Thailand
Dr. Sirintornthep Towprayoon

Technical issues related to the preparation of the GHG inventory:

A Study of Thai Emission Factors in Agriculture and Waste Sector

Workshop on Greenhouse Gas Inventories in Asia
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GHG Inventory

- Inventory year : 1990, 1994, 1998
- Source categories : CO2, CH4, N2O, NOx, CO, NMVOC
- Methodologies : 1996 IPCC revised Guideline
- Emission Factor : Mostly IPCC default

Emission factors used in inventory

Sector	IPCC default	Country specific	Development of EF
Energy	√		√
Industry	√		
Agriculture	√	√	√
LULUCF	√		
Waste	√		√

Agriculture sector : Rice field

Emissions of methane from rice fields can be represented as follows:

EQUATION 1

$$F_c = EF \times A \times 10^{-12}$$

where:

F_c = estimated annual emission of methane from a particular rice water regime and for a given organic amendment, in Tg /yr;

EF = methane emission factor integrated over integrated cropping season, in g/m^2;

A = annual harvested area cultivated under conditions specified above. It is given by the cultivated area times the number of cropping seasons per year, i.e., in m^2/yr.

Study of emission factor in rice field

- Factor effecting emission
- Scaling factor
- Model implementation

Factor influence emission

- -Soil type
- -Rice variety
- -Rice ecosystem
- -Fertilizer application
- -Drainage System

Methane emission involved with methane production and methane transportation via plant stem

Nitrous oxide involved with water drainage system

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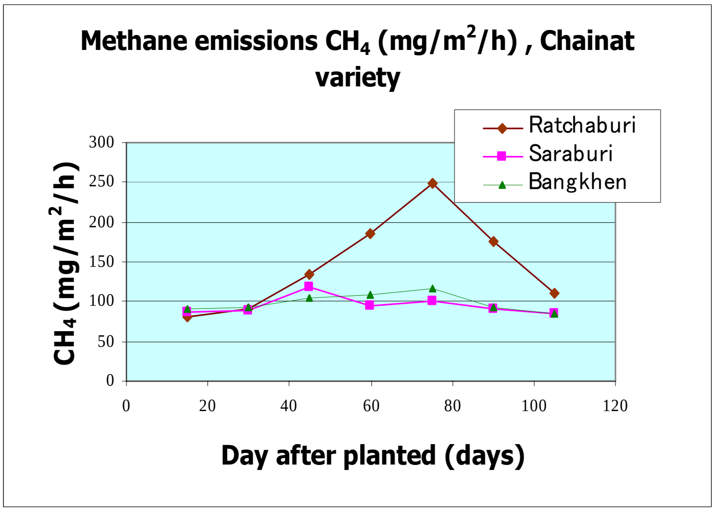
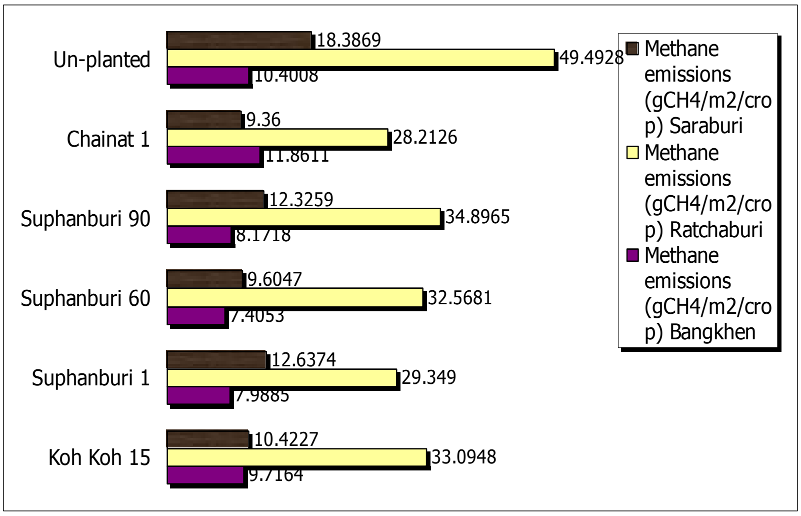
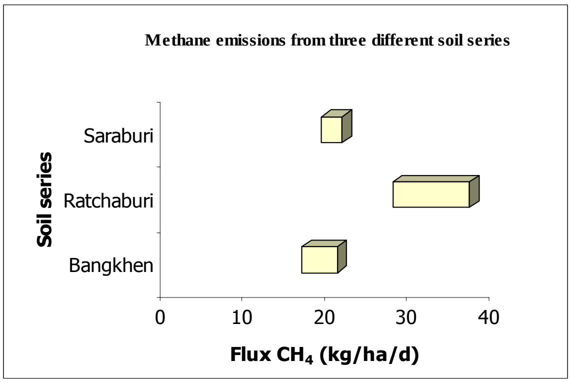
Factor effecting emission : Soil type



