BIOMETHANE PRODUCTION BY LICENSED BRAZILIANS LANDFILLS AND POTENTIAL ENERGY USE IN MUNICIPALITIES

PRODUÇÃO DE BIOMETANO POR ATERROS SANITÁRIOS LICENCIADOS BRASILEIROS E O USO DO POTENCIAL ENERGÉTICO EM MUNICIPIOS

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Abstract

One of the main challenges especially for small developing cities is to find economically viable alternatives to the management of municipal solid waste. This research aims to investigate the potential of biomethane production by licensed Brazilian landfills, to assess the feasibility of using biomethane energy in small municipalities. This study identified three biogas-upgrading facilities authorized by the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) as to know: GNR Dois Arcos, Gás Verde and GNR Fortaleza. Field research collected additional information about the landfills and biomethane facilities investigated, to create indexes for supporting decision-makers in the waste management sector. Indexes A and B were proposed, which represent: the relation between the biogas production and the mass of landfilled municipal solid waste, and the relation between the biomethane processing capacity in the facility and the biogas production potential, respectively. This study showed that one of the facilities with lower biomethane production and biogas processing capacities, and which receives municipal solid waste from several small municipalities - such as GNR Dois Arcos - presented a similar value for index A in relation to the biggest facility – such as Gás Verde - and the highest value for index B compared to the other two larger facilities.

Key words: Municipal solid waste, landfill, biogas, biomethane, renewable energy.

Resumo

Um dos principais desafios, principalmente para as pequenas cidades em desenvolvimento, é encontrar alternativas economicamente viáveis para a gestão dos resíduos sólidos urbanos. Esta pesquisa tem como objetivo investigar o potencial de produção de biometano em aterros sanitários brasileiros licenciados, a fim de avaliar a viabilidade de uso de energia de biometano em pequenos municípios. Este estudo identificou três instalações de aproveitamento de biogás autorizadas pela Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP) a saber: GNR Dois Arcos, Gás Verde e GNR Fortaleza. A pesquisa de campo coletou informações adicionais sobre os aterros e instalações de biometano investigados, a fim de criar índices para apoiar os tomadores de decisão no setor de gestão de resíduos. Foram propostos os índices A e B, que representam a relação entre a produção de biogás e a massa de resíduos sólidos urbanos depositados em aterro, e a relação entre a capacidade de processamento de biometano na instalação e o potencial de produção de biogás, respectivamente. Este estudo mostrou que uma das instalações com menor capacidade de produção de biometano e capacidade de processamento de biogas, que recebe resíduos sólidos urbanos de vários municípios

de pequeno porte - como a GNR Dois Arcos - apresentou valor semelhante para o índice A em relação à maior instalação - como Gás Verde - e o maior valor do índice B em comparação com as outras duas instalações maiores.

Palavras-chave: Resíduo sólido municipal, aterro sanitário, biogás, biometano, energia renovável.

INTRODUCTION

According to the National System of Sanitation Information (SNIS, 2020) from Brazil, about 65.11 million tons of municipal solid waste (MSW) were collected in 2019 and approximately 75.1% was disposed at landfills. About 68% of Brazilian municipalities house less than 20 thousand inhabitants and the majority of MSW generated in Brazil (as expected for a developing country) is biodegradable, aroun 51.% is characterized as organic fraction of municipal solid waste (OFMSW) (Alfaia et al., 2017, Vieira et al., 2019).

The production of biogas in landfills occurs naturally from the anaerobic digestion of the OFMSW contained in the landfill`s cells, promoted by anaerobic microorganism's consortia. Methane production in landfill depends mainly on: (i) MSW characteristics (such as composition, particle size, humidity, temperature and pH) and (ii) operational landfilling techniques (Nascimento et al., 2019). Methane is the main greenhouse gas among the emissions caused by the final disposal of solid waste, with a global warming potential 28 times greater than carbon dioxide over a 100-year horizon (IPCC, 2014). In this way, biogas must be captured and burned to mitigate the GHG emissions into the atmosphere. Moreover, this methane can be recovered as energy and use as electricity and/or biomethane to replace fossil fuels and natural gas, enforcing the National Policy of Solid Waste (PNRS, 2016).

