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TECHNOLOGIES FOR ENERGY RECOVERY OF LANDFILL WASTE: BIOGAS POTENTIAL IN THE MANAUS LANDFILL (AM)

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ABSTRACT

Urban solid waste management (RSU) is one of the biggest challenges in city management, while demand for electricity increases worldwide. Economically viable, socially fair and environmentally balanced solutions to such challenges need to be sought. Waste can no longer be seen as rejecting and being seen as an energy resource. The generation of energy through landfill waste is an alternative to the installation of new plants for energy production, can reduce the emission of greenhouse gases and also generate new jobs in the process. The objective of this research was to quantify the energy potential from waste stored in the Manaus landfill compared to the amount of energy already generated on site and the amount of families that could be supplied with their full potential. The results indicate that the landfill currently generates 13,642.83 kWh, but has the potential to produce 19,873 MWh/year, which would be enough to supply about 10,350 homes.

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INTRODUCTION

Technology has become an ally in the search for products and services that meet human needs by exploiting fewer natural resources. One of these needs that has been intensifying due to the development of cities is electricity (TRINDADE, 2019). Brazil has had an increase in average electricity consumption of 3.5% per year in the last ten years (MORAIS, 2015). In 2020, electricity consumption is estimated to be 61% higher than in 2010, reaching 730 TWh (TOLMASQUIM, 2012). At the same time, solid waste production grows about 7% per year worldwide (GOUVEIA, 2012). Data from ABRELPE - Brazilian Association of Public Cleaning and Waste Companies (2017) indicate that in 2017 the generation of Municipal Solid Waste in Brazil was about 78.4 million tons.Of the waste produced, around 59.1% were allocated to landfills (ABRELPE, 2017). The decomposition of waste generates gases, among them is methane, which is extremely aggressive to the environment.

Considering the data on the disposal of garbage in landfills presented by IBGE (2008), 12.4 million m³ of methane per day could be produced in Brazilian landfills. Additionally, using the garbage generation rate of 0.26 t/hab/year presented by the IPCC and considering the disposal of all garbage in landfills with possible power generation, this potential reach 15.8 million m³/day (ZANETTE, 2009). By burning methane and turning it into carbon dioxide it is possible to reduce the pollution rate emitted into the atmosphere by about 20 times. In addition, this gas can be transformed into electricity (ROYA et al., 2011). Biogas, as it is called, is one of the alternatives of energy use of waste that solve these two major problems of the 21st century: the growth of demand for electricity and the highest production of RSU (ZILOTTI, 2012). Despite all the potential for power generation, this feature is not yet harnessed in its total capacity. The national potential for biogas in the basic sanitation, solid waste and domestic sewage sector is three billion m³ per year (CIBIOGAS, 2013). In Brazil, the use of biogas still with only 0.0891% of its potential and installed

capacity of 154,667 MW (ANEEL, 2019). When it comes to northern Brazil, the scenario is even more complicated due to the situation of the basic sanitation of cities. In the northern region are the lowest basic sanitation rates in the country (IBGE, 2008). In a report by the TrataBrasil Institute (2017) with the sanitation ranking of the 100 largest cities in terms of population, Manaus appears among the 10 worst places. The city of Manaus, in Amazonas, has a landfill that during 2018 received an average of 2,587.2 tons of municipal solid waste per day, totaling 944,328 tons per year. The residues received are separated between garbage grounding, recycling and composting in the percentage of 98%, 2% and 0.1%, respectively (SEMULSP, 2019). Since 2008 methane capture and burning has been carried out to be transformed into carbon dioxide. And only in 2019 the landfill of Manaus also began to transform part of this gas into electricity (SEMULSP, 2019). The objective of this research was to analyze the potential of the landfill of Manaus, in Amazonas, for the generation of energy through biogas. Thus, obtaining the amount of energy currently generated in relation to its generation potential. In addition to assessing the ability to serve homes near the landfill.

