290-22

20th International Conference on Renewable Energies and Power Quality (ICREPQ'22)
Vigo (Spain), 27th to 29th July 2022

Landfill Gas Generation and Utilisation (Case study: Chasinato Landfill. Ambato, Ecuador)

S. Cabrera and A. Guevara

Ingeniería Mecánica, Facultad de Ingeniería Civil y Mecánica, Universidad Técnica de Ambato, Ecuador
e-mail: spcabrera@uta.edu.ec, aguevara8622@uta.edu.ec

1. Introduction

The landfill is a final disposal technique to confine solid waste, it has big potency as renewable energy source since it generates biogas from organic waste degradation process which can be used for cogeneration plants.

The purposes are to quantify the gas production potential of landfilled refuse and to suggest alternatives to use energy from Landfill gas generated. In 2020, the volume of solid waste disposed to Chasinato Landfill reached 250.61 tons per day, with 41.03% of organic waste.

Landfill gas (LFG) generated was evaluated using LandGEM and Ecuador LFG model, which was modified applying methane rates obtained with on site experimental measures. It was projected to obtain 365.40 cubic meters per hour in 2021, and 522.33 cubic meters per hour in 2029. The available power from recovered LFG reach: 820 kW in 2021 and 1,180 kW in 2029. The biogas generated reduces the impact related to global warming and would contribute cogeneration in low scale with electric energy and useful heat.

2. Case Study

In Ecuador, an average of 13,372.47 tons of solid waste was collected daily in 2018. Currently, the Per Capita Production of solid waste (PCP) reaches between 0.22 to 1.8 kg/inhab/day, with an average of 0.597 kg/inhab/day. According to the National Institute of Statistics and Census (INEC) of Ecuador, Ambato is a city with metallurgical, automotive and fruits production, it has 378,523 inhabitants and a solid waste production of 234.68 tons per day [4].

The GADM categorization and prioritization respond to the amount of urban solid waste generated. Being these of type: special greater than 500 t/day, large between 251 to 500 t/day, medium between 101 to 250 t/day, small 51 to 100 t/day and micro less than 50 t/day [5]. GADM Ambato corresponds to medium type, there are fifteen similar ones in this country (6.8% of total).

3. Methodology

LandGEM models use information about Chasinato landfill: opening and closing years, solid waste per year deposited in the landfill and the parameters k and L_0, selected or calculated based on geographic location or other features. Ecuadorian model is a modification of LandGEM adapted to geographic and climatologic conditions of Ecuador. Information of Ecuadorian landfills: Las Iguanas in Guayaquil, Pichacay in Cuenca, Chabay in Azogues, El Valle in Cuenca and Loja landfill were taken to adapt LandGEM for this country. The LandGEM and Ecuadorian models use (1) y (2) to estímate biogas production.

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k \cdot L_0 \cdot \left(\frac{M_i}{10}\right) \cdot e^{-kt_{ij}} \quad (1)$$

$$Q = \sum_{0}^{n} \frac{1}{\%\, vol} \, k \cdot M \cdot L_0 \cdot e^{-k(t-t_{lag})} \quad (2)$$

Where: Q_{CH4}= the annual production of methane in the year of calculation (m^3/year), Q= total quantity of landfill gas generated (m^3/year), i= time increment of 1 year, n= the different between the year of calculation and the first year, or total number of years modelled, j= cutting the year in tenth, k= the generation coefficient of methane or estimated rate of decay of organic waste(year $^{-1}$), L_0= the potential of CH_4 waste or estimated volume of methane generated per ton of solid waste (m^3/Mg), M_i= the mass of waste accepted in year i^{th} year (Mg), t_{ij}= the age of the waste section j^{th} accepted the year i^{th} (decimal year), % vol= estimated volumetric percentage of methane in LFG.

Chasinato landfill started its activities in 2004. In 2020, it received 250.61 tons of urban waste per day. This landfill accepts any kind of waste, but the principal residue to produce methane is the organic waste (in this case 41.03%) [3]. Ambato projects that in 2028 Chasinato landfill will use 100% of its capacity to dispose solid waste, so this would cause to stop its activities.

4. Results

Ambato is an agro-industrial city, with 41.03% of organic waste these features of its solid waste and the rainfalls are advantage to generate landfill gas. Estimation models predicted a production of landfill gas from 2010 to 2060.

