Jurnal Teknologi Industri Pertanian 32 (3): 305-310, Desember 2022
DOI: https://doi.org/10.24961/j.tek.ind.pert.2022.32.3.305
Terakreditasi Peringkat 2
SK Dirjen Pendidikan Tinggi, Riset, dan Teknologi No. 158/E/KPT/2021
Tersedia online http://journal.ipb.ac.id/index.php/jurnaltin

THE POTENCY OF BURANGKENG LANDFILL AS A SOURCE OF ENERGY

POTENSI TPA BURANGKENG SEBAGAI SUMBER ENERGI

Ary Mauliva Hada Putri[1)*], Tanti Ardiyati[1)], and Khoerul Anwar[2)]

[1)]Research center for chemistry, National Research and Innovation Agency
Kawasan Sains dan Teknologi (KST) BJ Habibie, Serpong, South Tangerang, 15314, Indonesia
Email : arym002@brin.go.id
[2)]Research center for transportation technology, National Research and Innovation Agency,
Kawasan Sains dan Teknologi (KST) BJ Habibie, Serpong, South Tangerang, 15314, Indonesia

Makalah: Diterima 25 Oktober 2022; Diperbaiki 8 Desember 2022; Disetujui 19 Desember 2022

ABSTRAK

TPA Burangkeng hanya memiliki satu zona aktif (zona D) yang dapat digunakan untuk menampung sampah. TPA Burangkeng memiliki kapasitas untuk menampung 168.000 m^3 sampah, namun jumlah sampah yang memasuki TPA mencapai 940 m^3 per hari, dimana 82,41% nya merupakan sampah organik. Dari jumlah penduduk di Kabupaten Bekasi tahun 2018, dapat diperkirakan jumlah sampah yang dihasilkan adalah 0,8 kg sampah/orang/hari. Dengan menghitung laju pertumbuhan penduduk di Kabupaten Bekasi dan perkiraan jumlah penduduk hingga tahun 2025, volume sampah di Kabupaten Bekasi diperkirakan sekitar 964 ton per hari. Penelitian ini bertujuan untuk mengetahui potensi energi dari sampah dan potensi pemanfaatannya guna memperkecil volume sampah yang dibuang ke TPA dan menjaga kelestarian TPA. Perhitungan dalam studi ini dilakukan dengan metode pengukuran langsung dan studi literatur. Didapatkan potensi kandungan gas metana pada zona D sekitar 60,7 %. Zona D sebagai satu-satunya zona aktif penampungan sampah di TPA Burangkeng memiliki potensi total volume gas metana mencapai 1.614.774 ton per tahun dengan potensi energi listrik sekitas 651 kW/jam.

Kata kunci: gas metana, listrik, sampah; sampah organik; TPA burangkeng

ABSTRACT

Burangkeng landfill has one active zone D that is usually used to accommodate waste. The capacity of Burangkeng landfill is able to accommodate 168,000 m^3 of waste, but the waste volume reaches 940 m^3 per day with 82.41% of that is an organic waste. From the population in Bekasi Regency in 2018 it can be estimated the amount of produced waste was 0.8 kg of waste/person/day. By calculating the rate of population growth in Bekasi Regency and the estimated population until 2025, volume of waste in Bekasi Regency was estimated around 964 tons per day. The purpose of this study was to determine the potency of generated energy from the organic waste in order to reduce the waste volume entering the landfill and to maintain the sustainability of the landfill. The calculation in this study was conducted using direct measurement and literature methods. It was found that the potential percentage of methane gas in zone D reach 60.7%. Zone D as the only active zone used for waste gathering has the potency of total volume of methane gas per year approximately 1,614,774 tons and it is able to produce the electricity power of 651 kWh.

