Waste power plant based on methane gas at Tamangapa Landfill Makassar: a potential study

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Abstract. Tamangapa landfill is main landfill in Makassar city. Some of significant problems arise from the Tamangapa landfil. One of them is environmental pollution caused by waste production. On the other side, the methane gas produced by organic waste can be used for electrical generation via waste power plant. This research examined the potential of methane gas production. It also studied the potential of electrical power generation based on sanitary landfill model. The prediction of waste amount had been done using linear regression method with SPSS software. Based on calculation, the cumulative methane gas production is 134,889.96 m3 in 2029. The cumulative electrical energy and power that can be generated are 1,065.63 GWh and 121.647 MW, respectively.

1. Introduction

Makassar is the capital of Sulawesi Selatan Province, Indonesia with a population of 1,671,001 people in 2018 [1]. The waste production in Makassar continues to increase every year, in line with the increasing of its population [2-6]. Tamangapa landfill is the only landfill in Makassar. This landfill began to be used on January 1, 1992 with 26.8 hectares area.

Proper waste handling needs to be done to minimize the impact on the environment given the limited land for landfill [7]. In general, there are three known waste disposal methods namely open dumping, controlled landfill and sanitary landfill [8]. Based on observations, the method of waste disposal in Tamangapa landfill is open dumping. The open dumping method is a method where waste that placed openly on the ground surface. This method is an unhealthy waste disposal method. Tamangapa landfill area based on satellite photo is shown in figure 1 [9].

2. Methods

In general, poor waste management will result in waste heaping. The accumulated organic waste will undergo anaerobic decomposition process. It will produce a gas called landfill gas. The landfill gas can cause unpleasant odors, increase the temperature around the landfill and can trigger an explosion [10].

Figure 1. Tamangapa landfill area (satellite photo).

The utilization of methane gas contained in landfill gas can provide benefits such as greenhouse effect and environmental damage reduction [11]. Methane gas can be produced from the decay of organic waste in landfills [12]. Methane is a gaseous hydrocarbon with CH_4 chemical formula. Methane consists of four hydrogen atoms bound to carbon atoms. Methane is a colorless and odorless substance. Methane has a boiling point of −161 °C or −257.8 °F at 1 atm pressure. Methane is only flammable when its concentration reaches 5-15% in the air [13].

Methane gas can also be used as fuel for waste power plant [14-16]. Tamangapa landfill has methane gas potential for waste power plant. The power plant can be operated directly connected to the load. This is known as the distributed generation (DG) system [17-19]. The power plant can be built if the waste disposal system is changed to become a sanitary landfill [20]. This method has been done in many other cities in the world [21]. For the sanitary landfill method, waste that reaches a certain height is buried with soil of a certain thickness.

3. Results and discussion

3.1 The amount of waste at Tamangapa landfill

The amount of waste for 10 years (2008-2017), based on data from Makassar Sanitation and Landscaping Service Office is shown in table 1 [22]. In 2017, total waste production reached 290,222 tons.

Table 1. The amount of total waste in Tamangapa landfill in 2008-2017.

Year	Weight (Ton)
2008	131,421
2009	168,204
2010	145,329
2011	162,057
2012	194,451
2013	193,405
2014	203,419
2015	246,970
2016	237,851
2017	290,222

3.2 Forecasting of waste amount at Tamangapa landfill

The forecasting of waste amount in Makassar until 2027 was carried out by a linear regression method, based on 2008-2017 waste production data. The regression analysis testing uses Statistical Product and Service Solutions (SPSS) software. SPSS can read various types of data by data inputting in the form of rows (cases) and columns (variables). The volume of organic waste is assumed to be 60% of total waste amount. The forecasting result of waste amount at Tamangapa landfill in 2018 - 2027 is shown in Table 2.

Table 2. The forecasting result of waste amount at Tamangapa landfill (2018-2027).

