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ENERGY PRODUCTION FROM THE SLUDGE OF A SEWAGE TREATMENT STATION

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Abstract: The world population grows exponentially, and Brazil is no different. Thus, we increasingly need natural resources; and, as a consequence, there is an increase in waste production. Brazil, a few years ago, developed its National Solid Waste Policy (PNRS) through Law No. 12,305/10, where, regardless of its origin, solid waste must be disposed of properly, minimizing possible environmental damage; while CONAMA Resolution 375/06 already defined the proper disposal of sewage sludge to protect the environment and the health of the population. However, some of these residues have a significant energy value in their reuse, as is the case of urban sewage sludge. In this context, the present work aimed to evaluate the production of biogas energy from the sludge of a Sewage Treatment Station (ETE). Therefore, the collection and characterization of the sludge from the ETE was carried out by measuring pH, electrical conductivity, determination of total solids, fixed and volatile, determination of chemical and biochemical oxygen demand. The anaerobic digestion process with control of pH, temperature, pressure and mechanical agitation was carried out for 25 days, with an expressive generation of biogas being observed. Therefore, this residue, as biomass for energy production, proved to be an alternative with considerable energy potential, in addition to being an option for the proper disposal of solid waste and environmentally sustainable.
Keywords: Solid Waste, Sludge, biogas, Biodigester.

INTRODUCTION

Much of the waste produced in water and sewage treatment systems is a global concern. Currently, sludge production in Brazil is estimated at between 150,000 and 220,000 tons of dry matter per year. According to Andreoli (2001) due to the low rates of sewage collection and treatment still existing in the country; and, due to the pressure from society for better environmental conditions, there is a potential tendency for a substantial increase in the amount of sludge to be disposed of in the next decade. After 20 years, including the "next decade" commented by Andreoli (2001), the same perspective continues for another decade, the substantial increase in the amount of sludge to be disposed.

The main water polluting agents in urban areas are sewage which, in most cases, is discharged directly into water bodies without any treatment. Faced with the intense degradation of water resources, sewage from Brazilian cities has been treated in sewage treatment plants (ETEs), which use different types of technological systems. In these systems, the water returns to the springs with a good degree of purity. However, there is the generation of a semi-solid, pasty residue of a predominantly organic nature, called sewage sludge. And, although this residue represents an average of 1% to 2% of the total volume of treated sewage, its management is quite complex and demands high costs. In addition, the destination of this sludge that is generated in the ETEs is a major environmental problem for companies destined to treat it (PETROZA, 2011).

One of the sustainable and environmentally advantageous alternatives for the disposal of sewage sludge is the anaerobic biological degradation of organic matter; In this process, methane, ammonia, carbon dioxide, carbon monoxide, sulfides and other substances are produced. Biogas is a mixture of these substances formed in anaerobic digestion, with methane as the main gas, due to its high heat capacity. The amount of each element in the biogas depends on the operating conditions of the ETE and the physicochemical characteristics of the sludge, such as retention time, temperature, pH, carbon-nitrogen-phosphorus ratio (BILOTTA; ROSS, 2016). In addition to energy production, the by-product of biological degradation can be used as fertilizers in agriculture, thus providing a correct destination for this residue. To meet energy demand while protecting the environment, anaerobic digesters are becoming a popular way to produce biogas from liquid and solid waste (BERHE et al., 2017; LEMMA; GETACHEW, 2020).

Thus, the present work evaluates the potential for the use of urban sludge from a sewage treatment plant in Bagé in the southern region of Rio Grande do Sul (RS) in Brazil for the production of biogas, proposing an energy and sustainable alternative. for the destination of this residue.

METHODOLOGY

The experiment was carried out at the Federal University of Pampa (UNIPAMPA), Campus Bagé - RS. The climate is classified as Cfa according to Köppen and Geiger (DUBREUIL et al., 2018). In Bagé/RS the average annual temperature is 17.6 °C, and in the months of the experiment it was between 12 °C and 15 °C.