Keywords**:** Burangkeng landfill,electricity, organic waste, methane gas, waste

INTRODUCTION

Most of the developing countries in Asia are dealing with issues to manage and control the accumulation of Municipal Solid Waste (MSW). A rapid economic growth, urbanization, living standards, and industrialization have caused excessive increasing in demand of energy, therefore it will contribute to the increasing of waste production (Kaur *et al.*, 2021). Infrastructure development and the application of waste minimization are critical in addressing the poor practices of waste management (Rafiee *et al*., 2018). MSW can be arranged in seven categories, namely food wastes, paper and boards, metals, wood, plastics and glass (Abdel-Shafy *et al.*, 2018). The prediction of global d aily production of generated solid waste in Indonesia until 2025 reaches 1.3 x 10^9 tons (Ham *et al.*, 2017). These problems of waste accumulation and increasing demand of energy can be solved by generating energy from MSW. Waste to Energy (WtE) is a process of gaining the electricity and heat from waste, which especially used non-recyclable waste (Beyene *et al.,* 2018). Modifying waste to energy can be a decent option to manage MSW properly, and produce sustainable non-fossil fuel energy. Waste-to-energy process can significantly reduce the volume of MSW, which was 50-90%, in order the remaining waste can be easier to be managed *(Kumar et al.,* 2017). Furthermore, MSW contains a net energy potential of about 0.13-0.38 tonnes of oil equivalent (toe), which can be generated using Waste-to-Energy (WtE) process (Rogoff *et al.*,

**Coressponding Author*

2019). MSW can be converted into various chemicals or fuels, namely biogas, hydrogen, alcohol, synthesis gas, organic acids, etc (Hidalgo *et al.*, 2019).

Burangkeng Landfill is located between Jati Kidul and Cinyosog villages of Burangkeng, Setu District, Bekasi regency. The location of the west side of Burangkeng landfill borders to residential area, the north and southern sides border to Cinyosog village and Jati Kidul residential area, then the east side borders to rice field, and vacant land. Burangkeng landfill has officially been operated in 1995 with an area of about 3.5 ha (Dinas Kebersihan dan Pertamanan Kabupaten Bekasi, 2018). After operated for 25 years, the area of TPA Burangkeng currently reaches ±11 ha. In the beginning Burangkeng landfill was applied to the open dumping system as application to the concept of waste management. The similar condition was also found in 90% of landfills in Indonesia (Mahyudin, 2017). Open dumping system required a large area. Nowadays, the capacity of Burangkeng landfill according to the Cleaning and Landscaping Agency report of Bekasi Regency in 2018 was applicable to gather waste of 168,000 m^3 , while the amount of waste entering the Burangkeng landfill could become of 940 m^3 per day, therefore Burangkeng landfill was estimated able to accommodate waste only for the next 6 months (Dinas Kebersihan dan Pertamanan Kabupaten Bekasi, 2018). Currently, the area that able to accommodate the waste was only one zone, zone D. While three other zones, A, B, and C were full of waste with a height of up to 11 m. Due to the overload capacity and limited condition of a Burangkeng landfill, the Bekasi Regency government has planned to close an open-air dump the Burangkeng landfill.

Burangkeng landfill has gathered waste that were generated from 16 districts in Bekasi Regency. The total number of districts in Bekasi Regency reaches 23 districts, therefore all of the produced waste can not be transported and accommodated to the Burangkeng landfill. It is also caused by the limited number of the waste trucks owned by the Local Government of Bekasi Regency. The number of trucks owned by the local government nowadays is 70 units with the capacity of each of the truck is about 6.7 m^3 of waste for one time delivery of waste and each of the truck is able to deliver the waste until two times a day. The total waste produced by the Bekasi Regency was around 6,750 m^3 per day, however, the total amount of waste that can be transported to the landfill reached 940 m^3/day or 14% of the total waste generated from Bekasi Regency. Hence, all of the waste that could not be delivered to the Burangkeng landfill was gathered to Sumur Batu landfill, which is located in Bekasi City.

Based on the information from Cleaning and Landscaping Agency Bekasi Regency, Bekasi Regency government has finished feasibility study to replace Burangkeng landfill to Bojongmangu area with the width of 20 Ha. When Bekasi Regency government planned to open a new landfill, some reconsiderations must be performed before closing the Burangkeng landfill, such as considering the condition of waste accumulation in the zones A, B, and C that have not been utilized and the potential of waste in zone D as the source of energy. When Burangkeng landfill condition was only closed and left without any further processing, beside it could cause healthy problems due to the smell of the waste and leachate contamination as well as other potential of diseases due to the waste accumulation, it also possible to have impact in the energy aspect due to the methane gas (CH_4) potential from the organic waste in the landfill (IPCC, 2014). Methane is an energy-rich component that is formed as the end product during the anaerobic decomposition of organic materials, such as domestic slurries and residues coming from food processing manufactories (Anukam *et al.*, 2019). Landfills are one of the most important anthropogenic sources of methane (CH_4) emission, which has a global warming potential 28 times that of carbon dioxide (CO_2) (IPCC, 2014). Landfill emitted 4,907 and 3,052 Gg CH_4, accounts for 17.5% and 19.6% of anthropogenic CH_4 emissions in the USA and Europe, respectively (Kormi *et al.*, 2018). Therefore, it was important to perform preliminary study on Burangkeng landfill to maximize the waste potential as the source of energy as well as to reduce the accumulation of landfill waste.

