Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Potential of electricity generation from waste managements: Case study in Mueang, Thailand

Apinya Pluemudom, Kruamas Smakgahn *

Environmental Sciences and Technology Program, Department of Science, Faculty of Liberal Arts and Science, Kamphaeng Saen Campus, Kasetsart University, Nakhon Pathom Province, 73140, Thailand

ARTICLE INFO

Article history:
Received 25 January 2017
Received in revised form
10 November 2017
Accepted 28 December 2017

Keywords:
Waste management
Open dumping
Landfill
Electricity generation

ABSTRACT

Municipal solid waste (MSW) is one of the major sources of greenhouse gases (GHGs). Its emissions to the atmosphere lead to global warming and climate change. Increasing in population and urban development is a key factor for waste generation. MSW generation had been increased from 420.68 tons per day in 2014 to 485,838 tons per day in 2026. This study aimed to calculate the potential of electricity generation from waste management. First order model (FOD) of IPCC guideline was used for the estimation of methane emission, and types of waste management was categorized into 4 scenarios: 1) Managed-anaerobic (S1), 2) Unmanaged-deep (>5 m waste) or high water table (S2), 3) Unmanaged-shallow (<5 m waste) (S3), and 4) Uncategorized (S4). The results showed that the possibility of electricity generation in 2026 would be 0.029, 0.0234, 0.0117, and 0.0176 (x10^9 kWh) from S1, S2, S3, and S4, respectively. The profits from electricity generation from S1, S2, S3, and S4 would be approximately 810,000, 650,000, 324,000, and 486,000 USD per year, respectively. The results indicated that the managed-anaerobic landfill showed highest benefit for energy generation.

1. Introduction

Open dumping of municipal wastes is one of the factors that enhance global warming. The microorganism in open dumping area degrades the waste, and the gas is generated and emitted into atmosphere (Ahmed et al., 2015). The main gas generated from waste degradation is methane, which it is one of anthropogenic greenhouse gas that has an effect on surface temperature due to climate change (Themelis and Ulloa, 2007). Waste disposal is one of the emission sources of greenhouse gases that can be managed and harvested in order to use as energy generation (USEPA, 2016). Landfill gas (LFG) is constituted of 50% of methane (CH_4), 45% of carbon dioxide (CO_2), and 5% of other minor constituents such as nitrogen (N_2), H_2S, and non-methane organic compounds (NMOCs) (Themelis and Ulloa, 2007; USEPA, 2016). LFG is the important greenhouse gas (GHGs) generated from the anaerobic biodegradation of municipal solid waste (MSW) in landfills. One kg of MSW generates 0.045 to 0.15 kg of methane emission, which it is approximately 0.09 to 0.30 kg of LFG (Themelis and Ulloa, 2007; USEPA, 2016). This study predicted the amount of methane gas generated from waste management in order to obtain the potential energy generation from the methane gas production. The study area located in Mueang district, Samut Prakan province, it is in the central of Thailand. Samut Prakan is the city with high growth rate of industrial sector development. The migration of workers into the city resulted in high amount of waste generation and accumulation which it is disposed into landfill.

2. Methodology

2.1. The study site

Samut Prakan province is located in central of Thailand, next to Bangkok metropolitan in the northern and western part, and next to Chachoengsao province in the eastern part. It is also located at the Chao Phraya River estuary on the gulf of Thailand. The western areas of the river mostly are rice paddy fields, shrimp farms, and mangrove forest. While the eastern parts of the Chao Phraya River are the metropolitan and industrial estates. The total area of this province is about 1,004 km^2 (USEPA, 2016). Approximately 47.2 km of the

* Corresponding Author.
Email Address: smakgahn@yahoo.com (K. Smakgahn)
https://doi.org/10.21833/ijaas.2018.03.002

boundary lay on a coastline. The population of Sumut Prakan is about 2,234,864 people and about 525,851 people are living in this study area.

2.2. Estimated population and waste generation

This study used the exponential method for the estimation of population and the amount of waste generation. The details for the estimation of population and waste generation were presented in Table 1. Since the increasing rate of population in this area is in exponential form, the exponential equations (Eq. 1 and 2) were used for the calculation of population.

$$P_t = P_0 e^{rn} \quad (1)$$

where,
P_t = number of population projection in 2014,
P_0= number of population projection in 2010,
r = population increasing rate per year,
n = the number of years.

$$r = [\text{loge}\ (P_t/P_0)]/n \quad (2)$$

where
r=population increasing rate per year (0.012),
P_t=number of population in 2014,
P_0=number of population in 2010,
n=the number of years.

