International Journal of Engineering &Technology, 8 (3) (2019) 240-245

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Dispersion model of methane (CH4) and carbondioxide (CO2) emissions from punggur landfill batam

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Abstract

One of bad impact from landfill is the increasing of air pollutant level, both in the form of gas and particulates, that is potentially to decrease air quality around landfill area. Dispersion analysis of air pollutant from all resources need to be conducted in order to estimate its bad impacts such as impact to environmental aesthetics, health, and global warming. The common method used is dispersion model of air pollutant. This method estimated quantity of CH4 and CO2 emission with LandGEM application, then calculated the emission of CH4 and CO2 with disperse Gauss equation. Air generated estimated in 2021 by CH4 and CO2 gas total as 2,87x104 Mg/year. The average wind speed in Batam is 6.73 km/hour with atmosfer stability at D condition (very unstable). The highest calculation of CH4 and CO2 concentrations in disperse emission at 123 meters were 0.059g/s and 0.007g/s.

Keywords: *Emission; CH4; CO2; Disperse.*

1. Introduction

Municipal solid waste management continues to be a major challenge in urban areas including landfill management [1 - 3]. Landfill produces wastewater with low biodegradability and emission of greenhouse gas [4], [5]. Low biodegradability wastewater very hard to treatment [6 – 8]. Zero waste in the ability to handle solid waste management including gas emission that new initiatives are needed [9]. Landfill is one of antropogenic greenhouse gas emission contributor, because landfill produces gas especially carbondioxide and methane during decomposition of solid waste [10]. Degradation process of organic matters that is sourced from solid waste will produce methane gas (CH_4), carbondioxide (CO_2), toxic residues and bad smell of anaerobic process. Methane and carbondioxide are greenhouse gas that is contributed to global warming [11] [12]. However, methane gas can be utilized as alternative energy resource . Therefore, the big amount of waste went into landfill is a chance to utilize its to alternative energy. The collecting system of gas (CH_4 and CO_2) is an effective way to reduce methane gas emission in landfill [13]. Nevertheless, existing condition shows that landfill still operated in open dumping system. The utilization of Landfill Gas (LFG) for energy interest requires free air of inhibitors at landfill such as Sulphate, Carbondioxide, Ammonium, Sodium, Kalium, Calsium, Magnesium, and some of organis compounds [14]. Efficiency of LFG collecting are around 20% to 90%, depends on cover’s type, leachate collector and density [15].

The impact of greenhouse gas emission by methane is 20 – 30 times higher than carbondioxide. Methane is the second highest greenhouse gas (based on Kyoto Protocol) after carbondioxide and it can effect 28 times higher to global warming [16]. Landfill has risks such as air pollution by gas, aerosol and greenhouse effect and also the breeding of disease vector like flies. Leachate and gas pollution from landfill to environments were potential because the timing is long enough, 20 – 30 years after landfill closed [17]. Hence, the information about concentrations of greenhouse gas emission were required, especially carbondioxide and methane. Those informations were used to know pollutant’s behaviour to anticipated, prevent and regulate the greenhouse gas. Gaussian Plume equation is commonly used to describes the patterns of carbondioxide and methane concentration which is calculated by LandGEM program.

Study about prediction of greenhouse gas like carbondioxide at landfill was conducted by Wibowo et al. [18] with title “Spatial Analysis Dispersion of Carbondioxide at Talangagung Landfill Using Gaussian Model and Geographic Information System Application. Wibowo et al. predicted emission with LandGEM application then modelized and conducted with existing pollution condition by giving geographic information system. Another study was conducted in Pekanbaru by calculated emission rate of methane and carbondioxide in Pekanbaru Landfill but without modeling so the emission dispersed was unidentified [19].

The aim of this study was to know quality of greenhouse gas emission such as carbondioxide and methane in Telaga Punggur Batam Landfill. The quality of emission were modelized and formed into geograhic information that is intergrated with landfill’s location. If dipersion of methane gas was known, the prevention effort could be conducted in order to recover methane gas and reduce the effect of carbondioxide gas. Some international studies modelized emission of landfill and the result were good between model outputs and field assessments [20]. Development countries like Indonesia was obligated to do this modeling because in Indonesia, landfill still use open dumping system without methane gas collecting system.