RESEACH AND METHODOLOGY

Procedures

This study was performed by measuring some parameters to get primary data and collecting secondary data by in-depth interview and literature study. The study was conducted by measured the gas potential content in the landfill area, measuring the density and analyzing the composition of wastes, then calculating the waste generation of the Bekasi Regency. Waste generation was calculated by multiplying the number of residents served and the waste generated per person every day. The projection of the daily waste volume in Bekasi Regency in the next 20 years was calculated based on the average population growth in Bekasi Regency and the prediction of the population for the next 20 years.

As an active landfill that accommodates waste including organic waste, the production of CH_4 gas in Burangkeng landfill (Gt) can be calculated using equation (1) to (4) as follows (Tabasaran, 1982; IPCC, 1996).

$$k.dt = \frac{d.Cg}{Cc - Cg} \quad \text{.......} \quad (1)$$

$$Cc = Ct \times (0.014T + 0.28) \quad \text{.......} \quad (2)$$

$$Gc = k.Gc \times Cc \quad \text{.......} \quad (3)$$

$$Gt = Gc \times 10^{-kt} \quad \text{.......} \quad (4)$$

where :
k : coefficient of reaction
C_g : carbon converted to gas
C_c : total carbon converted to gas
T : room temperature (25^0C)
t : year
$k.G_c$: total methane gas and carbon dioxide gas produced from 1 kg of organic carbon
G_t : total gas produced from the weight of incoming waste volume (tonnes/year)

Waste density is determined by weighting the sampling results of the organic waste from housing and markets per volume for 3 times (Indonesia National Standard, 1995). A 100 L waste volume is used for waste density sampling. Artesian well water sample is also used to measure the water chemical quality in laboratory.

Waste has also the potency to produce electrical energy. The energy conversion process used to produce electricity in general was divided into two processes, which are biological and thermal conversion. Biological conversion uses organic waste decomposing bacteria to produce methane gas. Through biological degradation process, this compound was converted into methane gas in the anaerobic condition (Yong *et al.*, 2019).

Instruments

The instruments used are thermocouple to measure the temperature of waste accumulation of the landfill (Fluke Coy brand, USA), pH-meter to measure leach's pH (Hana brand), gas flow meter to measure the gas flow rate produced by landfill waste (Ritter brand, Germany), and gas analyzer (Cubic Brand Gasboard-3100P series, Wuhan Cubic Optoelectronics Co. Ltd. China.

RESULT AND DISCUSSION

Landfill waste composition

Based on the waste composition percentage presented in Table 1, the amount of organic waste component that enters to the Burangkeng landfill was obtained approximately 774.65 m^3 per day or equals to 309.86 ton and the rest is an organic component. The organic waste contained in the landfill is higher than reported by the ministry of environment, in which total accumulation of the organic waste in landfill was around 60% (Ministry of Environment, 2017). It might be due to increasing of Bekasi Regency population, as reported by (Nofendri *et al.*, 2021) that each person can produce 0.8 kg waste/day.

Gas potency in zone D

The amount of wastes entered the landfill is calculated based on the amount of wastes entering to the landfill. Based on the truck capacities entering waste to the landfill, the amount of waste accumulated in the Burangkeng landfill is around 940 m^3 per day or equal to 376 tons per day. The number of trucks entering Burangkeng landfill was 70 trucks per day with each of the truck carried 13.5 m^3 of waste.

Tabel 1. Waste composition in Burangkeng landfill

Type of waste	Source of waste		Average (%)
	Residential area	Market area	
Organic (%)	68.05	96.77	82.41
Anorganic (%)	31.95	3.23	17.59
Density (kg/L)	0.40	0.45	0.43

Characteristics of waste in Burangkeng landfill was derived from 2 sources, i.e., residential area and market area. Burangkeng landfill has 4 areas, namely zones A, B, C, dan D. Nowadays, Burangkeng landfill has one active site area, zone D. The condition of 3 zones A, B, and C have been overloaded, in which the height of waste in the area reached 11 m. We analyzed and measured the gas content within all of zones in Burangkeng landfill. The result showed that there was 4 kinds of gases found in zone D (Table 2).