Factor effecting emission : Soil type and rice varieties

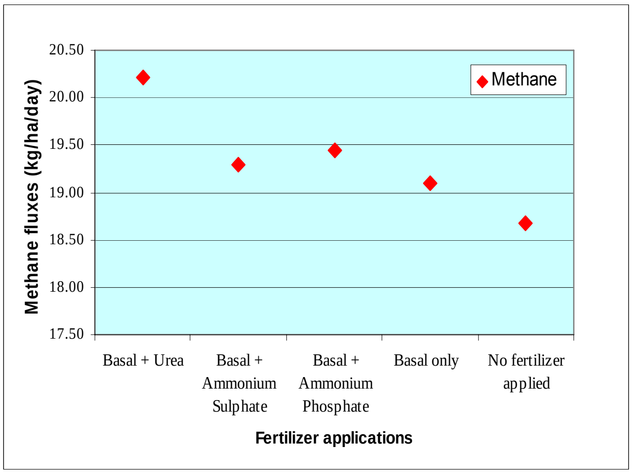


Factor effecting emission : Soil type and rice varieties



Soil series	Methane emission (kg/ha/d)	
	Maximum	Minimum
Bangkhen	16.50	4.26
Ratchaburi	27.57	9.33
Saraburi	18.86	2.54

Factor effecting emission : Fertilizers



Factor effecting emission : Fertilizers

Fertilizer	Methane emissions		Grain yield	Emission per yield
	(kg/ha/d)	(g/m2/d)	(kg/rai)	(kg CH4/kg yield)
Basal + Urea	20.22	2.02	774.70	0.47
Sulphate	19.29	1.93	743.48	0.46
Phosphate	19.45	1.95	750.00	0.46
Basal only	19.10	1.91	530.77	0.65
No fertilizer applied	18.67	1.87	398.25	0.84

Factor effecting emission : Water level management

Water management	Methane emissions (Ratchaburi soil series)		
	(kg/ha/d)	(g/m2/d)	kgCH4/ha/crop
Flooded every 7 days (5 cm.)	20.06	2.01	359.41
Flooded every 7 days (2.5 cm.)	19.71	1.97	353.29
Saturated soil (no water above ground)	19.42	1.94	348.08
7 cm depht flooded	20.48	2.05	367.06

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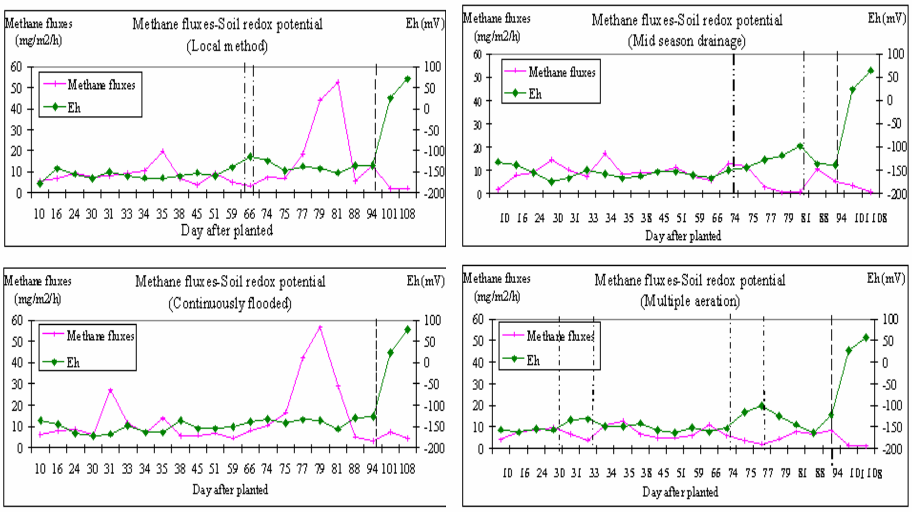
Factor effecting emission : Drainage System

