Estimation of national GHG emission from solid waste disposal sites by using field investigation results

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1. Introduction

- Typical LFG comprise of methane 40 – 60%, carbon dioxide 30 – 50%, oxygen 0 – 2%, nitrogen 0 – 10%, hydrogen sulfide in trace levels and non-methane organic compounds (NMOC) in trace levels

- The factors that influence the generation are waste composition, anaerobic environment, moisture content, acidity and temperature. In addition, the refuse density and consistency, the landfill design and other site-specific factors can affect the quantity and rate of methane generation

Methods for estimating methane emissions from solid waste disposal

- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Mass balance
- IPCC 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories : Single Phase - FOD Model
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories : Multiple Phase – FOD Model

Research Objectives

- To achieve an accurate estimation with IPCC Waste Model and also develop the country's default parameters for the emission inventory that can be applied to most developing countries-where the waste degrade under tropical condition.

2. Methodology

2.1 Study sites

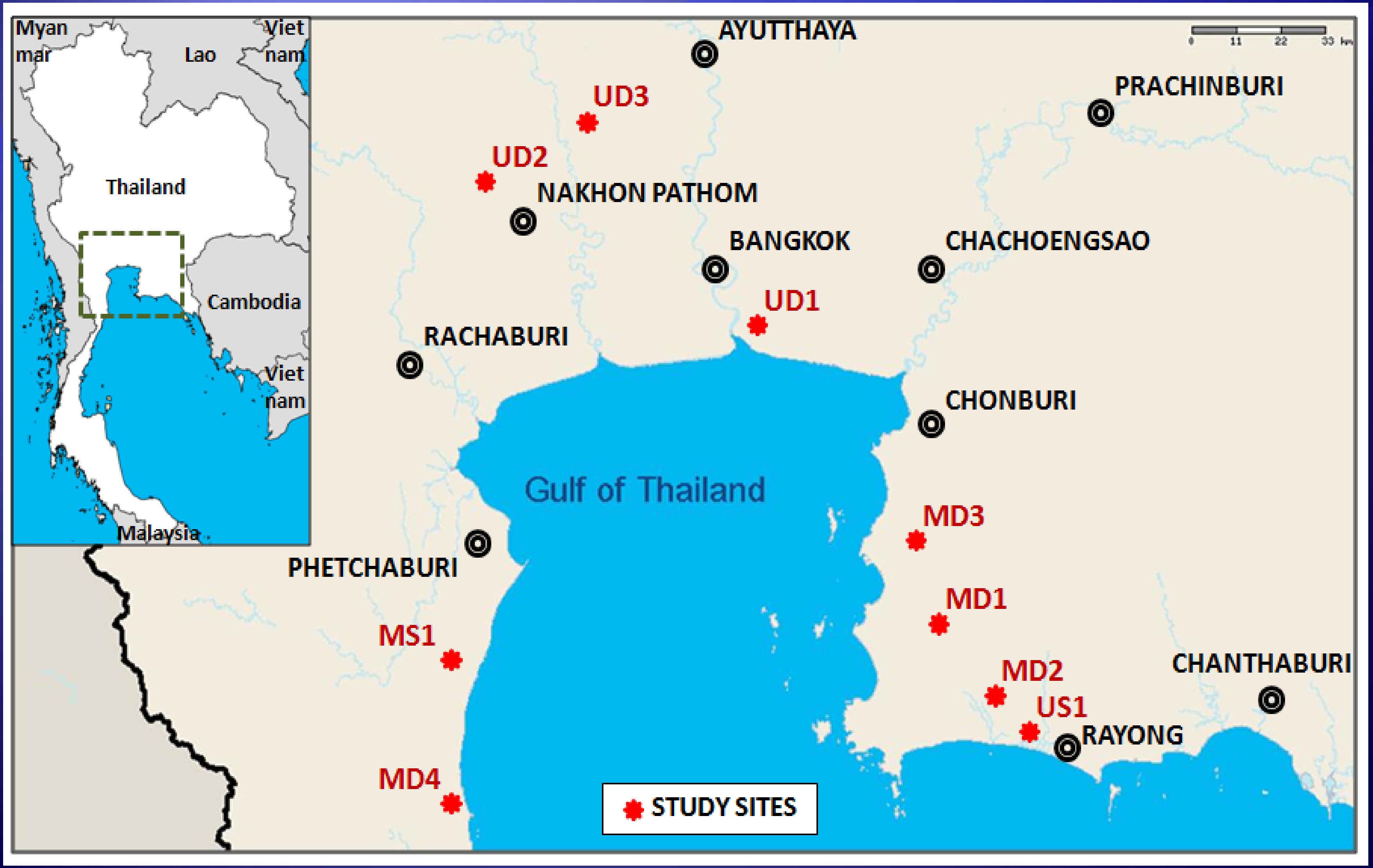
- 4 deep landfills
- 1 shallow landfill
- 3 deep dumpsites
- 1 shallow dumpsites

