

Estimation of Green House Gas (GHG) emission at Telaga Punggur landfill using triangular, LandGEM, and IPCC methods

Yodi¹, I W K Suryawan² and A S Afifah³

¹ Information System Department, Universitas Universal, Batam, Indonesia

² Environmental Engineering Department, Universitas Pertamina, Jakarta, Indonesia

³ Environmental Engineering Department, Universitas Universal, Batam, Indonesia

E-mail: iwayankokosuryawan@gmail.com

Abstract. Landfill gas (LFG) is one of the largest greenhouse gas (GHG) contributors. By knowing the GHG inventory, disaster prevention efforts can be carried out. The purpose of this study was to determine the GHG quantity of the Telaga Punggur landfill sector using triangular, LandGEM, and IPCC method. CH₄ and CO₂ that is calculated from Telaga Punggur landfill was peaked in 2021. LandGEM application estimated CH₄ and CO₂ emissions which are 1.7x10⁷ m³ and 1.1x10⁷ m³ at peak year, 2021. Total GHG for 2021 is 2.3x10⁷ m³/year with LandGEM program, 2.2x10⁷ m³/year with IPCC program, and 1.5x10⁷ m³/year with triangular program.

1. Introduction

Telaga Punggur landfill has been operating since 1997 with an area around 47 ha. Telaga Punggur landfill receives 700 – 800 tons of municipal solid waste (MSW) daily and produces 25-30 tons of leachate/day [1]. This leachate contain low biodegradability [2, 3]. To improve the biodegradability need advanced treatment processes [4, 5, 6]. The product of the anaerobic process in landfills is greenhouse gas (GHG) emissions, such as carbon dioxide (CO₂), methane (CH₄), dinitroxide (N₂O), and chlorofluorocarbon (CFC) that have a greenhouse effect greater than other gases to climate change [7]. Landfill is one of the contributors to anthropogenic GHG emissions because landfill produces gas generated, especially carbon dioxide and methane during the decomposition of biodegradable solid waste [8]. Landfill gas (LFG) collection systems (CO₂ and CH₄) are effective measurement to reduce gas emissions from landfill [9].

Landfill dumping produces CH₄ and CO₂ gas, where CH₄ gas is 21 times greater effect than CO₂ gas to global warming [10]. However, actual condition shows that landfill in Indonesia is still operating in an open dumping system [11]. LFG required for alternative energy and must be free from inhibitors such as sulfate, carbon dioxide, ammonium, sodium potassium, calcium, magnesium and some organic compounds in landfill [12]. The efficiency of collecting LFG ranges from 20% to 90%, depending on the type of cover, leachate collector system, and density [13]. The reduction of methane and carbon dioxide gas emission occurs because there is the reduction process in the landfill itself. The waste produced from the waste degradation process can be calculated using the triangle method which is known to be a chemical reaction that is degraded rapidly and slowly [14]. Chandrappa, et al. [15] state



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

that solid waste is a mixture of various components that have different chemical compositions and chemical formulas. Carbon is a major component of organic matter as an energy source, contained in organic materials that will be degraded rapidly or slowly, such as straw, sugar cane stems, municipal waste, leaves, etc. [16]. Nitrogen (N) is a major component derived from protein, for example in animal feces, and required to form bacterial cells.

The amount of waste generation can increase the generation of GHG formed in landfill is due to an increase in population and service. Land degradation such as green belt areas that can absorb carbon dioxide and methane, affect GHG emission range. The arising of methane gas and carbon dioxide gas produce from the waste decomposition process can be calculated using the triangle method, LandGEM, or IPCC program. This research is important to be discussed because it is associated with PP No. 61 of 2011 concerning the national action plan for GHG emission reduction and PP No. 71 of 2011 concerning the implementation of the national GHG emission inventory stating that each regency/city regional government area must carry out GHG inventory activities. The aim of this study is to calculate the GHG (carbon dioxide) inventory for the Telaga Punggur Landfill in Batam City using the triangular, LandGEM and IPCC methods.

2. Method

2.1. MSW generation and composition

The amount of waste generated from Telaga Punggur landfill was obtained from secondary data. Besides on secondary data, estimation of waste generated at Telaga Punggur Landfill can be estimated through population projections [17]. Projections of population can use arithmetic, geometric, or exponential equations. Waste generated in a city produces different compositions of waste that depends on the city's classification, standard of living, density, temperature, education and regulation.

2.2. Triangular method

Based on the ultimate data analysis, the gas data can be divided into rapid decomposable (RD) and slowly decomposable (SD)[14]. Rapid decomposable waste includes food, paper, cardboard, garden waste such as leaves, flowers and fruit, whereas for slowly decomposable waste are textiles, rubber, leather, wood, twigs and roots. The amount of theoretical chemical composition that is produced by gas emission can be calculated according to equation 1.