MATERIAL AND METHODS

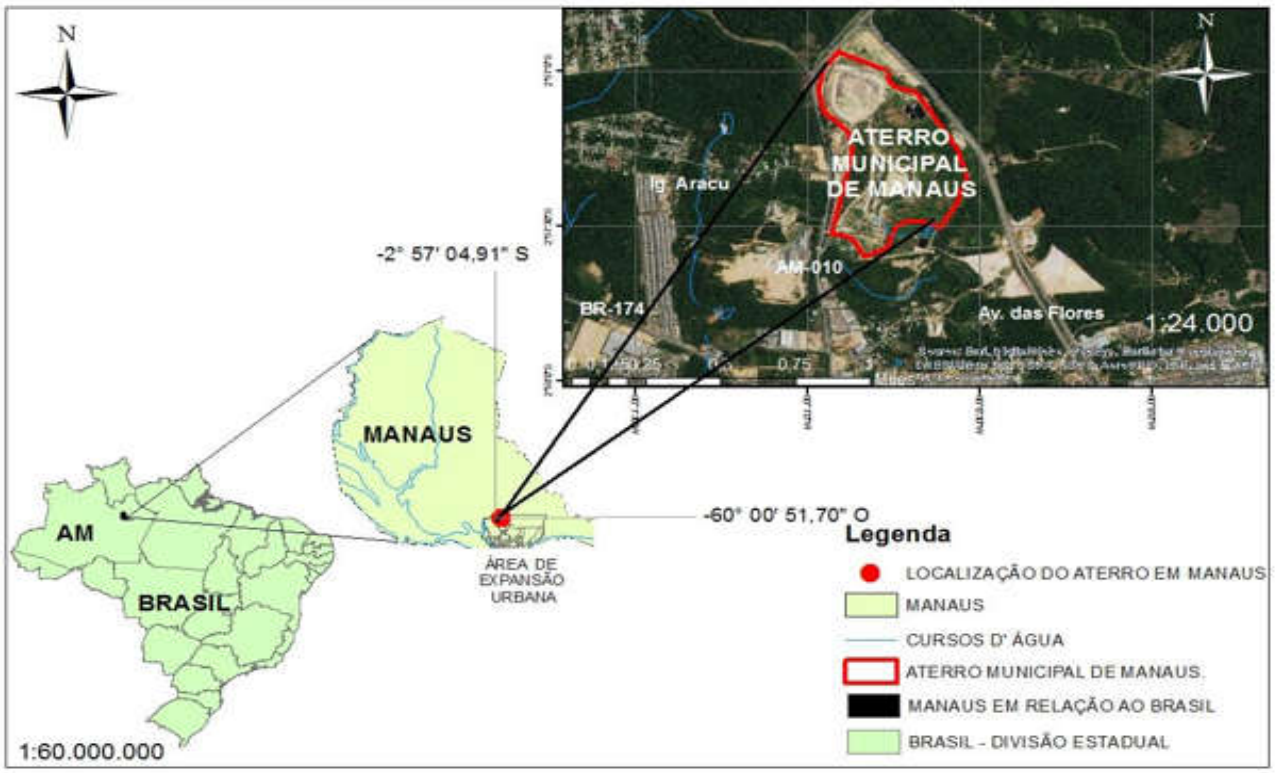
The study was developed in the manaus landfill, which is located at Km 19 of the AM highway - 010 (Manaus - Itacoatiara), on the right bank of the Igarapé Matrinxã, positioned in the geographical coordinates Lat: 02° 57' 23.86" S and Lon: 60° 00' 47.62" (figure 1). The Manaus landfill began as a dump in 1986 and the beginning of its recovery occurred in September 2006 after signing an Environmental Conduct Adjustment Term. In September 2007, the certification of the area was obtained as a landfill that now has 66 hectares.

A technical visit was made to the Manaus landfill to survey the processes that are effectively being carried out, amount of methane emitted and energy generated daily, amount of waste that arrives at the landfill today. In addition to planning for the future of the landfill considering that its capacity is close to exhaustion. To obtain the data, the database of the Municipal Secretariat of Public Cleaning (SEMULSP) was used, which stores, per month, the amount of waste collected and, since July 2006, the length of activity of the flare, the average percentage of methane in biogas, the flow rate biogas average and total CO2 equivalent original area. And since April 2019, the amount of energy generated daily in the landfill.