- Conducted from Sep. to Oct. 2005 for rainy season data, from Dec. 2005 to Feb. 2006 for winter season data and from Apr. to May 2006 for summer season data

Characteristics of study sites

Site	Landfill Open Year	Site Age from 2006 (yrs)	Area (m^2)	Disposal method	Average tipping (tones per day)
Pattaya (MD1)	2002	4	53,618	Deep landfill	240
Mabtapud (MD2)	2001	5	29,280	Deep landfill	58
Cha-Am (MS1)	2000	6	47,680	Shallow landfill	26
Laemchabang (MD3)	1999	7	71,200	Deep landfill	152
Hua-Hin (MD4)	1996	10	44,160	Deep landfill	46
Samut Prakan (UD1)	1999	7	25,600	Deep dumpsite	80
Nakhon Pathom (UD2)	1997	9	48,781	Deep dumpsite	180
Nonthaburi (UD3)	1982	24	67,367	Deep dumpsite	800
Rayong (US1)	2001	5	35,200	Shallow dumpsite	69

Location of study sites

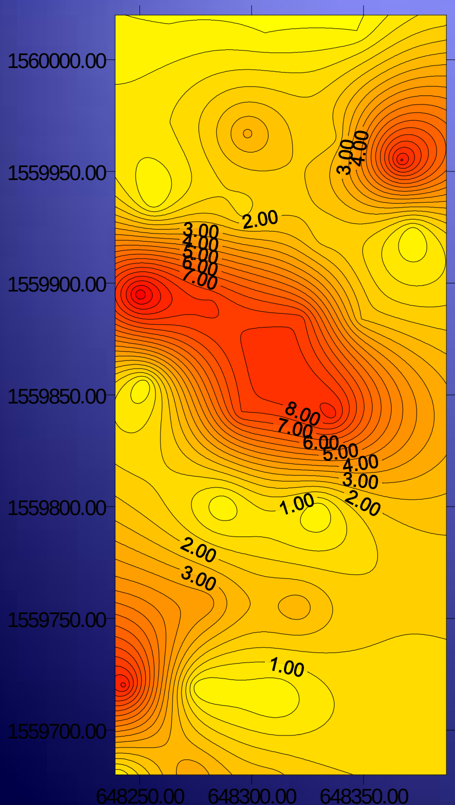


2.2 Methane emission rates and gas analysis

Closed Flux Chamber Method

- The chambers used in this study were constructed with Dia. 0.4 m. - PVC pipe, 0.25 m. in height having PVC cap at the top of chamber.
- To protect air intrusion, the chambers were sealed to the ground by firming soil around the outside.
- Methane samples were collected from a chamber after 1, 2, 3, and 4 minutes using 60-mL plastic syringes fitted with plastic valves.
- These gases were stored in 10-mL vacuum tube.
- The position of flux box was measured by handheld global positioning system (GPS).

2.3 Gas and data analysis



- Gas analysis : Shimadzu 14A gas chromatograph (Shimadzu Co., Japan)
- Geospatial distribution : Mapping software Surfer by Golden Software

Methane flux calculation

$$F = V/A\,(dC/dt) \qquad (1)$$

where V is chamber volume and A is the area covered by the chamber. The slope of the line, dC/dt, was determined by linear regression between CH_4 concentration and elapsed time.

2.3 Methane emission inventory (2006 IPCC Waste Model)

$$CH_4 Emissions = \left[\sum_x CH_4 generated_{x,T} - R_T \right] \times (1 - OX_T) \quad (2)$$

$$CH_4 \ generated_T = DDOCm \ decomp_T \times F \times 16/12 \qquad (3)$$

where $DDOCm\ decomp_T$ = $DDOCm$ decomposed in year T, Gg, F = fraction of CH_4 by volume in generated landfill gas (fraction) and 16/12 = molecular weight ratio CH_4/C (ratio).