Table 1: Estimated population and waste generation in 2014-2026

Year	Population (people)	Waste generation (Kg/day)
2014	525,851	420,681
2018	551,707	441,366
2022	578,835	463,068
2026	607,297	485,838

Table 1 described the population projection in 2014 to 2026. The population in 2014 is about 525,851 people, and the population projection in 2026 is increased about 13.41% from 2014. The estimated population and waste generation calculated by exponential method revealed that the relationship between population increasing rate and amount of waste generation is in linear form with r^2 =1. The census registration data in 2014 is used as basal data for the calculation. The registered population and non-registered population is 51% and 48% of total population, respectively. The proportion of the population for the round trip worker is about 1% of the total population, and they produced 420.68 tons of waste/day in 2014.

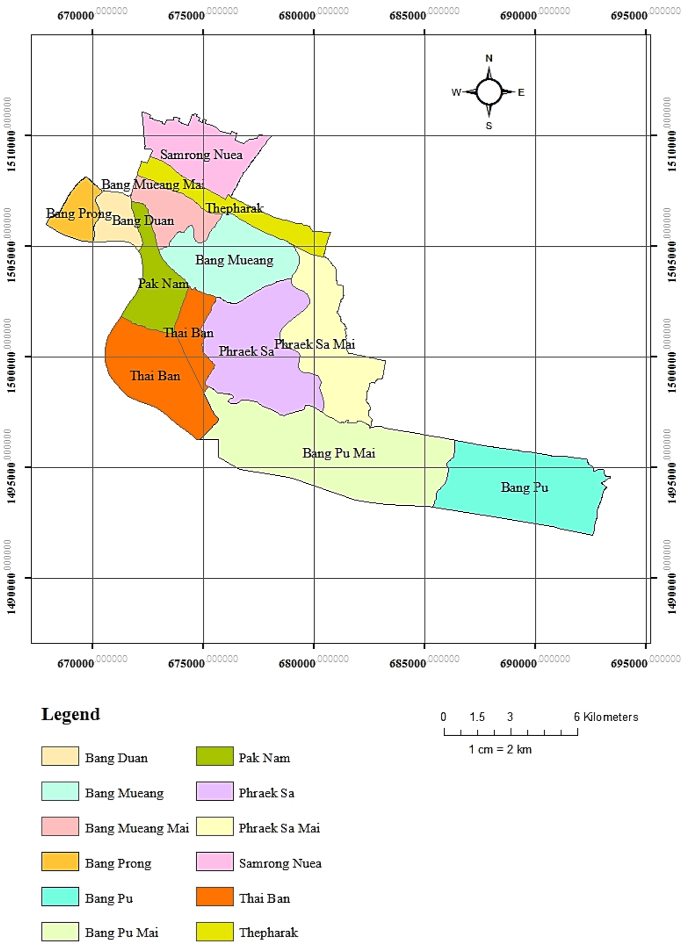

Fig. 1: The study area

The estimated population by using exponential equation method is 551,707, 578,835, and 607,297 people in 2018, 2022, and 2026, respectively. The estimated waste generation is 441,366, 463,068, 485,838 tons/day in 2018, 2022, and 2026, respectively. Thus, it is indicated that the number of population is the main factor for waste generation in every years.

High amount of solid waste accumulation has an effect on both human and environmental health of the area around the landfill (Giusti, 2009). The open dumping is piled up of bacteria and animal diseases (such as flies, mice, cockroaches, etc.). Most of open dumping wastes are municipal wet wastes, and animals play as carriers of diseases to the people in the communities around the landfill. People survive with the risk of respiratory depression and cholera (Giusti, 2009).

The wet wastes in open dumping are quickly decomposed by microorganism and produced bad smell as by-product, lead to the respiratory depression and affect to the mental health of the people. The main problem of open dumping or unmanaged landfill is odor and leachate from the waste degradation. These because the municipal solid wastes are dumped without waste sorting and it mingles with hazardous waste such as spray and battery, resulted in the toxicity to water and soil (Widmer et al., 2005).