The data obtained were tabulated and processed through Microsoft Excel software. With the methane percentage and the total amount of biogas per month, it was possible to calculate the methane volume emitted per month and then obtain the methane volume and average methane generated per year. The average methane percentage per year was also analyzed to reach a general value. And as for the electricity generated, the monthly amount was obtained. After all the analyses, the graphics were generated in the software. Based on the amount of methane estimated in the analyses, the energy potential of the landfill was calculated using the method proposed by CETESB (2006), chosen according to the reliability in the results and ease of application. It is presented by equation 1:

$$Px = [(Q * Pc\ (CH4)/31.536.000) * Ec * (K)] \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In what:Px, available power per year (KW/year);Q, flow of CH4 per year (m³/year);Pc (CH4), calorific value of CH4 per year = 35.53 x 106 J/m³ CH4;31,536,000 is the amount of seconds per year (s/year);Ec, gas collection efficiency (75%); and K, conversion constant (0.08) :



Source: The authors

Figure 1. Location of the Manaus municipal landfill

Ed = Px . 8760 …….(2)

In what: Ed, energy available per year [kWh]; 8,760 is the amount of hours in the year. To obtain the number of families that could have electricity supplied through biogas, equation2, 3 and 4 (MME, 2017) were used.

Energy Consumed (year/family) = Energy consumed (month/family) x 12 months (3)

Energy Consumed (year) = Max power x 8760h (4)

Number of Families Served = Energy Consumed (year) / Energy Consumed (year/family) (5)

The quantity and composition of waste disposed in landfills and management practices in disposal sites are the basis for estimating the potential for methane generation present in biogas, as pointed out by Zanette (2009) in his research on the potential biogas in Brazil. In the Manaus landfill the operation to control and measure the emission of gases is carried out exclusively by Conestoga, Rovers and Associados Engenharia Ltda (CRA). Det Norske Veritas (DNV) is responsible for certifying the emission reduction that is underway. According to the data presented in Table 1, from July 2009 to February 2019, 3,664,988 tons of biogas emissions were reduced, with the annual average of 333,181 and the daily average of 1,002 tons of biogas. According to Linard and Aquino (2016), the efficiency of the biogas collection system produced in a landfill at 75% can be considered. As presented in Table 2, it is possible to observe that the average methane present in the biogas generated in the Manaus landfill is 50.86%. Pecora et. al (2009), in his study of the São Paulo landfill, obtained as a result that there was 40% CH4 present in the biogas collected. For Oliveira (2000), 40 to 55% of biogas generated in anaerobic decomposition of organic matter corresponds to methane, which is in accordance with the results obtained. Figure 2 shows that the percentage of methane present in the biogas generated in the Manaus landfill grows over the years, with its highest value in 2019. For Zanette (2009) it is

Table 1. Biogas data collected at landfill (tons) - 2009 to 2019

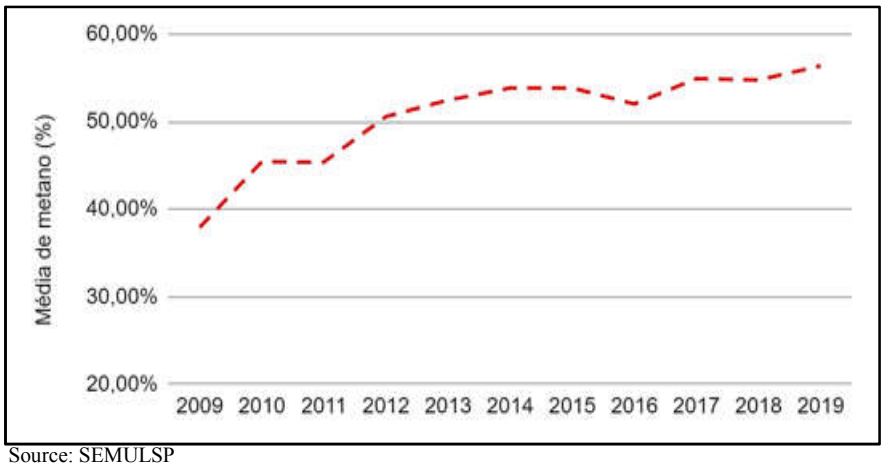
Year	Annualproduction	Monthlyaverage	Daily average
July toDec 2009	41.659	6.943	228
2010	194.287	16.191	532
2011	156.029	13.002	427
2012	341.833	28.486	934
2013	428.992	35.749	1.175
2014	484.420	40.368	1.327
2015	504.943	42.079	1.383
2016	465.064	38.755	1.271
2017	533.137	44.428	1.461
2018	453.321	37.777	1.242
Jan toFeb 2019	61.303	30.652	1.039
Total	3.664.988	334.430	11.019
Média	333.181	30.403	1.002

