age of disposal site and gas migration within or across the site boundary. They are not taken into account in this study.

Conclusion

From the estimation of methane emission potential from 142 waste disposal sites in Thailand by IPCC default method, it was found that about 138.9 Gg/year of methane gas could be released in the Year 2002 from those sites, which is considerably higher than 94.7 Gg/year obtained from Landfill Gas Emission Method (LandGEM) proposed by EPA. Actual measurement of methane emission in the representative landfill and open dumpsite gave an emission rate of 23.95 and 1.98 $g/m^2.d$ respectively. This data was then employed for the estimation of nationwide methane emission for which 64.3 Gg/year of methane emission was estimated. Nevertheless a wide range of variation in methane emission rate within and between the sites was expected as it could be affected by waste characteristics, climatic condition, disposal methods, age of disposal site and gas migration within and across the site boundary.

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