Gas production speed (ft³/yr) and amount of gas production (ft³) for RD and SD waste can be calculated by the equation in Figure 1.

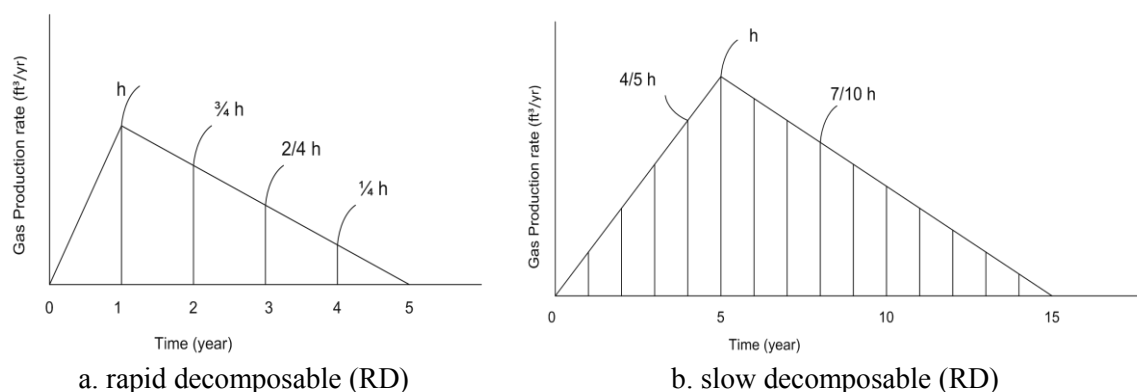


Figure 1. Triangular Rapid and Slow Decomposable [14]

2.3. IPCC (Intergovernmental Panel on Climate Change) method

The IPCC has compiled various standard methodologies to calculate emissions from various sectors. This research will use several parameters obtained from the results of field data but several other parameters still use the IPCC default, so this method is included in Tier-2. The process of calculating CO₂ and CH₄ emissions carried out by the IPCC waste calculation model begins with calculating the total decomposed waste piled up in landfills [8].

2.4 LandGEM method

Landfill gas production is estimated using the Landfill Gas Emissions Model (LandGEM) which provides an estimation tool to quantify landfill gas production from landfills. LandGEM is a first-order decomposition model that estimates the landfill gas rate based on the potential methane capacity (Lo m³ CH₄/ton) produced from waste and k decay rate (yr⁻¹). The input needed in this model is the year of landfill opened and closed, the amount of waste piled up per year, the local value of the methane generation rate constant (k), the potential capacity to produce methane (Lo).

3. Analysis and results

3.1. MSW generation and composition from Telaga Punggur landfill

Landfill location in the BBK area of Telaga Punggur Landfill in Nongsa District in Galang District serve Batam City. The MSW generation projection shows a close relationship to geometric equations. The calculation results show the value of the coefficient of determination (R²) 0.11 with the arithmetic method, 0.94 with the geometric method, and 0.92 with the least square method. The projection of MSW generation with geometric methods is shown in Figure 2.

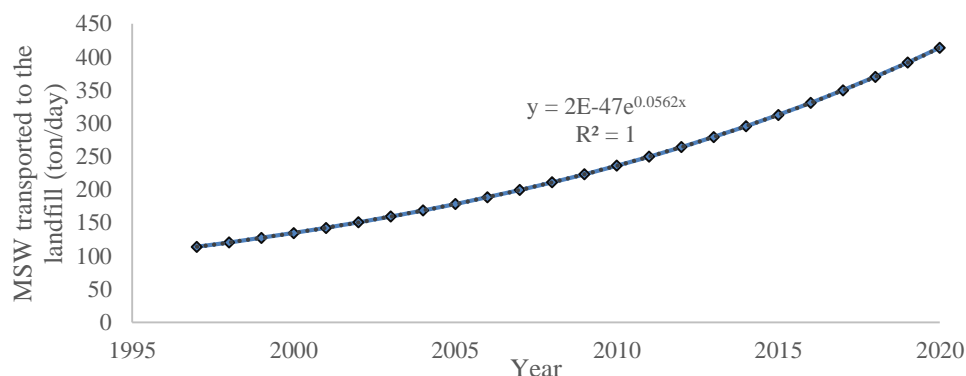


Figure 2. Projections of MSW generation transported to the Telaga Punggur landfill (ton/day)

The generation and composition of MSW (Table 1) of Batam City is based on projections from operational data and cleaning services [18]. MSW generation data is projected until 2020 because in 2020 at the Telaga Punggur landfill, it has used new cells. Calculation of GHG emissions for the triangular method is based on the dry weight of the waste.