Source: SEMULSP

Table 2. Average methane present in landfill biogas

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Averagemethane (%)	37,92	45,41	45,38	50,58	52,45	53,83	53,83	52,01	54,91	54,74	56,37	50,86

Source: SEMULSP



Source: SEMULSP

Figure 2. Average methane percentage per year

RESULTS AND DISCUSSIONS

In 2019, in relation to the municipal solid waste collected (RSU) by the Manaus Urban Cleaning System (SLUM), the amount reached 629,918 tons. Considering the number of 2,182,763 inhabitants in Manaus (IBGE, 2019), each manauara produced, on average, 1,188 Kg/day of RSU. Of the two types of waste entry into the Manaus landfill, 98.5% of the waste received at the landfill is through the concessionaires, totaling a daily average of 2,592.3 tons from January to August 2019.

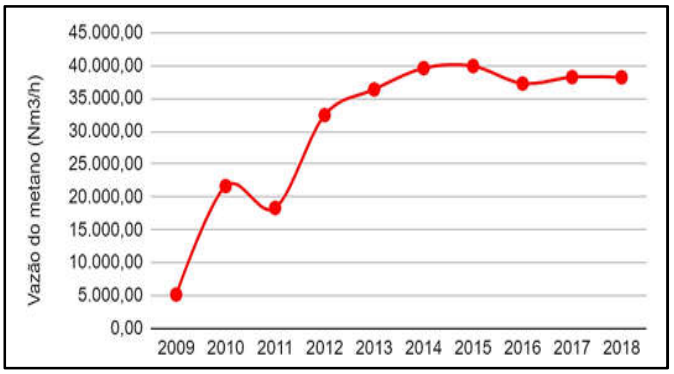
important to consider that the year in which the material of the waste was deposited in the landfill is irrelevant in determining the amount of methane generated each year, only the total mass of decomposition material on site is what matters. Thismayjustifythegrowthpresented. According to the data presented in Table 3, the amount of methane generated in the Manaus landfill from July 2009 to February 2019 was 316,034.68 m³/h with a monthly average of 33,449.14 m³/h. In his study on the Manaus landfill, Costa (2011) obtained the result of 15,000 m³/h and cited that there is a greater amount of methane in the range of 30,000 m3/h confined in the landfill. The value obtained is consistent with the projection of it. The initial years, 2009, 2010 and 2011, are the ones with the least methane capture. Figure 3 shows that the highest amounts of methane occur in the 4th and 5th years of collection, 39,604.93 m³/h and 39,924.49 m³/h, respectively. From the 5th year, it begins to present a stability in production, which converges with Zanette (2009) by highlighting that the maximum use of methane for the generation of electricity during the life of the project occurs from the beginning of the 5th year of the disposal of waste up to 4 years after the end of the use of the landfill.