The anaerobic biodigestion system was installed in the Biofuels Laboratory. The physical-chemical analyzes of the sanitary sludge were carried out in the laboratories of the Bagé campus. In order to analyze the energy generation potential of the raw material, physical-chemical analyzes were carried out, before biological degradation; and, the quantification of the total volume of biogas produced during 25 days of experiment.

The methodology to evaluate the amount of biogas generated was developed by Author herself at the Biofuels Laboratory, this consisted of connecting a bioreactor with a capacity of 2 L to a software for data collection, through temperature and pressure measurement sensors; and, to a biogas metering system.

The work began with the collection of raw material (sanitary sludge) at the ETE located in the city of Bagé (RS/Brazil), where it was placed in plastic bags with the aid of a collection tool, as shown in Figure 1.

The sludge was characterized from the analysis of pH, electrical conductivity (EC), total solids (ST), fixed solids (SF), volatile solids (SV), chemical oxygen demand (COD) and biological oxygen demand (DBO), based on the methodology exposed by APHA (2005), as recommended by CONAMA Resolution 375/06. The analyzes performed and standards used for characterization are described in Table 1.

After the characterization of the raw material (sewage sludge), biomass used, the sanitary sludge was conditioned to the bioreactor, which allowed the constant monitoring of the system, automated data extraction and collection of the gas produced.

The experiment used a biodigester connected to a Bernoulli base, acting on the principle of water column displacement, normalized as a function of pressure and temperature, making it possible to collect daily and quantify the volume of gas produced, as shown in Figure 2 (the) and (b).

The supply system took place in batch, that is, 1200 mL of sewage sludge, called biomass, was placed in the biodigester only at the beginning of the experiment. Therefore, the sludge collected from the ETE was inspected in order to maintain a pasty pattern in its viscosity.

The experiment containing sewage sludge (pasty) was maintained at an average internal control temperature of (35.92 ± 3.95) °C during the observed period; thus, a mesophilic digestion. A daily agitation of 260 rpm was performed in the bioreactor, both this rotation and the internal temperature were

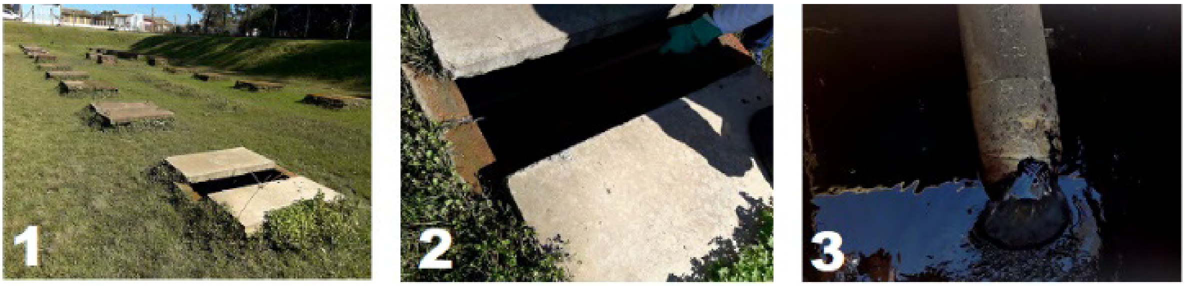


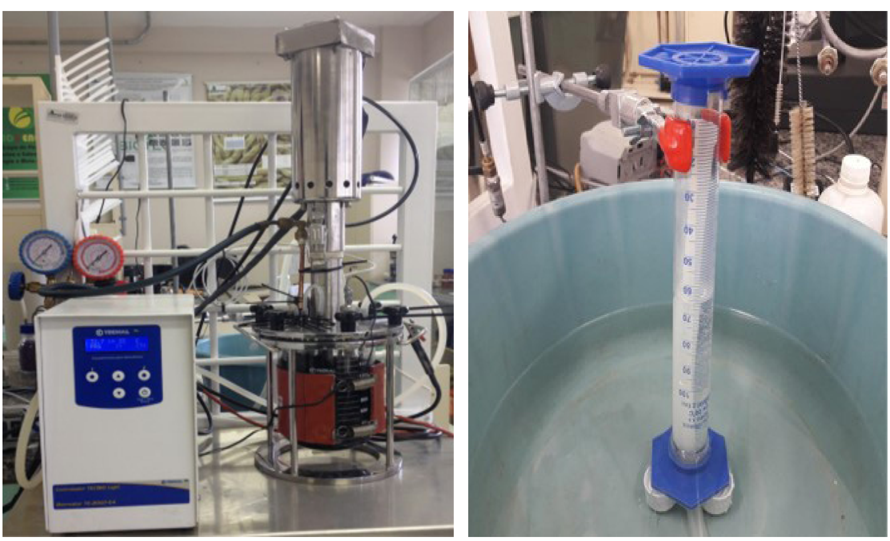
Figura 1. ETE Vila Gaúcha (1), Sludge collection, outside (2), Sludge collection, inner part (3).