Tabel 2. Gas potency in zone D

Gas potential	Percentage
CH_4	60.70
CO_2	38.48
H_2S	2.00
H_2	0.50

Based on Table 2, it can be concluded that the waste anaerobic decomposition process at Burangkeng landfill was normal happened in the landfill. On the other hand, the three other zones (A, B, and C) do not show the CH_4 gas potential. The waste accumulation in those three zones was old wastes and those were applied open dumping system. The prediction of waste accumulation in zone A is for 20 years old, B and C zones are 15 and 8 years respectively. After 2010 there is only one zone operated (zone D). The methane gas generation depends on the anaerobic fermentation process happened in the organic waste decomposition. Due to in earlier the Burangkeng landfill used open dumping system, the aerobic fermentation process was more dominant compared to the anaerobic fermentation.

Some of the wastes that decomposed naturally produced methane gas. There was a fire in zones A and B for 3 months in the dry season. In addition, there was a leachate well and a leachate pond in zone B but it did not function as well, so that the leachate flow from landfill is directly discarded to nearby river. The calculation of CH_4 gas production was performed in zone D because this zone was the new area for waste accumulation, therefore there was found a high potency of CH_4 content in zone D (Table 3).

Tabel 3. Calculation parameters

Parameter	Value
T (temperature inside the landfill)	54^0C
Waste entering the landfill	376 tons/day or 137,240 tons/year
Waste accumulation time	5 years
Organic carbon decomposition reaction coefficient (k)	0.03
Organic carbon converted into gas (Ct)	200 kg/ton
Gas produced by 1 kg organic carbon (kGc)	1,868 m^3

Tabel 4. The potency of electrical energy produced from waste in zone D

Parameter	Value	Information
Landfill area	110,000 m^2/4 zones = 27,500 m^2	Total width of the landfill/4 zones
Solid waste volume	302,500 m^3	Height = 11 m
Solid waste weight	151,250 ton	Solid waste gravity = 0.5*
Gas volume	15,125,000 m^3	Gas production 100 m^3/ton solid waste*
CH_4 volume	9,180,875 m^3	CH_4 gas content is 60.7% from the total gas volume
Total caloric value	324,222,600,625 BTU = 95,024,208 kWh	CH_4 caloric value = 35.315 BTU/m^3 1 kWh = 3.412 BTU
Thermal energy flow	52,068 kWh/day 2,170 kWh/hour	Degradation Period 5 years*
Potential energy generated	651 kWh/hour	Thermal Efficiency 30%

*Source : Ghosh *et al.,* 2018

Source Of Electrical Energy

The potency of wastes in Burangkeng landfill to produce electrical energy can be seen in Table 4. It shows that zone D was very potential to produce 651 kW of electricity per hour, which is able to be consumed by 500 households.

Waste Generation In Bekasi Regency

The accumulation of waste that were transported to the Burangkeng landfill can be calculated by dividing the amount of waste gathering to the landfill per day by the population of Bekasi Regency served in the waste collection to Burangkeng landfill (Ferronato *et al.,* 2019). Based on the interview with Cleaning and Landscaping Agency Bekasi, it was known that the service area of Burangkeng landfill is including 16 from 23 districts in Bekasi Regency. Therefore, the waste generation potency in Bekasi regency is 0.8 kg/person/day.

$$Waste\ Generation\ Potency = \frac{376\ ton/day}{\frac{65.22}{100} x 3{,}577{,}200\ people} = 0.8 \frac{kg}{person}/day \quad \text{…….. (5)}$$

Average population growth influences the projection of waste generation potency in the following years. Based on the Bekasi Regency population in 2018-2020 (Table 5), the population growth rate can be calculated. The method used in the population projection was Arithmetic and Geometric method, because those two methods have high accuracy (Keyfitz, 1981). Based on the calculation of population projection using those two methods, the chosen method with the smallest deviation standard was Geometric method (Table 5).