4 different drainage system

local method – drain 1 time during vegetative period
Continuous flood – no draining
Midseason drainage – drain 1 time during flowering period
Multiple drainage – drain 2 times during vegetative and flowering period

Methane emission and soil redox potential from 4 different drainage rice fields



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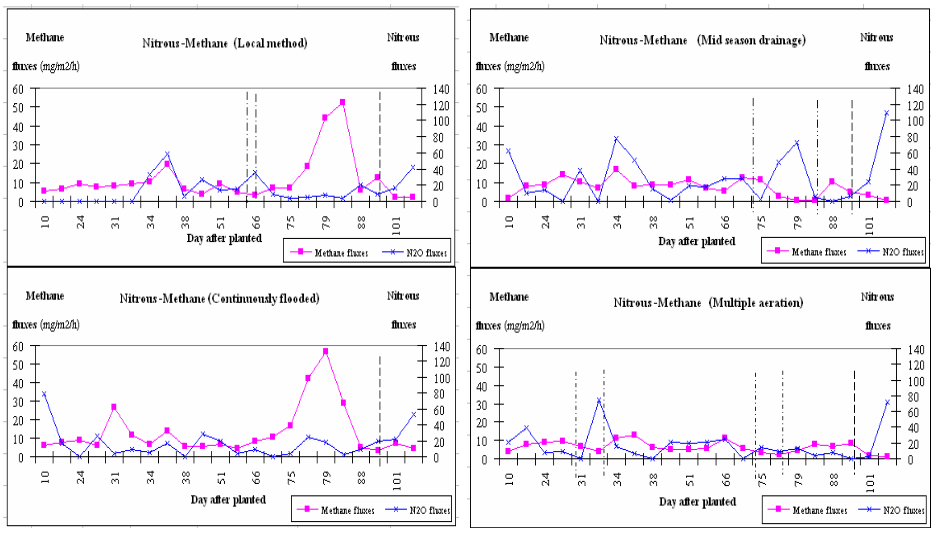
Nitrous oxide and methane emission from 4 different drainage rice fields



Emissions and grain yields from 4 different water management

Treatment	Product	Emissions		Emissions		Net GHGs		
		CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	Total
	kg/ha/crop	mg/m2/day	ug/m2/day	kg/ha/crop	kg/ha/crop	GWP/ha/crop	GWP/ha/crop	GWP/ha/crop
Local Method	4,375	213.88	291.66	239.55	0.33	5,030.54	102.43	5,132.97
Continuously flooded	4,350	217.50	331.68	243.60	0.37	5,115.59	115.16	5,230.75
Midseason drainage	4,075	155.02	545.63	173.62	0.51	3,646.12	159.28	3,805.40
Multiple aeration	3,875	139.99	343.60	156.79	0.38	3,292.49	119.30	3,411.79

grain yields

Mid season drainage < Local method **6.86 %**

Multiple aeration < Local method **11.43 %**

Net GHGs

Mid season drainage < Local method **25.86 %**

Multiple aeration < Local method **33.53 %**

Scaling factor

Scaling factor : water management

Rice ecosystem	Seasonal emission (g/m^2)			Reference
	Min.	Max.	Average	
Irrigated Thailand	12.40	55.20	38.76	Katoh et al 1999a
	17.40	68.20	39.14	Katoh et al. 1999b
	34.80	61.30	44.95	Katoh et al. 1999c
	0.45	44.29	15.00	Jermsawatdipong et al. 1994
	4.00	75.00	34.50	Yagi et al. 1994
	19.20	21.90	20.55	Karnchanasuntorn 1994
	0.50	59.04	9.38	Charoensilp et al. 1995
	6.93	10.02	8.38	Wongkumpoo 1999
	8.19	30.54	22.42	Jittasatta 1999
	1.76	38.10	21.46	Wanichpongpan 1993
	5.80	59.30	30.00	Chairoj et al. 1994
	-	-	26.624	Jermsawatdipong et al. 1999[a]
	7.608	16.848	10.569	Saenjan et al. 2000[b]
Rainfed Thailand	15.20	32.90	24.05	Teawyuenyong 1994
	1.90	71.00	41.11	Chairoj et al. 1994
	-	-	18.72	Jermsawatdipong et al. 1999[c]
Deep water Thailand	4.90	63.00	17.29	Charoensilp et al. 1996

[a,c] Reported in Thailand's First National Communication to UNFCCC (Draft) on March, 2000
[b] Unofficial report to TRF