3.2. CO₂ and CH₄ production

The estimation of methane and carbon dioxide emissions produced in this study is shown in Table 2 and Figure 3. The triangular method calculation shows the similarity of results with the emissions produced by Banjardowo landfill [19]. Higher calculation results were obtained in the study [20], with a total of 0.89 m³/kg for RD and 0.975m³/kg for SD.

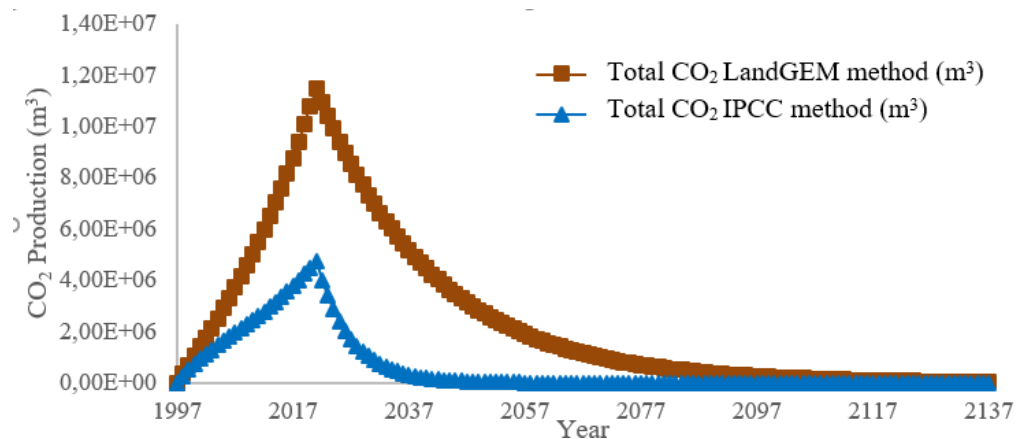
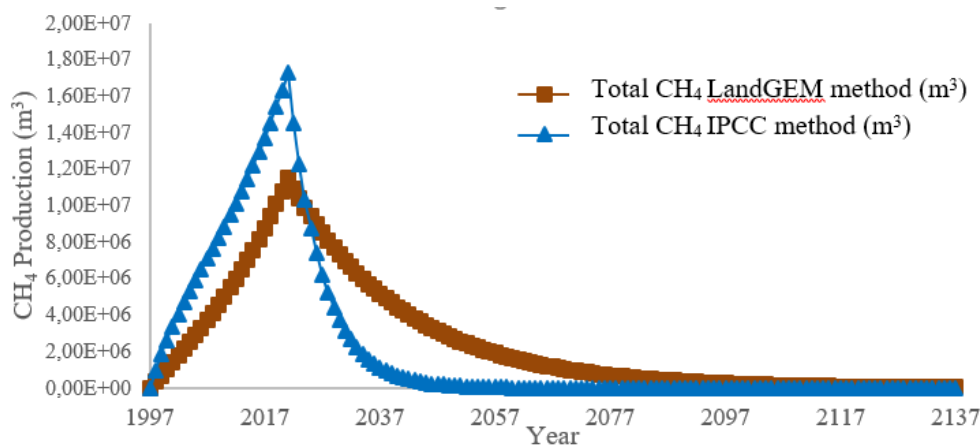
Table 1. Composition and characteristics MSW of Batam City

No	Component	%	Water content (%)
1	Organics	73.98	47.08
2	Paper	10.18	4.97
3	Glass	1.75	
4	Plastic	7.86	2.28
5	Metal	2.04	
6	Wood	0.98	0.32
7	Textile	1.57	0.63
8	Rubber	0.55	0.02
9	Battery	0.29	
10	Others	0.86	
	Total	100	55.3

Source: [18]

Table 2. The calculation results of theoretical amounts of CH₄ and CO₂ generated per unit dry weight with the triangular method

Characteristic	CH ₄ (m ³ /kg)	CO ₂ (m ³ /kg)
Rapid Decomposable (RD)	0.136	0.125
Slowly Decomposable (SD)	0.026	0.024

**Figure 3.** Estimation of CO₂ production (m³) with LandGEM and IPCC method.**Figure 4.** Estimation of CH₄ production (m³) with LandGEM and IPCC method.