No	Year	Weight of Total Waste (Ton)	Weight of Organic Waste (Ton)
1	2018	282,265	169,359
2	2019	297,707	178,624
3	2020	313,150	187,890
4	2021	328,592	197,155
5	2022	344,034	206,420
6	2023	359,477	215,686
7	2024	374,919	224,951
8	2025	390,361	234,217
9	2026	405,804	243,482
10	2027	421,246	252,747

3.3 The calculation of methane gas and electric power potential at Tamangapa landfill

The calculation of methane gas potential is based on parameters:

- methane gas weight parameters of 0.092 kg
- methane gas density of 0.0448 lb / ft3 = 0.7176 kg / m^3.

Thus, the volume of methane gas produced by 1 kg of organic waste is:

$$V = \frac{0.092\ \text{kg}}{0{,}7176\ \text{kg}/\text{m}^3}$$

$$= 0.12\ \text{m}^3$$

The calculation result of methane gas volume for 2018-2027 is presented in table 3 below. In 2027, methane gas produced by organic waste production in that year is 30,330 m^3.

Table 3. The forecasting of methane gas volume at Tamangapa landfill (2018-2027).

Year	Volume of Methane Gas (m^3)
2018	20,323
2019	21,435
2020	22,547
2021	23,659
2022	24,770
2023	25,882
2024	26,994
2025	28,106
2026	29,218
2027	30,330
Average	25,326

Methane gas with 1 m^3 volume is capable to generate electrical energy of around 7.9 kWh. The example of electrical energy calculations that can be generated from methane gas is presented below.

The sample used forecasting data for organic waste in 2018 amounting to 169.359 tons

Volume of methane gas = weight of organic waste x 0.12
= 169,359,000 kg x 0.12
= 20,323,080 m^3 of methane gas

Electrical Energy = volume of methane gas x 7.9 kWh
= 20,323,080 x 7.9
= 160,553,332 kWh

Generated Electrical Power: $\frac{\text{Electrical Energy}}{365 \text{x} 24}$

$= \frac{160,553,33}{8760}$

= 18,328 kW
= 18.328 MW

The waste power plant takes of 3 years minimum to start a production. For exsisting condition, Tamangapa landfill area is only sufficient for 11 years sanitary landfill activities. For the first year, waste hoarding activity is carried out every day. Within a year, the landfill zone is permanently closed. In the first year, the landfill does not produce methane gas. It caused by methane gas formation process need 3 years. So, production process is occurred in third year. Likewise for the second year onwards. The process of forming methane gas for 10 years will end in 2029.

The residence time or the lifetime of methane gas is around 5-7 years. In this research, it is estimated around 5 years. So, methane gas from landfill is still available for the first year until the fifth year. In the sixth year, methane gas produced from the first year has run out. The results of the cumulative calculation of methane gas, electrical energy and electrical power generated during 2018-2029 are presented in table 4.

Table 4. The cumulative amount of methane gas, electrical energy and electrical power for waste power plant operations for 10 years at Tamangapa landfill.

Year to	Year	Cumulative of Methane Gas Volume (m^3)	Cumulative of Electrical Energy (kWh)	Cumulative of Electrical Power (MW)
1	2018	-	-	-
2	2019	-	-	-
3	2020	20,323.08	160,552,332	18.328
4	2021	41,757.96	329,887,884	37.658
5	2022	64,304.76	508,007,604	57.992
6	2023	87,963.36	694,910,544	79.328
7	2024	112,733.76	890,596,704	101.666
8	2025	118,293.00	934,514,700	106.680
9	2026	123,852.24	978,432,696	111.693
10	2027	129,411.48	1,022,350,692	116.707
11	2028	132,570.72	1,047,308,688	119.556
12	2029	134,889.96	1,065,630,684	121.647

4. Conclusion

The forecasting of average methane gas production at TPA Tamangapa Antang Makassar for 2018-2027 is 24,762 m^3 per year. The methane gas can be used for waste power plant by method changing of waste disposal from open dumping to sanitary landfill. In 2029, the cumulative estimation of electrical energy and power that can be generated from methane gas are 1,065,630 GWh and 121,647 MW, respectively.

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