Estimation of greenhouse gas (GHG) emission at Telaga Punggur landfill using triangular, LandGEM, and IPCC methods

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**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]. The by 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 [2]. 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 [3]. Landfill gas (LFG) collection systems (CO2 and CH4) are effective measurement to reduce gas emissions from landfill [4].

Landfill dumping produces CH4 and CO2 gas, where CH4 gas is 21 times greater effect than CO2 gas to global warming [5].However, actual condition shows that landfill is still operating in an open dumping system. LFG required for alternative energy and must free from inhibitors such as sulfate, carbon dioxide, ammonium, sodium potassium, calcium, magnesium and some organic compounds in landfill [6]. The efficiency of collecting LFG ranges from 20% to 90%, depending on the type of cover, leachate collector system, and density [7]. The reduction of methane and carbon dioxide gas emission occures because there is reductions process in landfills 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 rapid and slowly [8]. Chandrappa, et al. [9] stated 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 rapid or slowly, such as straw, sugar cane stems, municipal waste, leaves, etc [10]. 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 due to an increase in population and service. Land degradation such as green belt areas that can absorb carbon dioxide and methane, affect GHG emissions 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.

1. Method

## MSW generation and composition

The waste generated from Telaga Punggur landfill obtained from secondary data. Besides on secondary data, estimation of waste generated at Telaga Punggur Landfill can be estimated through population projections [11]. Projections of population can use arithmetic, geometric, or exponential equations. Waste generated in a city produces different composition of waste that depends on the city’s classification, standard of living, density, temperature, education and regulation.

## Triangular method

Based on the ultimate data analysis, the gas data can be divided into rapid decomposable (RD) and slowly decomposable (SD) [8]. Rapid decomposable waste are 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.

CxHyOzN + H2O → CH4 + CO2 + NH3 (1)

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

|  |  |
| --- | --- |
| a. rapid decomposable (RD) | b. slow decomposable (RD) |

**Figure 1.** Triangular Rapid and Slow Decomposable [8]

## 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 (IPCC, 2006).

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).

1. Analysis and Result

## MSW generation and composition from Telaga Punggur landfill

Landfill location in the BBK area of ​​Telaga Punggur Landfill in Nongsa District in Galang District to serve Batam City. The MSW geneation 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 1.

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 [12]. 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.

## CO2 and CH4 production

The estimation of methane and carbon dioxide emissions produced in this study is shown in Table 2 and Figure 1. The triangular method calculation shows the similarity of results with the emissions produced by Banjardowo landfill [13]. Higher calculation results were obtained in the study [14], with a total of 0.89 m3/kg for RD and 0.975 m3/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: [12]

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

|  |  |  |
| --- | --- | --- |
| **Characteristic** | **CH4** (m3/kg) | **CO2**(m3/kg) |
| Rapid Decomposable (RD) | 0.136 | 0.125 |
| Slowly Decomposable (SD) | 0.026 | 0.024 |

Total CO2 LandGEM method (m3)

Total CO2IPCC method (m3)

**Figure 2.** Estimation of CO2 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 2. and Figure 3.). 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 x 107 m3 and with LandGEM of 1.1 x 107 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. An estimated 3.8% of the global warming potential of the United States arises from methane emissions from landfills [15, 16].

Total CH4 LandGEM method (m3)

Total CH4IPCC method (m3)

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

## 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 x 107 m3/year with the LandGEM program, 2.2 x 107 m3/year with the IPCC program, and 1.5 x 107 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 [17].

**Figure 3.** Estimation of GHG production (m3) with triangular, LandGEM and IPCC method.

1. Conclusions

The estimation results using triangular, LandGEM, and IPCC methods, the peak total LFG of 2.3 x 107 m3/year (LandGEM method), 2.2 x 107 m3/year (IPCC method), and 1.5 x 107 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.

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