Scaling factor : water management

Rice ecosystem	Seasonal emission (g/m^2)			Reference
	Min.	Max	Mean (per ecosystem)	
Continuously flooded	12.400	55.200	23.236	Katoh et al 1999a
	17.400	68.200		Katoh et al. 1999b
	34.800	61.300		Katoh et al. 1999c
	0.450	26.240		Jermsawatdipong et al. 1994
	4.000	75.000		Yagi et al. 1994
	19.200	21.900		Karnchanasuntorn 1993
	0.500	29.600		Charoensilp et al. 1996
	8.190	30.540		Jittasatta 1999
	1.760	25.700		Wanichpongpan 1993
	5.800	59.300		Chairoj et al. 1994
	-	26.624		Jermsawatdipong et al. 1999[a]
	7.608	16.845		Saenjan et al. 2000[b]
Multiple aeration	8.010	9.140	8.568	Wongkumpoo 1999
Rainfed Flood prone	15.200	32.900	35.970	Teawyuenyong 1994
	1.900	71.000		Chairoj et al. 1994
	-	18.720		Jermsawatdipong et al. 1999[c]
Deep water	4.90	17.80	13.400	Charoensilp et al. 1996

[a,c] From Thailand's First National Communication to UNFCCC (Draft), March, 2000.
[b]Unofficial reports to The Thailand Research Fund.

Scaling factor : water management

Category	Sub-category			Scaling factors (this study)	Standard emission factors(EF), g/m^2/season[a]
Upland	None			0[b]	0[c]
Lowland	Irrigated	Continuously flooded		1	23.236
		Intermittently flooded	Single aeration	---	No data
			Multiple aeration	0.369	8.57
	Rainfed	Flood prone		1.548	35.970
		Drought prone		---	No data
	Deep Water	Water depth 50-100 cm		0.577	13.400
		Water depth > 100 cm		---	No data

[a] Estimated from field experiments listed in Tables 3.
[b, c] The only one study conducted in upland systems of Thailand obtained on emission rate of 5.29 g/m^2/season [Karnchanasoonthorn, 1993]. However, emission rates should normally be close to 0 because true upland systems do not create anaerobic conditions for significant periods of time.

Scaling factor : organic amendment

Type & Amount applied (tons /ha)		Estimated Scaling factor	Reference
Azolla	0.6250	1.446	Charoensil et al. 1996
Compost	6.250	6.515	Charoensil et al. 1996
Compost	2.069	2.250	Wanichpongpun 1993
Green Manure	30.000	13.390	Jermsawatdipong et al. 1994
Green Manure	12.500	4.312	Charoensil et al. 1996
Rice Straw	2.000	12.850	Jermsawatdipong et al. 1994
Rice Straw Burned	12.500	1.190	Charoensil et al. 1996
Rice Straw Compost	3.100	0.686	Jermsawatdipong et al. 1994

Methane emissions (kg/hec/day)
from difference soil type and fertilizer applications

Province Name	Soil series	NF	CF	CF+OM	Average
Pathumthani	Rangsit	0.45	0.73	1.11	0.763
Ratchburi	Nakornpathom	1.13	2.32	5.93	3.127
Surin	Roi Et	3.77	5.41	6.33	5.170
Chiangmai	Hang Dong	0.89	1.76	1.31	1.320
	Average	1.56	2.56	3.67	2.595

Remarks: NF = No fertilizer application, CF = Chemical fertilizer, CF + OM = Chemical and organic fertilizer

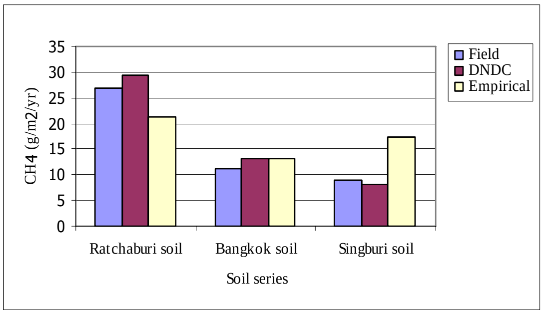
Reference: Jermsawatdipong et al., 1993 in Office of Environmental Policy and Planning, 2000b

Model implementation

- Process model- DNDC site and regional mode
- Empirical model

Model implementations : soil type

Treatments	Methane emissions		
	Field observed	DNDC model	Empirical model
	g/m2/yr	g/m2/yr	g/m2/yr
Ratchaburi soil	26.87	29.44	21.29
Bangkok soil	11.29	13.15	13.13
Singburi soil	8.91	8.13	17.35