Although it was not the first 5 years of landfill operation, it was the initial years of the area equipped for gas collection. This also matches the IPCC's first-order decay model (2006) which demonstrates that methane production gradually increases with the disposal of waste during landfill use and, although it decreases sharply after the end of the disposal of remains significant for a few years. In biogas generated by anaerobic decomposition of municipal solid waste, methane is what has the heat-saving power needed for combustion and power generation. Its calorific power is 35.53x106 J/m3 CH4 and in the Manaus landfill the use of this gas generated 81,857 KWh of energy (Table 4) in 6 months. However, its energy generation capacity is 19,873 MWh/year. In his study on a landfill in Minas Gerais, Reis et. al (2017) concluded that the maximum amount of energy to be generated in the landfill is approximately 38,000 MWh/year. The difference is due to the amount of methane generated in the Minas Gerais landfill, which is influenced by the percentage of each type of waste deposited, the amount of waste that can be decomposed, and the percentage of methane present in biogas. The energy generated in the Manaus landfill differs greatly from its potential because it is still a pilot project. As it can be noted in Figure 5, the power generation in the landfill has many fluctuations since its implementation precisely for this reason and are not yet with the most suitable equipment for the operation. According to the Monthly Review of the Electric Energy Market of the Energy Research Company (EPE, 2017), since February 2017 the average consumption in residential units is practically stationary at 160 KWh/month. With the current power generation, at its maximum generation, it would be possible to supply 125.20 homes with electricity from the landfill. However, using all its generation capacity, it would be possible to supply and power to 10,350 homes. The biogas use plant at the Macaúbas landfill in Sabará - MG, implemented by the company AsjaBrasil (2017), serves 25,000 families annually. Considering that the generation potential of the Sabará landfill is more than double the Manaus landfill, it is plausible that it supplies about twice as many residences as well, proving the veracity of the results. The efficiency for power generation will depend on several factors, from gas capture, the climate of the region, the quality of equipment and the initial design.

Table 3. Methane flow produced at Manaus landfill in m³/h - jul. from 2009 to Feb. 2019

Year	Methaneflow(m³/h)
Jul - Dec 2009	5.163,82
2010	21.655,99
2011	18.337,35
2012	32.460,15
2013	36.363,30
2014	39.604,93
2015	39.924,49
2016	37.251,54
2017	38.239,11
2018	38.205,42
Jan and Feb 2019	8.828,59
Total	316.034,68
Average per month	2.724,44

Source: SEMULSP



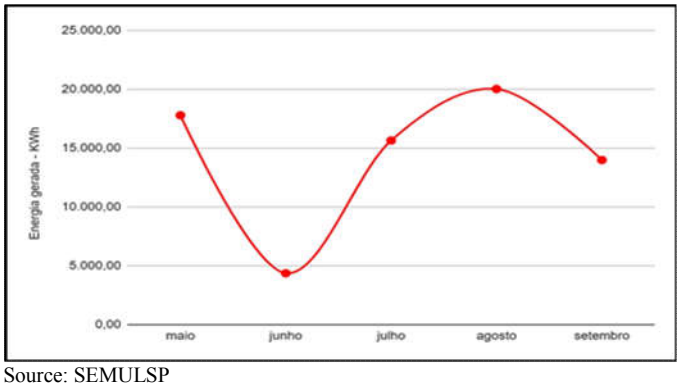
Source: SEMULSP

Figure 3. Methane flow at m³/h in Manaus landfill

Tabela 4. Energia gerada no aterro de Manaus em KWh

Month	Generatedenergy - KWh
May	17.798,00
June	4.373,00
July	15.656,00
August	20.033,00
September	14.000,00
October	9.997,00
Total	81.857,00
Average	13.642,83

Source: SEMULSP



Source: SEMULSP

Figure 5. Energy generated in Manaus landfill

Losses such as gas leakage by landfill cover, losses by the drainage network and related to the amount of slurry present are avoided.

Conclusion

It is concluded that the Manaus landfill has power generation potential of 19.8 MWh/year, compared to the 81,857 KWh of

energy generated in 6 months of operation. Using all its energy capacity it would be possible to supply 10,312 homes while currently at its maximum power, it is possible to provide power to only 125.20 families. Economic and financial feasibility studies are recommended to analyze investment, operation and maintenance costs for project expansion.

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