2.3. Estimated methane emissions from landfills

The first order model (FOD) proposed by Intergovernmental Panel on Climate Change (IPCC, 2006) was used for the estimation of methane emission from waste disposal site (Noor et al., 2013; Kornboonraksa et al., 2005; Gyalpo, 2008).

$$Q = (MSW_T * MSW_F * MCF * DOC * DOC_F * F * 16/12 - R)\,(1 - OX) \qquad (3)$$

where

Q=Total methane emissions (Gg/year)
MSW_T=Total solid waste generation (Gg/year)
MSW_F=Fraction of solid waste disposed to landfill
MCF=Methane correction factor (fraction) (Table 2)
DOC=Degradable organic carbon (fraction)
DOC_F=Fraction of DOC dissimilation
F=Fraction of CH_4 in landfill gas
R=Recovered CH_4 (Gg/year)
OX=Oxidation factor (fraction)

The available data in 2014 was used as the case study; including the amount of total solid waste which it was about 420,681 tons/day. MSW_F selected from national specific MSW disposal figures (in unit of kg/capita/day) was used instead of MSW_T and it was taken as 0.8. While default value of MCF was used as 1, 0.8, 0.4 and 0.6 for managed – anaerobic, unmanaged – deep (>5 m waste) or high water table, unmanaged – shallow (<5 m waste) and uncategorized management method, respectively (Giusti, 2009). In addition, the default value of DOC is equal to 0.14, DOC_F was 0.5, and F was 0.5. This study assumed that there is no recovery methane emission, therefore, R is assumed as zero and oxidation factor is zero (Widmer et al., 2005; IPCC, 2006).

Table 2: Solid waste classification and Methane Correction Factor (MCF) default values

Type of site	Methane Correction Factor (MCF) Default Values
Anaerobic managed	1.0
Unmanaged deep and/or high water	0.8
Unmanaged shallow	0.4
Uncategorised	0.6

Data source: IPCC (2006)

3. Results and discussion

This study classified the calculated methane production based on process of waste management. The waste management is classified into 4 scenarios as shown in Table 3.

3.1. Scenario 1: Anaerobic managed solid waste disposal site (Sanitary landfill)

Waste management in this scenario, the location of the waste disposal was fully under control (the waste was directed to specific disposal areas, it was also protected from the scavenging and fires). It was covering with at least one level of covering material, compacting and leveling waste by mechanical method. This sanitary landfill management produced highest methane production in comparing to other waste management types. It is possible to control the quantified methane production and utilize in field as renewable energy. The calorific value of methane production in this scenario is about 0.091-0.105 ($x10^9$ MJ) and the potential of electricity generation is about 0.0253-0.0293 ($x10^9$ kWh). The total benefit from electricity generation is approximately 2,182,000 USD or 75,000,000 THB.

3.2. Scenario 2: Unmanaged solid waste disposal sites deep and/or with high water

Unmanaged solid waste disposal site is the sites that are not met the criteria of managed solid waste, with depths of 5 m. to greater than 5 m. and/or high water table at ground level of disposal site, such as pond, river or wetland.

The garbage was dumped into puddles or holes with depth greater than 5 m. or more without surface compression. Emission of methane is directly released into the atmosphere.

The calorific value of methane production is about 0.073-0.084 ($x10^9$MJ) and the potential of electricity generation is about 0.0203-0.0234 ($x10^9$ kWh). Total benefit from electricity generation in the unmanaged – deep management is approximately 1,746,000 USD or 60,700,000 THB.

Table 3: Estimated methane emissions and its benefit as carbon credit and energy generation

Management method	Years	Methane emission Gg/year	CO_2 equivalent (Mt CO_2eq)	Benefit from carbon credit (x10^6 $)	Volume of CH_4 (x10^6m^3)	Calorific value (x10^9MJ)	Equivalent electricity generation (x10^9kWh)	Benefit from electricity (x$10^6$$)
Anaerobic managed solid waste disposal site	2014	3.58	0.075	0.34	5,371.51	0.091	0.0253	2.024
	2018	3.76	0.079	0.36	5,635.63	0.096	0.0266	2.128
	2022	3.94	0.083	0.37	5,912.74	0.101	0.0279	2.232
	2026	4.14	0.087	0.39	6,203.47	0.105	0.0293	2.344
Unmanaged solid waste disposal sites deep and/or with high water	2014	2.87	0.060	0.27	4,297.21	0.073	0.0203	1.624
	2018	3.01	0.063	0.28	4,508.51	0.077	0.0213	1.704
	2022	3.16	0.066	0.30	4,730.19	0.080	0.0223	1.784
	2026	3.31	0.070	0.32	4,962.78	0.084	0.0234	1.872
Unmanaged shallow solid waste disposal site	2014	1.43	0.030	0.14	2,148.60	0.037	0.0101	0.808
	2018	1.50	0.032	0.14	2,254.25	0.038	0.0106	0.848
	2022	1.58	0.033	0.15	2,365.10	0.040	0.0112	0.896
	2026	1.66	0.035	0.16	2,481.39	0.042	0.0117	0.936
Uncategorized solid waste disposal site	2014	2.15	0.045	0.20	3,222.91	0.055	0.0152	1.216
	2018	2.26	0.047	0.21	3,381.38	0.057	0.0160	1.280
	2022	2.37	0.050	0.23	3,547.64	0.060	0.0167	1.336
	2026	2.48	0.052	0.23	3,722.08	0.063	0.0176	1.408