DNDC model (Li et al., 1992)
Empirical model (Huang et al., 1998)

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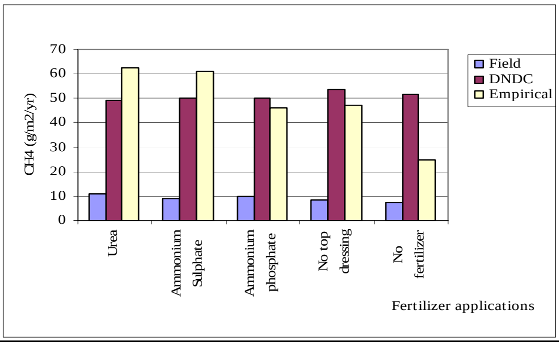
Model implementations : fertilizer application

Treatments	Methane emissions		
	Field observed	DNDC model	Empirical model
	g/m2/yr	g/m2/yr	g/m2/yr
Urea	10.89	49.17	62.67
Ammonium Sulphate	8.8	49.94	61.01
Ammonium phosphate	9.71	49.94	46.19
No top dressing	8.4	53.75	47.13
No fertilizer	7.44	51.83	24.91

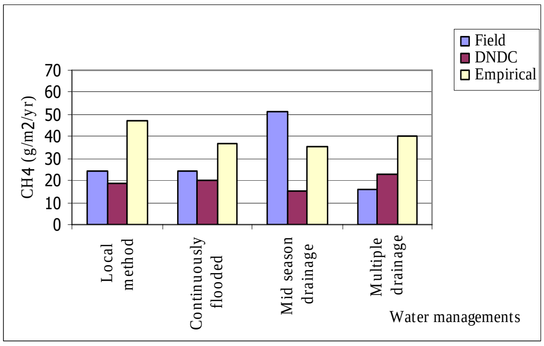


DNDC model (Li et al., 1992)

Empirical model (Huang et al., 1998)

Model implementations : drainage system

Treatments	Methane emissions		
	Field observed	DNDC model	Empirical model
	g/m2/yr	g/m2/yr	g/m2/yr
Local method	23.96	18.42	47.47
Continuously flooded	24.36	19.99	36.93
Mid season drainage	51.38	15.51	35.26
Multiple drainage	15.68	22.88	40.23



DNDC model (Li et al., 1992)

Empirical model (Huang et al., 1998)

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Waste sector : Solid Waste Disposal Site (SWDS)

- Tier 1

EQUATION I
Methane emissions (Gg/yr)
=
$$(MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 - R) \times (1-OX)$$

Tier 2

LFG	=	2LoR(e+kc - e-kt)
LFG	=	Total amout of landfill gas generation in current year (m3/yr)
Lo	=	Total methane generation potential of waste (m3/ton)
R	=	Average annual waste acceptance rate during active life (ton)
k	=	Decay constant for the rate of methane generation (1/yr)
t	=	Time since landfill opened (yr)
c	=	Time since landfill closure (yr)

Waste Sector: Landfill

Locations	Nakornpathom	Huahin	Suphanburi
Ambient temp.(^{O}C)[1/]	35.3	34.1	34.8
Velocity (m/s) [1/]	0.43-0.45	0.23-0.30	0.31-0.36
Flow rate (m^3/s) [1/]	0.0075-0.008	0.0018-0.0024	0.0024-0.0029
Temp.(^{o}c) [1/]	37.5-38.6	35.1-36.5	36.6-37.5
Humidity (% rh) [1/]	56.1-56.4	53.6-54.4	54.7-55.1
% CH_4 [2/]	19.21-28.36	4.08-13.74	8.53-13.84
% CO_2 [2/]	12.23-18.38	2.27-8.69	5.10-8.74
Flow rate (m^3/yr) [1/]	236,520-252,288	56,765-75,686	75,686-91,454
CH_4 (m^3/yr) [3/]	45,438-71,678	2,318-10,399	10,214-15,358
Total waste in landfil, Flow rate (m^3/yr) [4/]	977,616	545,574	252,287
Total CH_4 (m^3/yr) [4/]	234,233	57,545	38,888