The energy use from OFMSW can be applied as an interesting alternative fuel in smaller regions and must be considered as an important sustainable local strategy (EPE, 2014, Adnan et al., 2019). The landfill's biogas can be used to produce heat, or even be converted into heat and electricity through a CHP (combined heat and power) generator (GIZ, 2019). Another possibility is the biogas upgrading into biomethane via its purification process, replacing fossil fuel and natural gas. The biogas upgrading necessarily implies the removal of CO_2 in order to increase the methane content and the energy density of gas, and removal of H_2S and siloxanes which is harmful to engines and equipment (Petersson and Wellinger, 2009), Thrän et al., 2014, Hoo PY et al., 2018). According to Czyrnek-Delêtre et al. (2016), the mainly biogas upgrading Technologies are: membranes; adsorption (such as PSA - pressure swing adsorption); scrubbing (such as water, organic physical scrubbing and chemical scrubbing) and cryogenic (operated at low temperatures and high pressures). The final product is biomethane, whose methane concentration is above 90% (ANP, 2017).

According to EPA, the simplest and often most economical use of biomethane is as fuel for boilers, industrial processes and/or internal combustion engines (EPA, 2020). The biomethane as vehicle fuel or as renewable natural gas has being a sustainable and competitive alternative due to its high calorific potential. However, the ANP Resolution No. 685 (ANP, 2017) only regulated the guidelines for biomethane production in Brazil in 2017. Irena, 2018 points out gas grid injection as the most common and generally the most economical biomethane application when biomethane plant is close to the gas grid.

This research aims to investigate the potential of biomethane production by licensed Brazilian landfills and evaluate the viability of biomethane's energy use in municipalities.

MATERIALS AND METHODS

This study identified the authorized landfills biomethane facilities registered at the ANP standards and resolutions for biomethane's quality and production in Brazil (ANP No. 8/2015, ANP No. 685/2017 and ANP No. 734/2018). There are three biogas-upgrading facilities authorized by the ANP as to know: GNR Dois Arcos, Gás Verde (both located in Rio de Janeiro State, Southeast region) and GNR Fortaleza (located in Ceará State, Northeast region).

Table 1 presents the landfills characterization.

Biomethane facilities information and data were collected based on: (i) Access to Information Act, Law No. 12527 (Brazil, 2011); (ii) public information at the ANP Electronic Information System, whose responsibility involves the regulation and authorization of biomethane producers; (iii) field investigation carried out at the biomethane facilities from landfills (GNR Dois Arcos and GNR Fortaleza).

Table 1. Characterization of landfills with biomethane production facilities

Landfill	Characteristics
Fortaleza's Landfill	
Biomethane Facility	GNR Fortaleza
MSW per day (tMSW/d)	5,000
Population (citizens)	3 millions
Municipalities	Fortaleza and Caucaia
Landfill Area (m²)	1,230,000 (old part) 526,000 (new part)
Seropédica's Landfill	
Biomethane Facility	Gás Verde
MSW per day (tMSW/d)	10,000
Population (citizens)	7,053,808
Municipalities	Rio de Janeiro, Seropédica, Itaguaí, Mangaratiba, São João de Meriti, Piraí and Miguel Pereira
Landfill Area (m²)	3,000,000
Dois Arcos' Landfill	
Biomethane Fcility	GNR Dois Arcos
MSW per day (tMSW/d)	762
Population (citizens)	530,000
Municipalities	São Pedro da Aldeia, Cabo Frio, Búzios, Casimiro de Abreu, Silva Jardim, Araruama, Iguaba Grande and Arraial do Cabo
Landfill Area (m²)	750

Indexes A (Equation 1) and B (Equation 2) have been proposed in order to compare the biomethane facilities with different production capacities, which represents: (A) biogas production per ton of landfilled MSW ($m^3\ t^{-1}$); (B) biomethane processing capacity per biogas production potential.

$$\text{A index} = \frac{\text{biogas production } (m^3\ day^{-1})}{\text{landfilled MSW } (t\ day^{-1})} \quad (1)$$

$$\text{B index} = \frac{\text{biomethane processing capacity } (m^3\ day^{-1})}{\text{biogas production } (m^3\ day^{-1})} \quad (2)$$

RESULTS

Landfills Biomethane Production in Authorized Facilities in Brazil

Table 2 shows the status of authorized biomethane facilities in Brazilian landfills, as biogas upgrading process, operational requirements, biogas processing capacity and biomethane production flow.