Tabel 5. The population of Bekasi Regency 2018-2020

Year	Population
2018	3,577,200
2019	3,690,000
2020	3,805,200

Source: The Central Bureau of Statistics

The projection of population in 2021 can be calculated using the equation (Hidalgo *et al.,* 2019):

$$Pn = Po \times (1 + r)^t \quad \text{…………………………… (6)}$$

$$r = \left(\frac{Pt}{Po}\right)^{\frac{1}{t}} - 1 \quad \text{.. (7)}$$

By assuming the Bekasi Regency population in 2018 (Table 5) as the basic year population (Po) and the population in 2020 as the t year population (Pt), the population growth rate in Bekasi Regency can be calculated as follows

$$r = \left(\frac{3{,}805{,}200}{3{,}577{,}200}\right)^{\frac{1}{2}} - 1 = 0{,}03138 \quad \text{……............... (8)}$$

By knowing the population growth rate, the population of Bekasi Regency in 2028 (Pt) with t = 10 years (from basic year which is 2018) is estimated approximately:

$$P_{2028} = 3{,}577{,}200 \times (1 + 0.03138)^{10} = 4{,}872{,}258 \ldots\ldots \quad (9)$$

The calculation in the waste management was assumed that the waste volume reduced 25% every 5 years. It was according to the existing condition of waste generation in Burangkeng landfill that implements 3R (reduce, reuse, and recycle) concept pioneered by Telaga Sakinah residents, therefore the average waste production decreases in a number of 25% per 5 years. Besides processing waste to compost or utilizing waste as a source of electricity (garbage power plant), implementing the 3R (reuse, reduce, and recycle) concept is the affordable and easy solution to the environmental preservation.

The projection of waste generation was performed in the waste generation value of 2018 which was 0.8 kg/person/day *(*Nofendri *et al.,* 2021) with the assumption of waste generation increase was approximately 4%. The waste generation value was also influenced by the amount of waste transported into the landfill by Cleaning and Landscaping Agency in Bekasi Regency (or waste service percentage). In 2018, the amount of waste transported to the landfill was 65.22% and increasing each year which is in this term the increase is assumed to be 5% for each year. By knowing the calculation parameter of the waste generation value and the population, the waste volume can be projected until 2025 as follows (Table 6).

Tabel 6. The projection of generated waste and population in Bekasi Regency

Year	Population	Waste generation (tons/day)
2021	3,924,636	241
2022	4,047,791	450
2023	4,174,810	666
2024	4,305,816	860
2025	4,440,932	964

Landfill waste management

Waste characteristic that has different characteristics between an old and a fresh waste accumulation requires a different management between the zones according to the waste characteristics. Mostly, the waste accumulation in A, B and C zones are 10 until 20-years-old, then the most dominant components of the waste are anorganic components. The waste management for this kind of waste can be done through burning using an incinerator. While the waste in D zone which is fresh organic materials, so that the management can be done by utilizing the methane gas as the energy source for electricity.

The condition of Burangkeng landfill now with the amount of waste entering the landfill was around 940 m^3/day and the width left in the D zone that can accommodate waste was only 168.000 m^3, therefore it can be calculated that Burangkeng landfill can only be used for the next 6 months. If Bekasi Regency government is serious in managing Burangkeng landfill waste, the government does not need to close Burangkeng landfill and open a new landfill. The potency of electrical energy from CH_4 gas in the waste accumulation in D zone and the result of anorganic waste burning in A, B, and C zones can be used for the needs of the residents and small industries around Burangkeng landfill, so that Burangkeng landfill waste can be a valuable asset for Bekasi Regency government as well as the people who live surrounding that area.

CONCLUSION AND RECOMENDATION

Burangkeng landfill waste has a large potential as a renewable energy source because organic waste gathering to the landfill can be converted into methane gas (CH_4) and it can be used as electrical energy source or as a fuel for power plant. Zone D as the only active zone used for waste containment has the methane gas potential approximately 1.614.774 ton/year and capable of producing power 651 kWh.

Waste to Energy (WtE) as an effective and efficient waste management in Burangkeng landfill can reduce the waste volume gathering to the landfill as well as making the landfill as the renewable energy source, which is valuable for small industries and houses surrounding the landfill. Other uses of Waste to Energy (WtE) include infrared heating and compressed natural gas (CNG) as fuel for vehicles, or as a national gas supply, even though this process requires expensive cost to increase the capacity of gas. The recommendation for Bekasi Regency government is to reconsider the plan to cover Burangkeng landfill up considering the potential of energy from the waste that can be used as the fuel either for power plant or as the source of energy for industries and people who live around the landfill.

ACKNOWLEDGEMENT

A special gratitude to Research Center for Physics, the Indonesia Institute of Sciences for funding these activities over internal grant Riset Mandiri on 2015. The author thanks Suharwadji Sentana and Neni Sintawardhani for suggesting this topic and their guidance in doing this article.

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