The calculation of CO₂ emissions using the LandGEM program shows higher results than calculations with the IPCC program (Figure 3. and Figure 4.). The calculation results on CH₄ emissions show a lower value in the calculation of the LandGEM program. The results of the calculation of the estimated CH₄ production are higher in the calculation with IPCC which is equal to 1.7×10^7 m³ and with LandGEM of 1.1×10^7 m³ in the peak year is 2021. Methane is 21 times more efficient in trapping heat than carbon dioxide (CO₂) which contributes is very important for climate change [21]. An estimated 3.8% of the global warming potential of the United States arises from methane emissions from landfills [22, 23].

3.3. Total GHG emissions

The results of the analysis of the total landfill gas landfills produced by the Telaga Punggur landfill for the postoperative period show the total gas generation value is at its peak in 2021, one year after the landfill ends. The calculation results show a value of 2.3×10^7 m³/year with the LandGEM program, 2.2×10^7 m³/year with the IPCC program, and 1.5×10^7 m³/year using a triangular program. When peak conditions, the calculation results between LandGEM and Triangular models only have 0.42-4.3% errors in 2014-2021. The results of the LandGEM and IPCC model calculations begin to differ in the process after 2021. The LandGEM program is usually chosen as a more representative determinant of landfill gas emissions because it is the most reliable model for quantifying emissions levels and giving the most conservative and closest estimates [24].

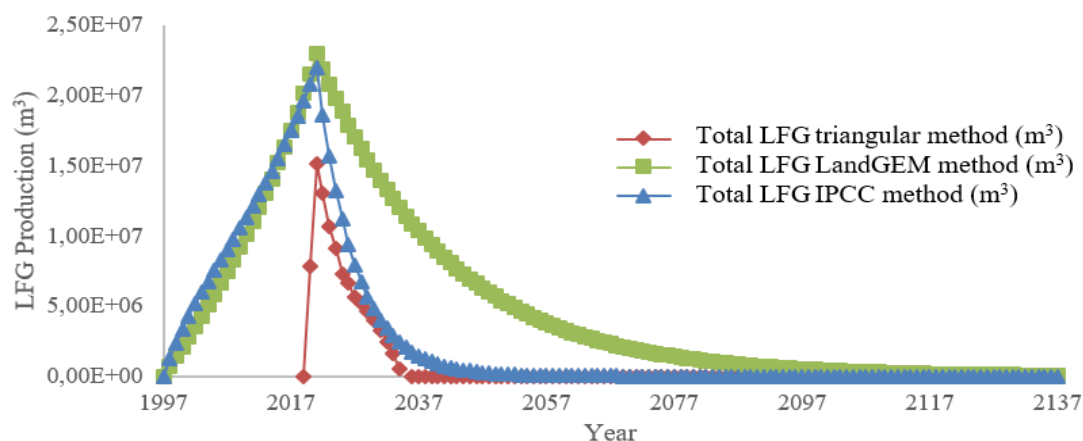


Figure 5. Estimation of GHG production (m³) with triangular, LandGEM and IPCC method.

4. Conclusion

The estimation results using triangular, LandGEM, and IPCC methods, the peak total LFG of 2.3×10^7 m³/year (LandGEM method), 2.2×10^7 m³/year (IPCC method), and 1.5×10^7 m³/year (triangular method). Error calculation between LandGEM and IPCC is only 0.42-4.3% errors in 2014-2021. To support the calculation, further monitoring of air quality is required in the field.

5. References

- [1] R. Efriningsih, L. Puspita and R. Ramses, "2016. Evaluasi kualitas lingkungan perairan pesisir di sekitar TPA Telaga Punggur Kota Batam berdasarkan struktur komunitas makrozoobenthos," *SIMBIOSA*, pp. 1-15, 2016.
- [2] N. Amaral-Silva, R. Martins, S. Castro-Silva and R. Quinta-Ferreira, "Ozonation and perozonation on the biodegradability improvement of a landfill leachate," *Journal of Environmental Chemical Engineering*, vol. 4, no. 1, pp. 527-533, 2016.
- [3] D. Bila, A. Montalvao, A. Silva and M. Dezotti, "Ozonation of a landfill leachate: evaluation of toxicity removal and biodegradability improvement," *Journal of Hazardous Materials*, vol.