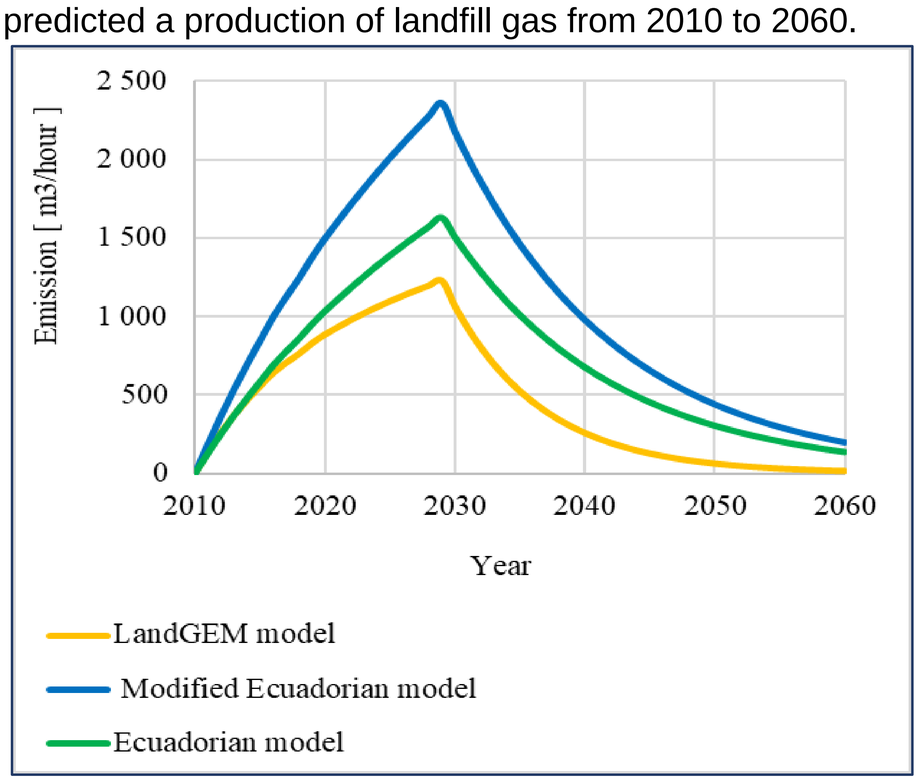

Figure 1. Biogas emissions in Chasinato landfill, comparison between three LFG models (m^3/hour)

5. Discussion

Ecuadorian model was modified with a rate of methane obtained by experimental measurement on site. Biogas of Chasinato landfill contents 34.62% of methane (CH_4), 25.71% of carbon dioxide (CO_2) and 8.08% of oxygen. A variation of methane rate in the Modified Ecuadorian model causes a high estimation of landfill gas than last twice. In 2029 the highest estimation will be 2,359 m^3/hour.

Chasinato landfill produces less quantity of biogas according Pichacay and Las Iguanas landfills. This LFG would generate renewable energy to be applied in the same landfill. With an efficiency of 30% in the extraction system the averaged biogas recovered and estimated by LFG models for 2021 was 365.40 m^3/hour. This biogas could produce 820 kW of energy to feed any type of generator, before LFG recovered must be treated.

Table 1. Analysis of electrical and thermal energy production.

In 2021	
Electric power at 61% of max load	304 kW
Total recovered in heat water at 61% of max load	372 kW
Operation daily hours	12
Energy production per month	109,440 kWh
In 2029	
Electric power at 88% of max load	438 kW
Total recovered in heat water at 88% of max load	536.8 kW
Operation daily hours	12
Energy production per month	157,680 kWh

6. Conclusion

In Ecuador 51% of GADM dispose of their waste in landfills and/or emergent cells, while 49% dispose of their waste in open-air dumps. GADM Ambato corresponds a medium type landfill with a solid waste production of 234.68 tons per day. It would project that in 2028 Chasinato landfill would use 100% of its capacity to dispose solid waste. It was estimated the generation of biogas in Chasinato Landfill in 2021, among three LFG models applied, the highest estimation corresponds to modified Ecuadorian model with 1,607.06 m^3/hour and an average content of 34.62% methane, 25.71% CO_2 and 8.08% O_2. Electrical and thermal energy produced in the cogeneration system could be used in landfill illumination, and the heat water recovered could be employed in containers cleaning and garbage trucks washing.

7. Acknowledgement

Opinions, findings, or conclusions expressed herein are those of the authors. They are grateful to GIDSA-EPM: Municipal Public Company for Whole Management of Solid Waste Ambato, Research and Development Directorate of the Technical University of Ambato (DIDE-UTA), and GasGreen S.A.. The authors acknowledge constructive comments received from their reviewers.

8. References

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