$$DDOCm \ decomp_T = DDOCma_{T-1} \times \left(1 - e^{-k}\right) \quad (4)$$

$$DDOCma_T = DDOCmd_T + \left(DDOCma_{T-1} \times e^{-k}\right) \quad (5)$$

where $DDOCma_T$ = *DDOCm* accumulated in the solid waste disposal site at the end of year *T*, Gg, $DDOCma_{T-1}$ = *DDOCm* accumulated in the SWDS at the end of year *T*-1, Gg, $DDOCmd_T$ = *DDOCm* deposited into the SWDS in year *T*, Gg, *k* = reaction constant ($k = \ln(2)/t_{1/2}$), y^{-1}, and $t_{1/2}$ = half-life time, y.

$$DDOCm = W \times DOC \times DOC_f \times MCF \quad (6)$$

where *W* = mass of waste deposited, Gg, *DOC* = degradable organic carbon in the year of deposition, (fraction, Gg-C/Gg-waste), DOC_f = fraction of *DOC* that can decompose, (fraction), and *MCF* = CH_4 correction factor for aerobic decomposition in the year of deposition, (fraction).

Methane correction factor (MCF)

Type of Site	MCF Default Values
Managed – anaerobic	1.0
Managed – semi-aerobic	0.5
Unmanaged – deep (≥ 5 m waste) and /or high water table	0.8
Unmanaged – shallow (<5 m waste)	0.4
Uncategorised SWDS	0.6

Uncertainty for IPCC default values: ±20 to ± 30%

Recommended default half-life (IPCC, 2006).

Type of Waste		Climate Zone							
		Boreal and Temperate (MAT ≤ 20° C)				Tropical (MAT > 20° C)			
		Dry (MAP/PET < 1)		Wet (MAP/PET > 1)		Dry (MAP < 1000 mm)		Moist and Wet (MAP ≥ 1000 mm)	
		Default	Range	Default	Range	Default	Range	Default	Range
Slowly degrading waste	Paper/textiles waste	17	14 – 23	12	10 – 14	15	12 – 17	10	8 – 12
	Wood/ straw waste	35	23 – 69	23	17 – 35	28	17 – 35	20	14 – 23
Moderately degrading waste	Other (non – food) organic putrescible/ Garden and park waste	14	12 – 17	7	6 – 9	11	9 – 14	4	3 – 5
Rapidly degrading waste	Food waste/Sewage sludge	12	9 – 14	4	3 – 6	8	6 – 10	2	1 – 4
Bulk Waste		14	12 – 17	7	6 – 9	11	9 – 14	4	3 – 5

MAP : the mean annual precipitation , PET : potential evapotranspiration

Oxidation factor (OX)

Type of Site	Oxidation Factor Default Values
Managed [1], unmanaged and uncategorized SWDS	0
Managed covered with CH_4 oxidizing material [2]	0.1

1 Managed but not covered with aerated material

2 Examples: soil, compost

MCF EVALUATION USING ERROR FUNCTION ANALYSIS

- Main objective is to minimize the difference between the calculated gas emission rates and the actual emission rates that effect by MCF
- The error function equation used is