- 117, no. 2-3, pp. 235-242, 2005.
- [4] I. W. K. Suryawan, M. J. Siregar, G. Prajati and A. S. Afifah, "Integrated Ozone and Anoxic-Aerobic Activated Sludge Reactor for Endek (Balinese Textile) Wastewater Treatment," *Journal of Ecological Engineering*, vol. 20, no. 7, 2019.
 - [5] J. L. De Moraes and P. P. Zamora, "Use of advanced oxidation processes to improve the biodegradability of mature landfill leachates," *Journal of Hazardous Materials*, vol. 123, no. 1-3, pp. 181-186, 2005.
 - [6] I. W. K. Suryawan, A. S. Afifah and G. Prajati, "Pretreatment of endek wastewater with ozone/hydrogen peroxide to improve biodegradability," *AIP Conference Proceedings*, vol. 2114, no. 1, p. 050011, 2019.
 - [7] A. M. Sari, A. T. Lando and A. S. Mustari, "Estimasi emisi metana (CH₄) dari TPA Tamangapa," Departemen Teknik Lingkungan Fakultas Teknik Universitas Hasanuddin, 2012.
 - [8] IPCC, "Climate Change 2014; Mitigation of Climate Change. Cambridge," University Press, Cambridge, 2014..
 - [9] R. Bian, D. Xin and C. Xiaoli, "Methane emissions from landfill: influence of vegetation and weather conditions.," *Environmental Technology*, pp. 1-9, 2018.
 - [10] S. M. Loureiro, E. L. L. Rovere and C. F. Mahler, "Analysis of Potential for Reducing Emissions of Greenhouse Gases in Municipal Solid Waste in Brazil, in the State and City of Rio de Janeiro", *Waste Management*, vol. 33, pp. 1302-1312, 2013.
 - [11] I. W. K. Suryawan, G. Prajati and A. Afifah, "Bottom and fly ash treatment of medical waste incinerator from community health centres with solidification/stabilization," *AIP Conference Proceedings*, vol. 2114, no. 1, p. 050023, 2019.
 - [12] E. C. Rada, M. Ragazzi, P. Stefani, M. Schiavon and V. Torretta, "Modelling the Potential Biogas Productivity Range from a MSW," *Sustainability*, vol. 7, pp. 482-495, 2015.
 - [13] Y. Sun, D. Yue, R. Li, T. Yang and S. Liu, "Assessing the performance of gas collection systems in select Chinese landfills according to the LandGEM model: drawbacks and potential direction," *Environ Technol.*, vol. 36, p. 2912-2918, 2015.
 - [14] G. Tchobanoglous, H. Theisen and S. Vigil, *Integrated Solidwaste Management.*, New York: McGraw-Hill, 1993.
 - [15] R. Chandrappa and D. Das, "Solid waste management," *Verlag Berlin Heidelberg*, 2012.
 - [16] E. Damanhuri, *Diktat Kuliah TL 3104 Pengelolaan Sampah*, Bandung: ITB Bandung, 2010.
 - [17] G. Prajati, T. Padmi and B. Rahardyan, "Projection of Big Cities Waste Management and Cost Based on Economic and Demographic Factors in Indonesia," *IOP Conference Series: Earth and Environmental Science*, vol. 97, pp. 1-8, 2017.
 - [18] PemerintahKotaBatam, "Operasional pelayanan kebersihan," <https://arsipskpd.batam.go.id/batamkota/skpd.batamkota.go.id/kebersihan/kebersihan-kota-batam/komposisi-dan-karakteristik-sampah/index.html>, 2016.
 - [19] N. Arfiantinosa and I. D. A. A. Warmadewanthi, "Estimation of Methane Generation From Sanitary Landfill," *The 4th International Seminar on Environmental Engineering*, pp. 524-531, 2013.
 - [20] R. O. Yusuf, J. A. Adeniran, J. A. Sonibare and Z. Z. Noor, "Application of the Triangular Model in Quantifying Landfill Gas Emission from Municipal Solid Wastes," *Pollution*, vol. 5, pp. 71-80, 2019.
 - [21] Y. Yodi, Y. Adicita, M. R. Apritama, I. W. K. Suryawan and G. Prajati, "Dispersion model of methane (CH₄) and carbondioxide (CO₂) emissions from Punggur landfill Batam," *International Journal of Engineering and Technology(UAE)*, vol. 8, 2019.

- [22] E. Tagaris, R. Sotiropoulou, C. Pilinis and Halvadakis, "A methodology to estimate odors around landfill sites: The use of methane as an odor index and its utility in landfill siting," *Journal of the Air and Waste Management Association*, vol. 53, pp. 629-634, 2003.
- [23] A. B. Akolkar, M. K. Choudhury and P. K. Selvi, "Assessment of Methane Emission from Municipal Solid Wastes Disposal Sites," *Research Journal of Chemistry and Environment*, vol. 12, pp. 49-55, 2008.
- [24] I. Paraskaki and M. Lazaridis, "Quantification of landfill emissions to air: a case study of the Ano Liosia landfill site in the greater Athens area," *Waste Management and Research*, vol. 23, pp. 199- 208, 2005.