Source: Author.

Description	Rule
pH	Instrument method (Metrom pH meter 827)
Electric conductivity	instrument method (Hanna HI meter 9835)
Total solids	Gravimetric Method - ABNT NBR 10664:1989
Fixed Solids	
volatile solids	
Chemical Oxygen Demand	ABNT NBR 10357:1988
Biochemical oxygen demand	instrument method (DBO Aqualytic AL606 System)

Table 1. Analyzes and standards followed.

Source: Author.



(a) (b)

Figure 2. (a) Biodigester; (b) Bernoulli basis.

Source: Author.

measured by means of a controller coupled to the bioreactor.

In addition, for process monitoring, greater precision in the collection and analysis of data during the experiment, pressure and temperature sensors were connected to the bioreactor, through which the data were sent to the Sitrad Pro software from Full Gauge Controls (Figure 3) and the pH measurement was carried out. This way, it was possible to store, configure, evaluate and link to an Excel spreadsheet, continuously, internal and external temperature, pressure and time data.

Finally, this continuous monitoring allowed analyzing the behavior of the data during the anaerobic digestion process.

RESULTS AND DISCUSSIONS

Table 2 presents the analysis of sewage sludge, with measurements being carried out in triplicate.

When choosing the type of treatment to be used, according to the characteristics of the effluent, the biodegradability factor must be considered, which is the capacity of the residue to decompose biologically. Biological systems sizing are not performed with low biodegradability, so that the removal of organic load can be optimized, aiming to reduce the concentration of BOD at the exit of the biological treatment (CLAAS; MAIA, 1994 apud CUNHA, 2019, p. 54 and BRAGA et al., 2012, p. 38). According to Claas and Maia (1994) apud Cunha (2019) and Braga et al. (2012), the biodegradability factor can

Figure 3. Sitrad Pro program interface.

Source: Author.

Analysis	Results
pH	7,37 ± 0,03
Electric conductivity	1411 ± 16,10 µS/cm
Total of solid	45,12 % ± 2,45
Fixed solid	18,02 % ± 1,72
Volatile solids	26,49 % ± 0,99
Chemical Oxygen Demand	3,03E+03 mg/L
Biochemical oxygen demand	2640 mg/L

Table 2. Analysis of sewage sludge.

Source: Author.

be verified through the calculation obtained through Equation 1.

$$f_b = DBO_5\ 0{,}65 \times DQO \qquad (1)$$

Where:

f_b = factor of biodegradability (varies from 0 to 1)

DBO_5 = biochemical demand of oxygen in 5 days

DQO = chemical demand of oxygen

The constant 0.65 is adopted for primary effluents. According to the biodegradability factor (f_b), the lower the BOD/COD ratio, that is, closer to zero, the lower the biodegradability of this effluent and, consequently, the greater the impact on the environment. In addition, BOD also evaluates the biological treatability of an effluent, the higher the BOD value, the greater the biological lability of the organic compounds present in a given effluent. On the other hand, the recalcitrance of this same organic load can be evaluated by the COD.

Thus, for the same effluent, the COD/BOD ratio expresses a lot about which type of oxidation will be effective in the degradation of the organic load present. For a given effluent, if the COD/BOD ratio < 2.5, it is easily biodegradable. If the ratio $5.0 <$ COD/BOD ≥ 2.5 this effluent will require care in choosing the biological process in order to have a desirable removal of organic load, and if COD/BOD > 5, then the biological process has little chance successful, and chemical oxidation appears as an alternative process (JARDIM and CANELA, 2004 apud BRAGA et al., 2012, p. 38).