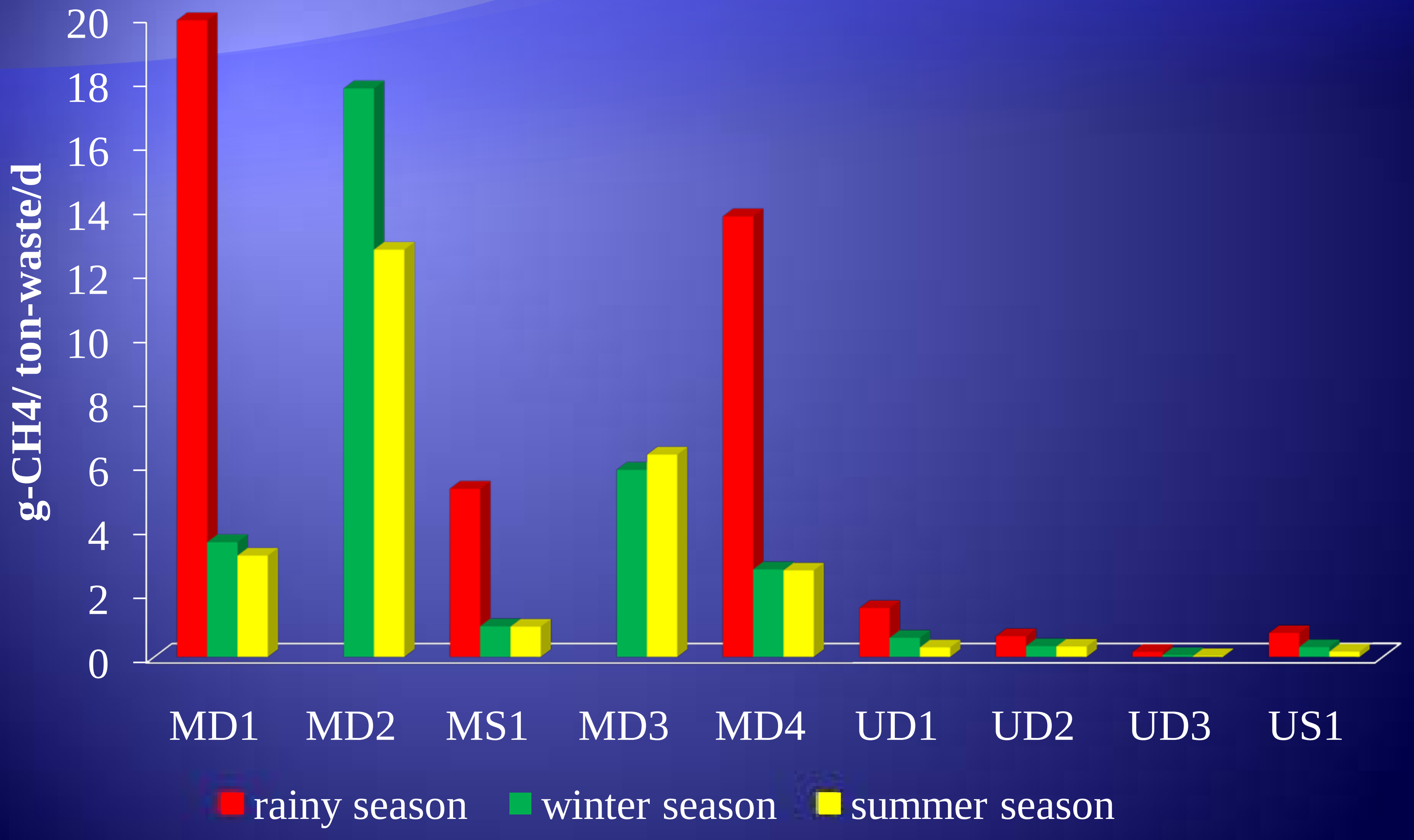
$$E = \sqrt{\sum_{i=1}^{n} (Qc - Qob)^2}$$

where: E is error function, Qc is calculated emission rate in units of volume per time, Qob is observed emission rate in units of volume per time and n = number of waste disposal sites.

- IPCC Waste Model and information of study sites including waste composition, waste in place history, and operation practice were used.
- In order to optimize MCF, other parameters were fixed with IPCC default values for tropical climate region except OX.
- The default half-life values for food waste, paper, wood and textiles were 2, 10, 20 and 10 years, respectively.
- The default delay time was 6 months.
- The value of oxidation factor for landfill was fixed at 0.15 as followed Chomsurin (1997).
- OX of dumpsite had been evaluated by error function analysis.

3. Results

Summary of avg. spatial CH_4 emissions



Seasonal variation

- In wet season, CH_4 emission was higher than dry season about 5 - 6 times in landfill and 2 - 5 times in open dumpsite.
- CH_4 emission in winter season was closed to CH_4 emission in summer season in landfill.
- In open dumpsite, CH_4 emission in winter season was higher than emission in summer season about 2 times .