Remarks: Benefit as carbon credit =4.5$/t$CO_2$ equivalent, benefit as electricity generation =0.08 USD/kWh or 2.7815 THB/kWh, 1USD=34.53 THB currency exchange rate on 25/2/2016

3.3. Scenario 3: Unmanaged shallow solid waste disposal site

All solid waste disposal sites that are not met the criteria of managed solid waste disposal site which a depth less than 5 m. The garbage was dumped in puddles or holes with a depth of less than 5 m. The calorific value of methane production is about 0.037-0.042 (x10^9MJ) and the potential of electricity generation is about 0.0101-0.0117 (x10^9 kWh), the total benefit from electricity generation is approximately 872,000 USD or 30,000,000 THB.

3.4. Scenario 4: uncategorized solid waste disposal site

All uncategorized solid waste disposal sites are included in this scenario. The calorific value of methane production is about 0.055-0.063 (x10^9MJ) and the potential of electricity generation is about 0.0152-0.0176 (x10^9kWh). The revenue from electricity generation in the uncategorised management is approximately 1,310,000 USD or 45,000,000 THB. The estimated methane emission using number of population and amount of waste in Mueang district, Samut Prakan province in 2014 was 3.58, 2.87, 1.43, 2.15 Gg/year from S1, S2, S3, and S4, respectively. Whereas the total amount of calculated methane emissions in overall of Samut Prakan province was 0.81 gCH_4/ton-waste/day or 295.65 g. CH_4/ton-waste/year (Wangyao, 2010).

4. Conclusion

Potential of electricity generation from waste managements; case study in Mueang district, Samut Prakan province, Thailand, the study can be concluded that managed-anaerobic landfill sites (sanitary landfill) showed highest benefit for renewable energy generation. However, solid waste management in the study area mostly are open dumping (not sanitary landfill), as a consequence, approximately 1,300,000 USD of carbon credits had been lost, which it was equal to 12 years of the opportunity to generate electricity from the waste management. Therefore, expanding the landfill site in the study area is strongly recommended.

Acknowledgment

We extend great thanks to Department of city planning, Samut Prakan Provincial Administrative Organization, Prakkasa Municipality, Mueang Samut Prakan Municipality, Samut prakan province, Thailand for statically data related waste management in study area.

References

Ahmed SI, Johari A, Hashim H, Mat R, Lim JS, Ngadi N, and Ali A (2015). Optimal landfill gas utilization for renewable energy production. Environmental Progress and Sustainable Energy, 34(1): 289-296.

Giusti L (2009). A review of waste management practices and their impact on human health. Waste Management, 29(8): 2227-2239.

Gyalpo T (2008). Quantification of methane emissions from uncontrolled dumping of solid waste and from different sanitation systems in developing countries. Institute of Biogeochemistry and Pollutant Dynamics, Department Environmental Sciences, ETH Zürich, Zürich, Switzerland.

IPCC (2006). Guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change. Genève, Switzerland.

Kornboonraksa T, Chiemchaisri C, Chiemchaisri W, Towprayoon S, and Visvanathan C (2005). Determination of methane gas emissions from waste disposal sites in Thailand with geographical information system application. Thai Environmental Engineering, 19(3): 11-23.

Noor ZZ, Yusuf RO, Abba AH, Hassan MAA, and Din MFM (2013). An overview for energy recovery from municipal solid wastes (MSW) in Malaysia scenario. Renewable and Sustainable Energy Reviews, 20: 378-384.

Themelis NJ and Ulloa PA (2007). Methane generation in landfills. Renewable Energy, 32(7): 1243-1257.

USEPA (2016). Causes of climate change. United States Environmental Protection Agency, Washington, USA. Available online at: http://www.epa.gov

Wangyao K (2010). Application of the IPCC Waste Model to solid waste disposal sites in tropical countries: case study of Thailand. Environmental Monitoring and Assessment, 164(1): 249-261.

Widmer R, Oswald-Krapf H, Sinha-Khetriwal D, Schnellmann M, and Boni H (2005). Global perspectives on e-waste. Environmental Impact Assessment Review, 25(5): 436-458.