So, according to Table 2, there is a biodegradability factor around 0.57, which is an intermediate value between 0 and 1, while the treatability ratio was around $1.14 < 2.5$, demonstrating the ability of the residue to decompose biologically, allowing the removal of the organic load with a consequent reduction in the concentration of BOD, that is, the sludge, the biomass used in the experiment, is conducive to the development of methanogenic bacteria, as it has a favorable amount of organic material anaerobic digestion.

Petersen et al. (2003) emphasizes that these organic residues, when properly managed and recycled, cease to be pollutants and become precious inputs for sustainable agricultural production, nourishing plants with sources of nutrients and organic matter, increasing production. On the other hand, when there is direct disposal without any type of treatment in agricultural soil, it contaminates underground water, also flowing into water bodies, where there is low dissolved oxygen in the water, making it impossible to maintain life and contaminating the environment. Another relevant factor is the contamination of soil and water by harmful organic compounds and pathogens (CONTIN et al., 2012).

Therefore, the proposal to use sludge as an energy alternative, in addition to being environmentally correct, sustainable, has high added value, as it involves energy generation, that is, the production of methane, a fuel gas with a high calorific content.

CONAMA Resolution 375/06 does not present reference values for EC in sewage sludge. According to Matos et al. (2017), electrical conductivity values close to 0.6 dS/m do not compromise the quality of the biofertilizer produced with regard to safety regarding its application in the soil related to salinity. And, according to Almeida (2010), the usual interval in irrigation water in terms of electrical conductivity varies from 0 to 3 dS/m. The values observed for electrical conductivity in this work did not vary significantly before and after anaerobic digestion, with an average of around 1.14 dS/m. So, within the range of Almeida (2010), but well above that established by Matos et al. (2017); however, Silva et al. (2012) says that high EC values in the digested substrate can lead to an increase in salinity, compromising its application in conjunction with the irrigation system; however, if used in a controlled way as a biofertilizer, there are no negative effects.

Other studies according to Matos et al. (2017) performed by Medeiros et al. (2011), Nunes et al. (2009) and Mesquita et al. (2015) found values above 3 dS/cm for EC, that is, above the limit of Almeida (2010), Matos et al. (2017) and those found in this work. Thus, evidencing the quality and possible use of the digested substrate in this study as a biofertilizer; thus not presenting a risk to the soil and the plant in terms of salinity.

Figure 4 shows the biogas production of the experiment during the observed time. The total cumulative production of biogas during 25 days of retention was approximately 2000 mL. It is observed that the highest production was in the first week, reaching the peak of digestion in the 4th. day, representing 51.3% of the total production, demonstrating the potential for oxidation of organic matter; in the next weeks production continued, but less expressively, between 20 mL and 100 mL so far.

In the mesophilic system, it can be mentioned as benefits the greater stability of the system, which tends to suffer less from acidification, since its reactions are slower, it is possible to adjust the system, as well as the sludge that presents a better decontamination index (APPELS et al. al., 2008).

According to Hobbs et al. (2018) the pH is a parameter for the evaluation of the activities that are taking place inside the reactor and with it it is possible to observe the activities of the enzymes, knowing that it can inactivate the anaerobic activity if the values are not within the ideal ranges, knowing that methanogenic bacteria are more sensitive to change. The microorganisms responsible for methane production proliferate in a narrower range than the anaerobic digestion itself, which is 6.6 to 7.6 (PARRA-OROBIO et al., 2018).