All three biomethane facilities hold a different biogas upgrading process: (i) GNR Fortaleza uses the physical absorption with organic solvent; (ii) Gás Verde uses the membrane separation and cryogenic processes; (iii) GNR Dois Arcos uses the water scrubbing process. GNR Fortaleza is the only biomethane producer authorized by ANP to inject gas into the grid (licensed in 2020), while Gás Verde and GNR Dois Arcos are licensed for gas transportation in cylinder trucks.

Commercial Purposes and Final Uses of Landfills Biomethane

In 2019, biomethane was used for the first time in a steel company in Brazil. The biomethane injected into the industry's complex pipeline has been applied for thermal use in the steel production process. Up to 72,000 m^3 biomethane d^{-1} (renewable gas) from Seropédica's Landfill replaced about 30% of the consumption of natural gas (fossil energy source) used for heating (Ternium, 2019).

GNR Fortaleza injects biomethane into the natural gas grid. This biomethane is transported to the natural gas distribution centre via a 23 km gas pipeline (owned by the Natural Gas Company of Ceará State) and is used for cooking, heating and/or vehicle fuel (CEGÁS, 2018). Gás Verde compresses biomethane in cylinders and trades with local industries (heating) and gas stations (fuel), while GNR Dois Arcos compresses and sells biomethane to the gas stations.

Table 2. Biomethane facilities authorized by ANP in landfills

Facitily	MSW per day (t day^{-1})	Biogas Processing Capacity (m^3 day^{-1})	Minimum Biogas Volume to Operate (m^3)	Maximum Capacity (Nm^3 day^{-1})	Average Capacity of the System (Nm^3 day^{-1})	Biogas Purification Process	Production Flow
GNR Fortaleza	5,000	300,000	3,750	110,000	0 – 100,000	Physical Absorption with Organic Solvent	Gas Grid Injection
Gás Verde	10,000	480,000	No information	204,000	0 – 150,000	Membrane Separation and Cryogenic Separation	Gas Cylinder Transportation by Truck
GNR Dois Arcos	762	35,000	700,0	16,000	0 – 14,000	Water Scrubbing	Gas Cylinder Transportation by Truck

Comparison between Biomethane and Natural Gas Qualities

According to the ANP (ANP, 2017), the performance properties (Wobbe index - WI, high heating value – HHV, and methane content - $\%CH_4$) present different limits of values by region (North, Northeast and Southeast) according to the characteristics of the natural gas reservoirs. As biomethane is interchangeable with natural gas, the specifications must present such similarities.

The biomethane produced by GNR Fortaleza shows the highest HHV (36,068.97 kJ m^{-3}), while the Gás Verde biomethane presents a slightly higher WI among the other producers (47,379.43 kJ m^{-3}) and GNR Dois Arcos reached the highest methane content (96.46 $\%CH_4$).

Table 3 shows the content of O_2, CO_2 and H_2S

in the biomethane produced in the studied landfills. The O_2 content is higher in Gás Verde (0.45 $\%O_2$), as well as the percentage of H_2S (0.05 mg m^{-3}), even if in small quantities. GNR Fortaleza shows a higher percentage of CO_2 (2.04 $\%CO_2$). Table 3 also shows the values of siloxanes and halogenates present in the Brazilian biomethane facilities. It was observed that the halogen-chlorine content, whose highest value is present at GNR Dois Arcos, is related to the OFMSW. The halogen-fluorine present in GNR Dois Arcos, has its origin related to fluorinate water. Siloxanes, whose highest value is found at GNR Fortaleza, are present in a very small quantity due to the lower amount of products containing silicates (such as shampoos, conditioners and cleaning products – commonly found in the sewage, increasing the siloxane content into the biogas from wastewater treatment plants).