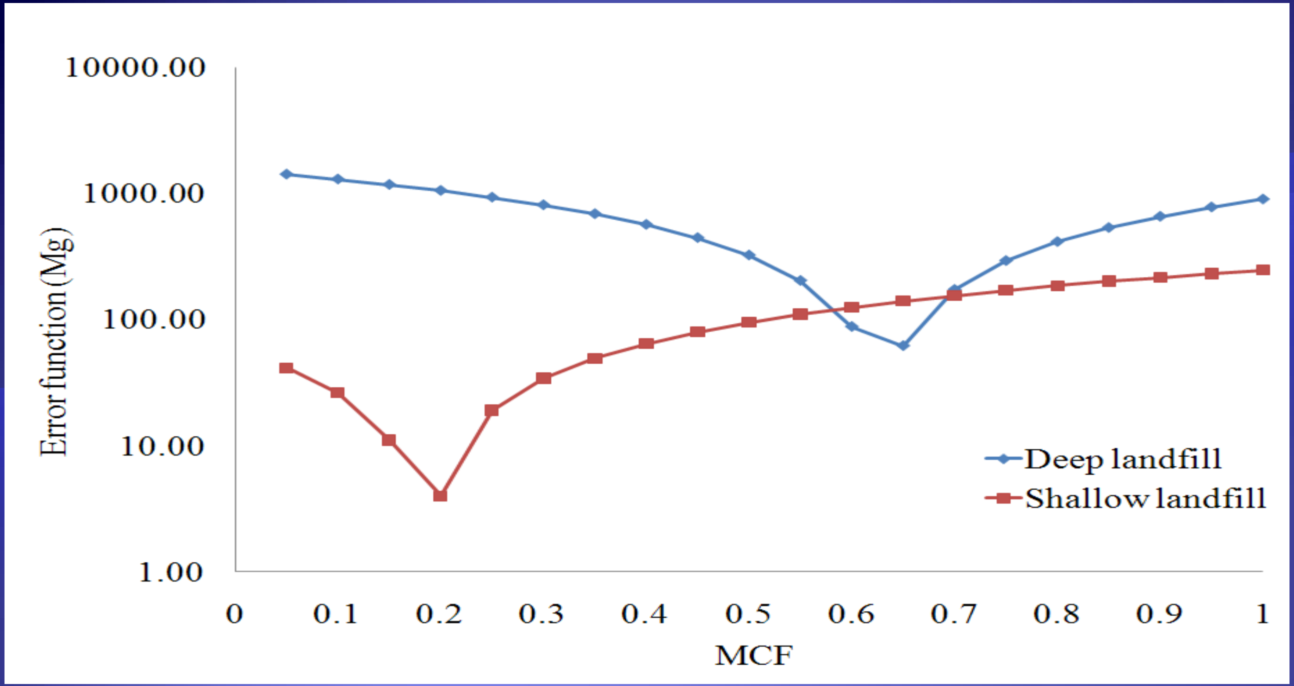
Site condition effect

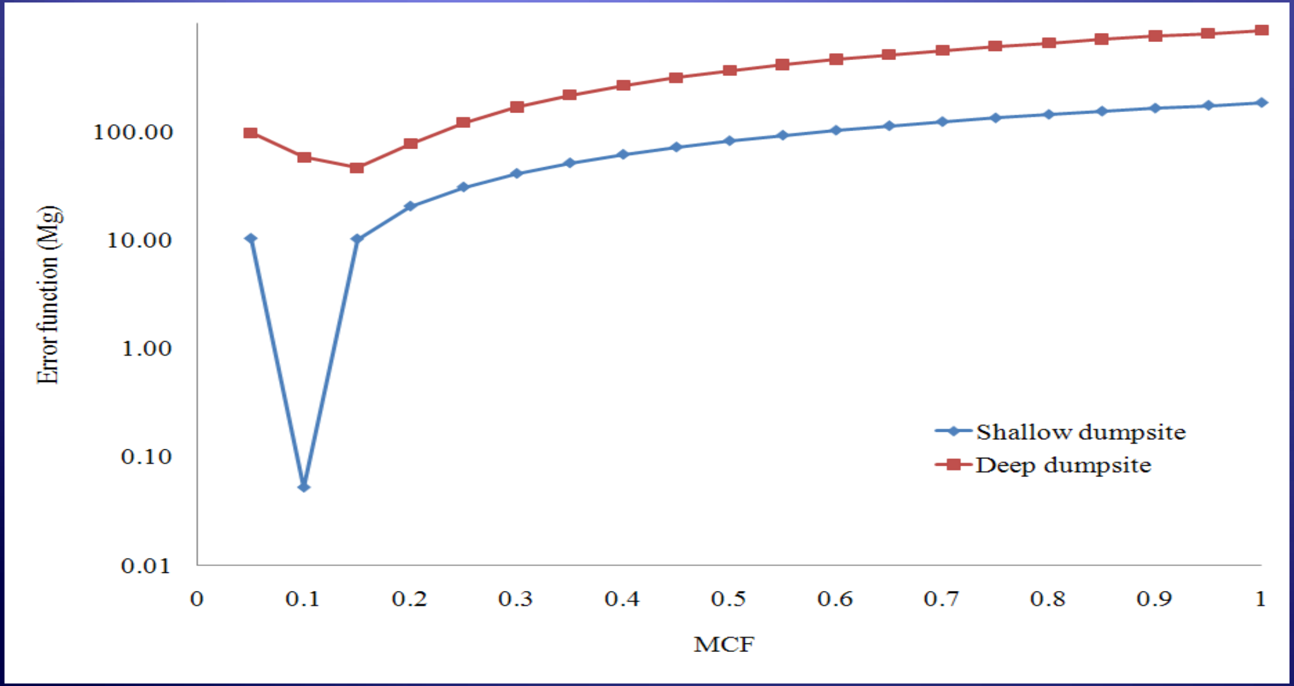
- Average spatial methane emissions from unmanaged sites were quite lower than managed sites in all seasons.
- At Cha-Am landfill, the only one of shallow managed site in this study, the methane emission was lower than other managed sites. Intrusion of air into the landfill might be decreased anaerobic waste degradability.