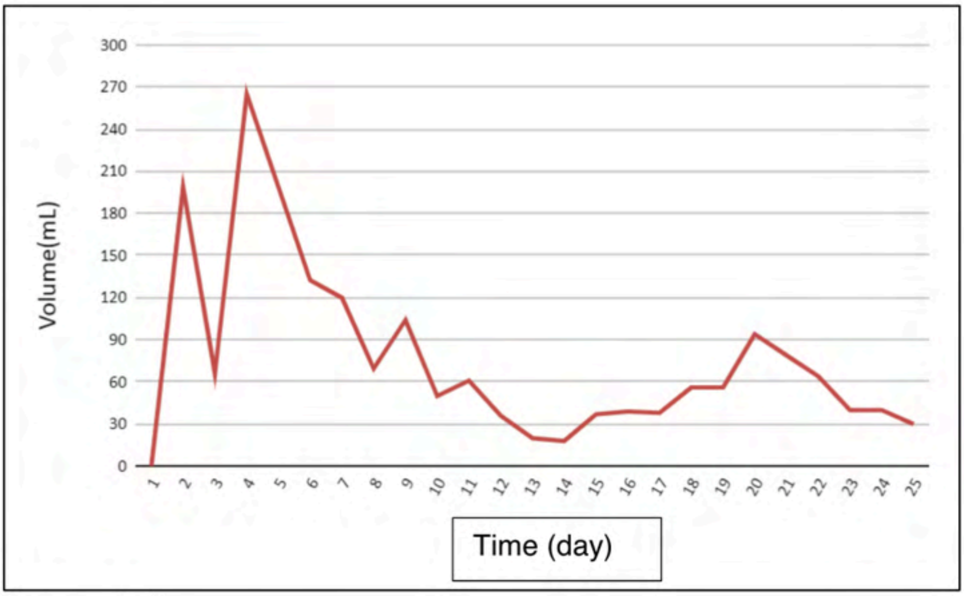


Figure 4. Daily volumetric production (mL) of Biogas.

Source: Author.

And, according to Latif et al. (2017) in their study verified the methane production between different pH values and found that the production tends to be higher when it is in a range close to 7.0.

Thus, as the experiment was carried out at an average temperature of 35.92 °C, that is, in a mesophilic medium; the stability of the system is observed and with the average pH around 7.4, it indicates favorable conditions for the production of biogas, not inhibiting the first and following phases of anaerobic digestion. In view of this, it is evaluated that there were good conditions in this study of biogas formation (Figure 4); and, consequently, methane, due to the pH being within the range favorable to the microorganisms responsible for the anaerobic digestion process (QUADROS, 2010; PARRA-OROBIO et al., 2018).

Furthermore, a small increase in pH values was observed at the end of the anaerobic digestion process, tending to alkalinization, although there was no significant difference between the average pH values of the initial and final biomass of the process. The increase in pH observed in the anaerobic digestion process is expected, since the acids contained in the used biomass (sludge) are transformed into gaseous products (SILVA; FAUSTINO; NOVAES, 2007). Matos et al. (2017) reaffirms that the alkalinization of the substrate resulting from the biodigestion process is an expected phenomenon, as the acids contained in the tributaries are transformed into gaseous products. Therefore, the results presented in this work demonstrate that the values are in the recommended range for use as biofertilizers, which comprises the range of 6.7 to 8.0 (KHALID et al., 2011).

Finally, it must be noted that the agitation performed was significant during the experiment; this facilitated the release of biogas, methane, during anaerobic digestion, promoting process improvement and continuous biogas production; as a result, increased substrate (sludge) retention time and temperature stability throughout the process.

CONCLUSIONS

According to Parra-orobio et al. (2018), theoretically, sludge from an ETE, in addition to being compatible (anaerobic and aerobic), usually has a sufficient amount of nutrients to provide bacterial growth. In this context, in view of the performance of the experiment presented in this work and analysis of the data obtained, it is concluded that the use of ETE sludge as biomass for the production of energy by biodigestion is an alternative with considerable energy potential, in addition to being an option for the proper disposal of solid waste and environmentally sustainable. From this perspective, alternative energy sources are fundamental for energy management and effluent treatment.

Decentralized technologies are seen as green solutions, particularly in rapidly urbanizing cities. Thus, further research on the energy potential through waste reuse is a current need.

For future work, we intend to verify the economic viability of both energy generation and the implementation of a biodigester in the ETE evaluated in this experiment.

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