2. Method

2.1. LandGEM

Analysis of methane and carbondioxide's production were conducted in all over Telaga Punggur landfill areas based on total amount of projected waste per year , from 1997 until 2020 (Figure 1). Waste generated was projected by arithmetic, geometric and least square method. Secondary datas were collected from Batam's city government [21], which is total amount of waste that is went into Telaga Punggur Landfill. Projection of waste generated in landfill then used to project rate generated of methane and carbondioxide gas emission. Rate generated of methane and carbondioxide gas emission in landfill area then analyzed by LandGEM spreadsheet application in order to analysis gas emission's quantity. Model's parameter that is required in LandGEM analysis were occupied by LandGEM application and suited with research study location :

1) Methane generated coeficient (k) : 0.04 per year (conventional)
2) Methane generated potential capacity (Lo) : 100 m^3/Mg (conventional)
3) Organic carbon non methane (NMOC) : Unknown

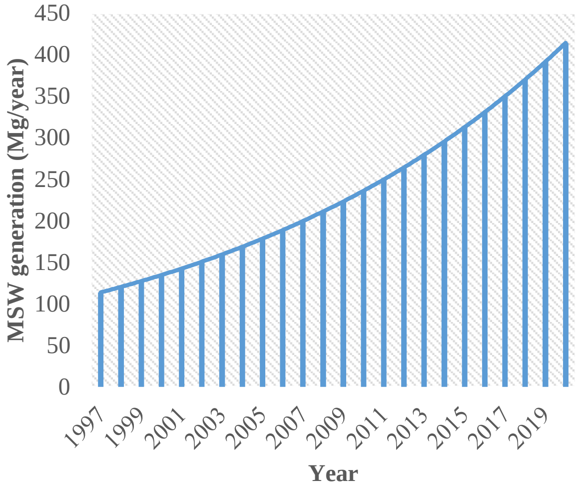

Fig. 1: Projection of MSW Generation from Telaga Punggur Landfill.

2.2. Model gaussian plume

Gaussian Plume model is often used to modelized pollutant's dipersion at surface or plateu continously [22], as of this pollutant's dispersion has normal probability distribution indicated with bell curve. The following is Gaussian Plume equation that is used to analysis concentration distributed in steady state condition.

$$c(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z}\exp\left(-\frac{1}{2}v\left(\frac{y}{\sigma_y}\right)^2\left[\left(\frac{z-H}{\sigma_z}\right)^2+\left(\frac{z+H}{\sigma_z}\right)^2\right]\right) \quad (1)$$

Where
He = effective height of emission, m
u = mean wind speed affecting the plume, m/s
m = emission rate of pollutants, g/s
σ_y , σz = dispersion coefficients or stability parameters, m
C = concentration of gas, g/m^3
x,y,z = coordinates, m

Witono (2003) [23] stated that mixing to vertical direction was not good because of the unstable atmosphere. This unstable atmosphere happened because of quite high insolation, so as heat up earth surface and make air low layer heats. Atmosphere become stable when earth surface colder than its air layer above, like cold and bright night. Its air layer above were cooled and cause no mixing at vertical direction. Air stability distribution's parameters are function of :

a) Atmosphere stability or turbulence
b) Wind range direction
c) Ground level
d) Surface roughness
e) Pollutant's time transport
f) Wind speed

Atmosphere stability value is function of atmosphere stability (turbulence structure and wind speed) and distance from emission source. Atmosphere stability predicted at 10 meters high wind speed by noon (insolation) or night (cover by clouds). Atmosphere conditions are classified as shown at Table 1.

Table 1: Classification of Atmosphere Stability Based on Wind Speed, Solar Intensity and Cloud Cover [23]

Wind speed	Solar Intensity (Noon)			Cloud Cover (Night)	
m/s	Hard (sun > 60^o)	Medium (sun 35^o - 60^o)	Low (sun 35^o - 60^o)	>50%	<50%
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F

3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Environmental conditions can be adjusted with Pasquill-Gifford curve [24] that is used to calculate σy and σz (in meters). X direction is value of atmosphere stability A, B, C or D.

2.3. Data analysis

Model's data analysis used descriptive analysis. Descriptive analysis only given information about point location that is polluted by air emission at Telaga Punggur Landfill, Batam. Model making in this study includes determination of pollutant concentration at some points and map distribution. Concentration calculation at some points based on emission level that is produced by landfill. The following were phase to make dispersion model :

a) Calculation of load emission that is produced at Telaga Punggur landfill with LandGEM application
b) Calculated meteorological influences to pollutant dispersion process at atmosphere. Dispresion process influenced by clouds, direction and wind speed also temnperature
c) determination of atmosphere stability. Atmosphere stability determined by class stability criteria table based on Pasquill-Gifford. This criteria is determined by wind speed and solar radiation or cloud cover
d) Distribution pattern analysis with Surfer 10 application.