Viability of Biomethane Production in Landfills of Different Sizes

Table 4 shows the correlation between the mass of landfilled MSW and the biogas production in each landfill, represented by A index and the correlation between the biogas processing and biomethane production capacities of each installation, shown by B index. In all, GNR Fortaleza (which uses the physical absorption with organic solvent processes) presents the highest biogas yield (A index) among the studied facilities. Overall, GNR Dois Arcos (which uses the water scrubbing process) shows the highest B index value (Table 4), despite presenting the lower biogas and biomethane production capacity, compared to the other two larger producers.

Table 3 - Biomethane`s quality certification in brazilian landfills

	Biomethane's Quality Certification Results					
Facitily	Oxygen (O_2 % mol)	Carbon Dioxide (CO_2% mol)	Sulfide Gas ($mgH_2S\ m^{-3}$)	Siloxanes ($mgSi\ m^{-3}$)	Halogen-Chlorine ($mgCl\ m^3$)	Halogen-Flourine ($mgF\ m^{-3}$)
GNR Fortaleza (Jan/19-Mar/20)	0.06 (0.02-0.63)	2.04 (1.30-2.45)	0 (0-0.07)	0.09 (0.01-0.16)	0.42 (0.16-0.51)	0.04 (0-0.25)
Gás Verde (Jun/19-Jun/20)	0.45 (0.14-0.90)	1.04 (0-0.11)	0 (0-1.0)	0.05 (0.01-0.3)	0.67 (0.06-0.24)	0.09 (0-0.02)
GNR Dois Arcos (Jan/19-Mar/20)	0.38 (0.03-0.80)	1.04 (0.03-2.79)	0 (0-0)	0.05 (0-0.13)	0.67 (0-3.01)	0.09 (0-0.33)

Table 4 - Indexes A e B for each biomethane's facility quality certification in brazilian landfills

Facitily	Landfilled MSW ($t\ day^{-1}$)	Biogas Processing Capacity ($m^3\ d^{-1}$)	Index A ($m^3\ d^{-1}$)	Index B ($m^3\ m^{-3}$)
GNR Fortaleza	5,000	300,000	60	0.36
Gás Verde	10,000	480,000	48	0.31
GNR Dois Arcos	762	35,000	46	0.45

DISCUSSION

Concerning Fortaleza's landfill, the intermediate researched size, shows the highest A index, but an intermediate B index. According to Sun et al., 2015, physical absorption with organic solvent presents the efficiency range of 90.0 - 95.5% (adopted at GNR Fortaleza); water scrubbing range of 88.9 - 92.8% (GNR Dois Arcos), the membrane and cryogenic separation ranges from 82.4 - 98.0% and 84.9 - 96.7% respectively (adopted at Gás Verde).

Although GNR Fortaleza and GNR Dois Arcos adopted foreign technologies, their plant project planning was developed nationally. Both chose appropriate purification techniques according to their operation capacity, biogas yield and quality, in order to reach the biomethane requirements established by the ANP. Among several parameters, biogas diffuse losses and methane losses in biogas purification are the main factors affecting the total energy efficiency (Sun et al., 2015).

CONCLUSIONS

Biomethane's production from landfills in small municipalities is economically viable and achievable when the company operating the landfill and the biomethane producer act as partners allowing data transparency and the integration process from capture to final biogas purification stage. It was verified from indexes A and B proposed that biogas purification technologies presented different performances. It was possible to observe that a biomethane production facility with intermediate capacities for biogas processing and landfilled MSW presented an A index with a higher value in relation to the other facilities, as well as the landfills with smaller and greater landfilled MSW showed similar values for A index. It was also found that a facility, although with lower capacity for biomethane production and biogas processing receiving MSW from several small municipalities in the region, such as the GNR Dois Arcos, presented a higher B index compared to the other two larger producers. Another factor to be highlighted is that although foreign technologies are adopted it is very important that the facility project - especially in small landfills – is developed nationally in order to reduce operation and maintenance costs.

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