[1/] Field measurements

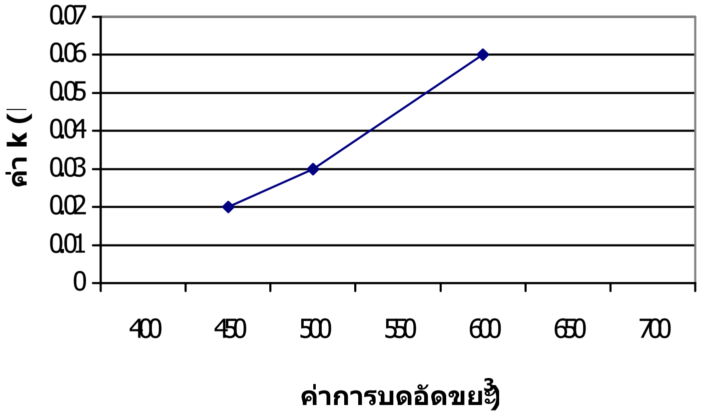
Waste: Landfill

K value (l/yr)

Municipal	k (l/yr)	Compaction ration (kg/m^3)
Suphanburi	0.02	450
Huahin	0.03	500
Nakornpathom	0.06	600

Lo value

Locations	Lo (m^3/ton)
Municipal	121.4
Bangkok	103.7



Waste: Landfill

Methane emission (Mg/yr) from landfill using actual Lo

Municipal	1990	1994	2000	2005	2010
1.Khonkean	132*	364*	1,352	2,422	3,216
2 Chantaburi	36*	73*	1,179	1,840	2,113
3.Chiangrai	56*	120*	1,267	1,932	2,203
4.Chiangmai	508*	898*	3,112	5,305	6,929
5. Nakornpathom	243*	505*	2,240	3,475	4,390
6.Nakornratsima	434	1,130	2,976	4,178	5,069
7.Nakornsawan	181	450	1,855	2,834	3,551
8.Udonthani	61*	150*	1,190	1,942	2,496
9.Phisanulok	86*	191*	1,311	2,109	2,696
10.Songkhla	1,256	2,626	5,804	7,528	8,806

* ใช้วิธีการกำจัดขยะโดยการเทกอง ใช้ค่า Lo = 60.7 m3/ton เนื่องจากการกำจัดขยะโดยวิธีการเทกองจะถือว่ามีการเกิดก๊าซฝังกลบมีปริมาณเป็นครึ่งหนึ่งของการกำจัดขยะโดยวิธีการฝังกลบ

Waste: Landfill

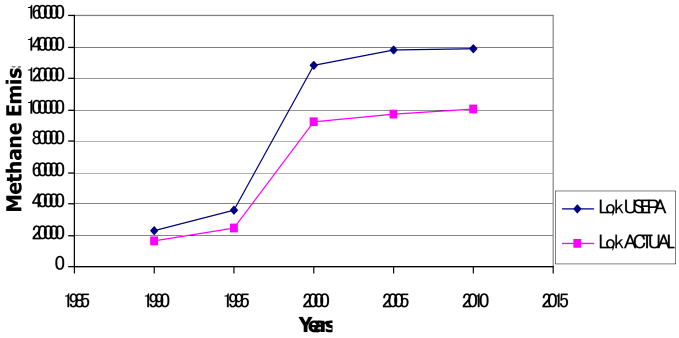
Methane emission (Mg/yr) from landfill using actual Lo

(continuous)

Municipal	1990	1994	2000	2005	2010
11.Ubonratchathani	59*	131*	901	1,791	2,448
12.Samutprakarn	159	561	2,410	4,485	6,010
13.Chonburi	312*	742*	4,128	7,677	9,935
14.Nakornsithammarat	212*	407*	1,882	2,934	3,713
15.Prachubkirikhan	60*	140*	1,133	1,850	2,379
16.Suphanburi	50*	99*	862	1,565	2,085
Total	3,848	8,587	33,602	53,867	68,039
Bangkok	12,280	16,180	58,661	43,465	32,200
Grand total	16,128	24,767	92,263	97,332	100,239

* ใช้วิธีการกำจัดขยะโดยการเทกอง ใช้ค่า Lo = 60.7 m3/ton เนื่องจากการกำจัดขยะโดยวิธีการเทกองจะถือว่ามีการเกิดก๊าซฝังกลบมีปริมาณเป็นครึ่งหนึ่งของการกำจัดขยะโดยวิธีการฝังกลบ

Comparison of methane emissions estimated using Lo and k value from USEPA and actual value



The End

Sawasdee