Parameter evaluation

- The best fitting values of MCF were 0.65, 0.20, 0.15 and 0.10 for deep landfill, shallow landfill, deep dumpsite and shallow dumpsite, respectively when OX values were justified to 0.15 and 0.70 for landfill and open dumpsite, respectively.
- The MCF values obtained are thus lower than the IPCC default values. In contrast, OX values are higher than the IPCC default values. As the air permeability of the cover soil in landfills and open dumpsites corresponds with poor operation in case of landfill, the MCF and OX were different from IPCC default values.

Results of error function analysis

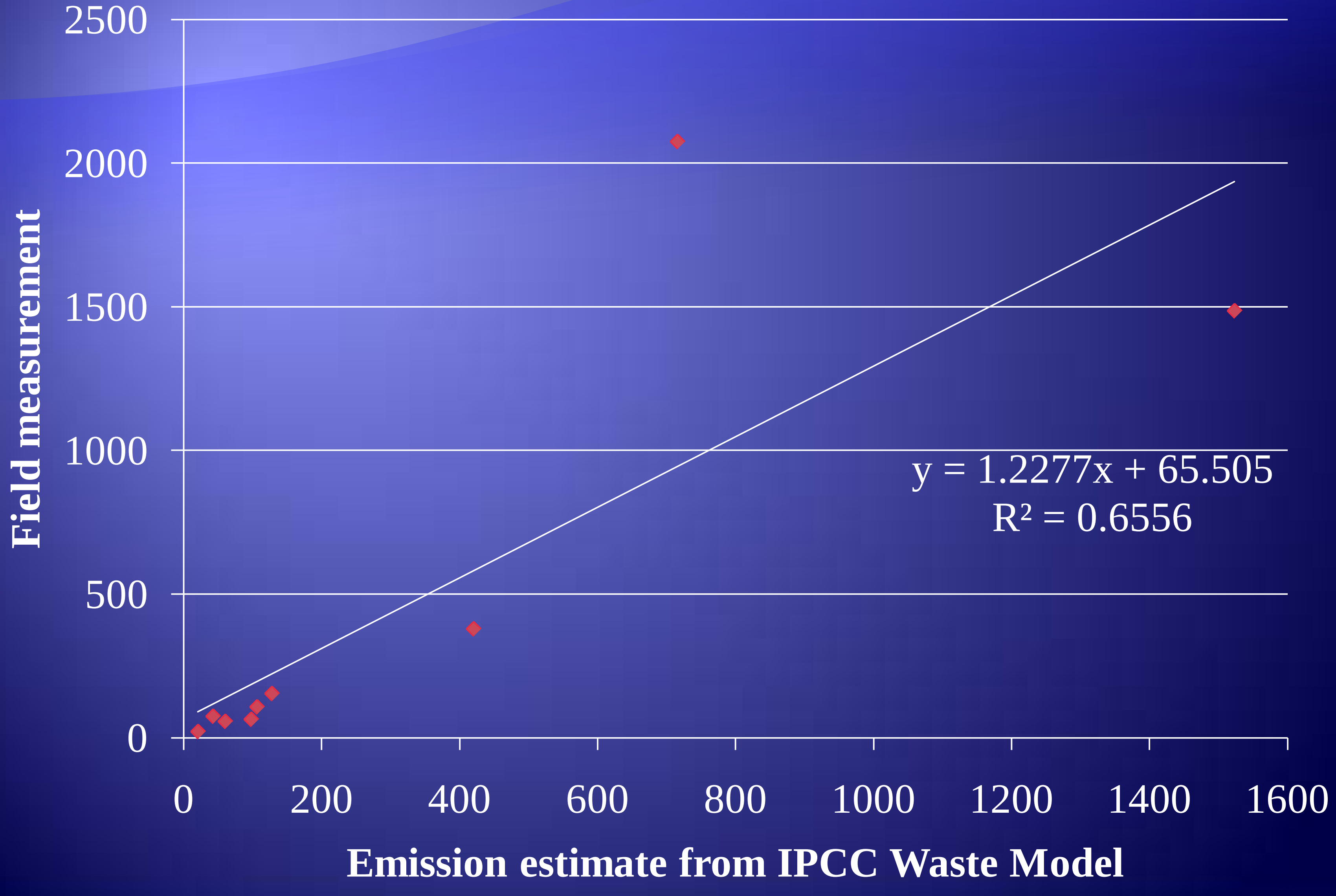




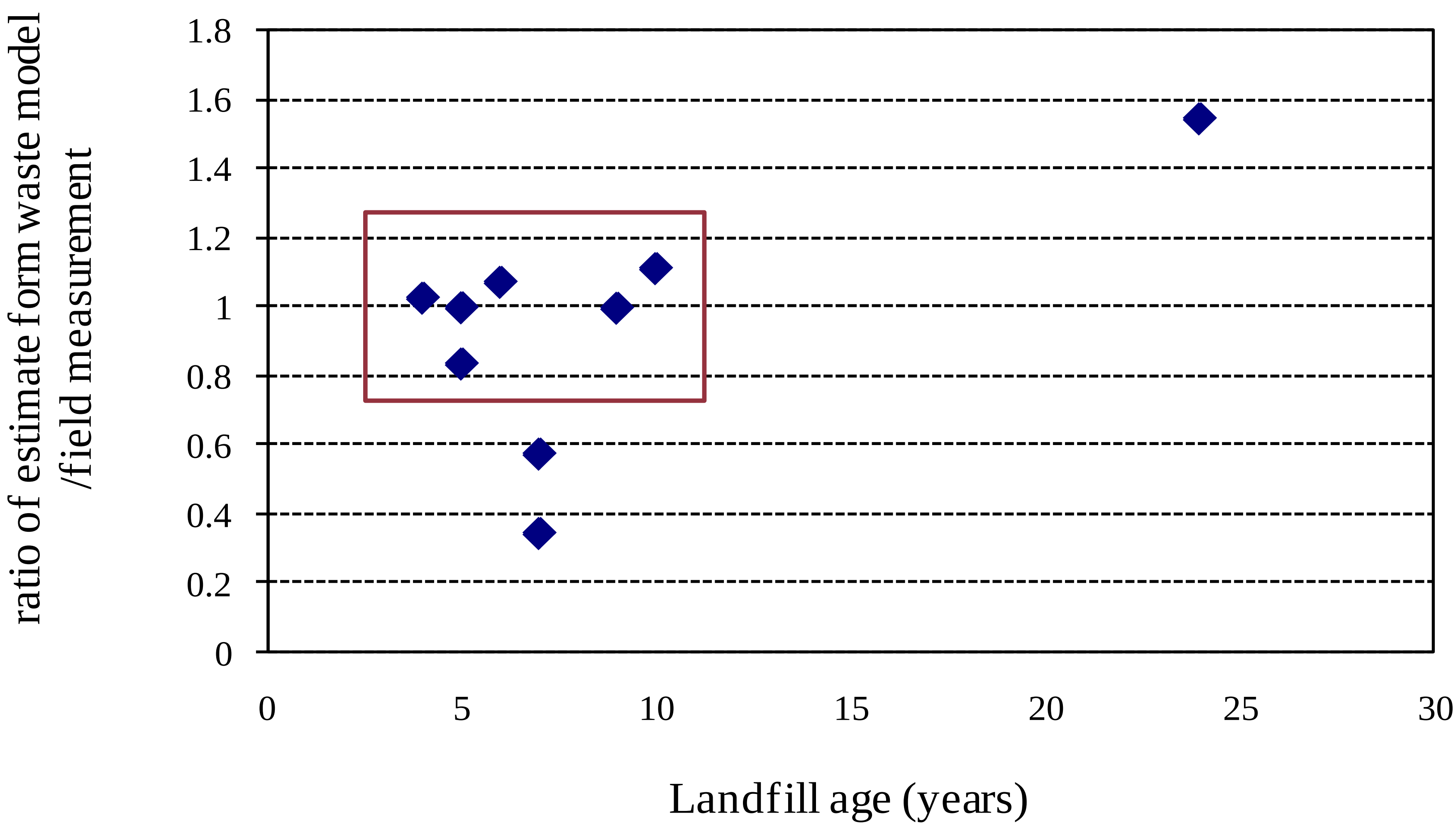
Comparison of model parameters with field investigations

Site	Selected MCF	Selected OX	IPCC Waste Model	Field measurement	Diff.
MD1	0.65	0.15	1,523.30	1,485.75	-2.53%
MD2	0.65	0.15	127.76	153.01	16.50%
MD3	0.65	0.15	715.62	2,074.87	65.51%
MD4	0.65	0.15	420.11	378.21	-11.08%
MS1	0.2	0.15	60.07	56.08	-7.11%
UD1	0.15	0.70	42.45	73.89	42.55%
UD2	0.15	0.70	106.12	106.52	0.37%
UD3	0.15	0.70	97.67	63.26	-54.39%
US1	0.1	0.70	20.60	20.65	0.25%