3. Result and discussion

3.1. LFG generation

Waste generated projection at Telaga Punggur landfill showed average growth by 3,58 ton/year. Regression value were obtained by calculating with geomethric method, which are 0.94 (Table 2). Based on waste generated projection, waste generated at based year of projection (Figure 1) that is calculated with geomethric method was 1186.195 ton/year. LandGEM analysis showed landfill gas total that is produced by Telaga Punggur Landfill were at highest point in 2021 which is $2{,}87 \times 10^4$ Mg/year whilst methane and carbondioxide gas generated each are $7{,}67 \times 10^3$ Mg/year and $2{,}314 \times 10^4$ Mg/year. Gas production that is produced by waste degradation in Landfilling process will run out in 2137. Gas emission prediction that is produced by Telaga Punggur Landfill showed at Figure 2.

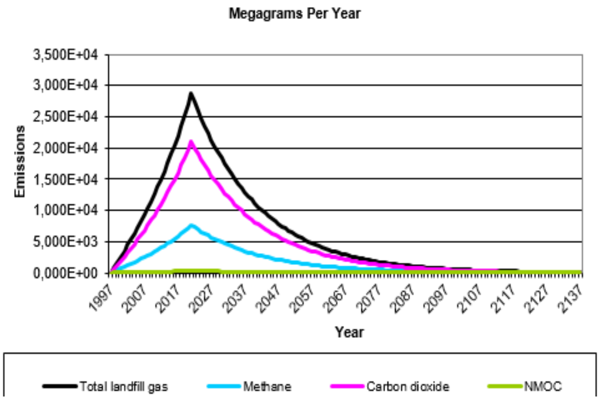

Fig. 1: Projection of Greenhouse Gas Emission Level as Methane, Carbondioxide and NMOC

Table 2: R Coefficient of Waste Generated Projection at Telaga Punggur Landfill

Method	R
Arithmatic	0,90
Geomethric	0,94
Least Square	0,92

3.2. Atmosphere stability

Temperature and cloud cover in pollutant dispersion process will influence air stability. Gradient of temperature changing will strongly influence to atmosphere stability. Pasquill atmosphere air stability in Batam City for one last year that is analyzed by wind speed (see Figure 2 and Table 1), showed that atmosphere stability has many varians which are B (unstable) in November and December, C (a little stable) in April, May, June, October and D (very unstable) in July, August, September, January, February and March.

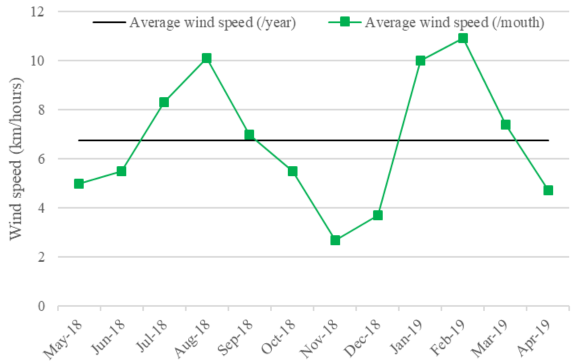

Fig. 2: Processed Data of Monitoring Average Wind Speed in Batam City [25-36] [24 – 33] [34], [35].

Climate factor inluenced to determination of stability class that is used as coefficient in modeling calculation. Wikandari et al (2015) stated that the higher inversion layer of dispersion space, the lower pollutant concentration [37]. Furthermore, height of the receiving point of the ground influences the emission amount and also the difference climate like rainy and dry season.

Table 3: Maximum Wind Speed and Direction in Batam City

Time	Maximum wind speed (km/hours)	Direction
May-18	33,3	Northeast
Jun-18	29,6	Southwest
Jul-18	29,6	Southeast
Aug-18	35,2	Southwest
Sep-18	45	West
Oct-18	37	Southeast
Nov-18	33,3	Southwest
Dec-18	29,6	West
Jan-19	27,8	Northeast
Feb-19	33,3	Northeast
Mar-19	29,6	Northeast
Apr-19	31,5	Southwest

3.3. Model dispersion

Model calculated based on wind speed average per year which is 6.73 km/hours with atmosphere stability at D condition. Distribution range and maximum concentration of dust were obtained by CH_4 and CO_2 concentration based on Gauss model, 80 – 500 meters from landfill that is fell at human average height. The highest calculation of emission was obtained at range 122 meters with CH_4 and CO_2 concentration, 0,059 g/s and 0,007 g/s. This results were lower than Wibowo et al study, which is 2.72 g/s [18].

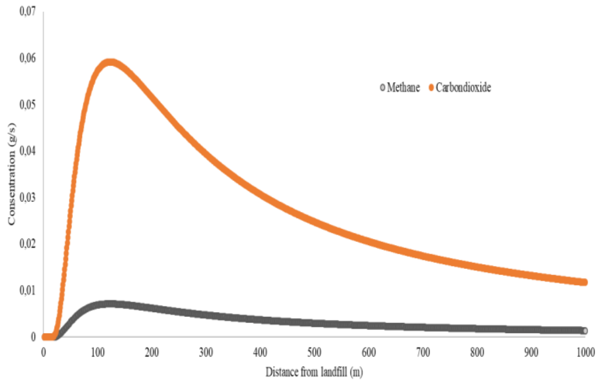

Fig. 3: Concentrate Distribution of CH_4 and CO_2 at D Condition of Atmosphere Stability.

Figure 4 and 5 showed concentrate distribution of CH_4 and CO_2 ambient at steady state for D atmosphere stability condition. Overlay map of dispersion condition was conducted by Google earth application. This map showed that most of the emission occured around landfill location. Concentration of CH_4 and CO_2 were pictured by Surfer 10 application. Concentration scales at countour maping were shown by color gradation. Low concentration to high concentartion were indicated with light blue to green. This color scale is used to read map easily.

Fig. 4: CH_4 Dispersion at Atmosphere Stability D Condition (with Unit G/S).

Fig. 5: CO_2 Dispersion at Atmosphere Stability D Condition (with Unit G/S).

Usually, concentration in actual conditioan is higher than concentration that is calculated with Gauss model. Calculation with model only resourced from landfill without regard to another activities like road's dust, motor vehicles fume, absorption by plants and another fugitive emission. Fam et al (2018) results showed that on-road transportations contributed to the largest of greenhouse gas [38], and this indicated that transportation around Punggcur landfill can impact the concentration of CO_2 and CH_4.
Mostly, developing countries are looking for practical solution such as rehabilitation of municipal solid waste dumping, the standarized of closing landfill, recovery of methane gas in landfill, waste incineration with energy recovery, organic waste composting, recycling and also minimization of leachate water. Modeling methane gas was initial step as practical solution to methane gas and energy recovery. However, based on dispersion not all of methane gas could be collected. This method better supported by collecting system of methane gas as Tchobanoglous (1993) was explained [17].
Research that is conducted by Talaiekhozani et al., (2018) stated methane gas estimated 114,000,000 m^3 between 1997 to 2003 with potential 131,670 MW electrical generation or around $10.53 million [39]. The potential of methane gas at Telaga Punggur Landfill in range 1997 – 2003 almost similar with Talaiekhozani et al estimation. Landfill with gas collecting system can used and recovered by 41-81% [40]. The using of methane gas is one of prevention effort that can pressure dispersion of air pollution and control air pollution if there was no adsorption by plants.
Beside LFG, landfill technology can be replaced by incineration process like incinerator. However, this method requires experts, cost and high energy. Moreover, incineration method has bigger effect to greenhouse effect than landfill if operation and monitoring were not conducted properly. Incineration is not suitable to apply in developing countries such as Ethiopia, Nepal, Sri Lanka, Tunisia, Algeria and others because these countries still produce organic waste with high water containing but low calor value [41]. Based on this, incinerator is also not suitable to apply in Indonesia as the same reason with another developing countries which is low calor value [42] [43].

4. Conclusion

Total amount of CH_4 and CO_2 gas that is produced based on LandGEM are 2,87x104 Mg/year. Average wind speed at Batam City is 6.73 km/hours with atomosphere stability at D condition (very unstable). The highest calculation of disperse emission occured at 122 meters with CH_4 and CO_2 concentration, each are 0,059 g/s dan 0,007 g/s. However, another factors that influenced to emission concentrate like contributor and absorbent emission need further attention.

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