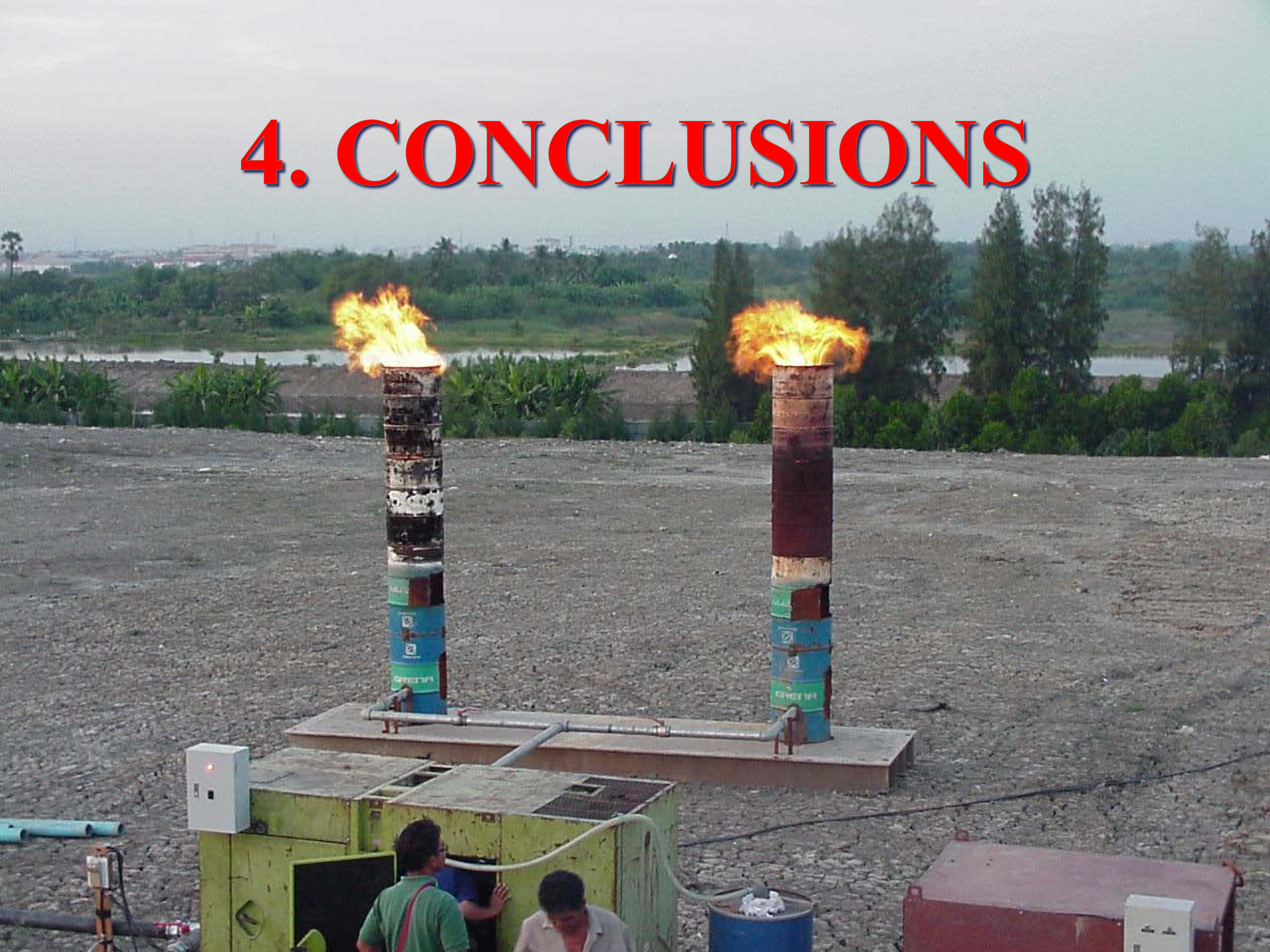
Relation of estimate methane emission and field measurement (Mg)



Ratio of methane emission from waste model versus field measurement



4. CONCLUSIONS



- The calculated methane emissions from the IPCC Waste Model gave good results compared to field measurement in many cases.
- The key parameters including the MCF, OX, half-life and delay time that were obtained from this study can be used as country-specific parameters for Thailand and other tropical countries in the IPCC Waste Model
- Using these country-specific values also helps to reduce uncertainties as well as to improve the quality of estimation.


Thank you very much
for your attention