Theoretical Study for the Use of Sewage Biogas for Electricity Production in Pernambuco

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Highlights:

· Alternative for using biomethane produced by the biodigestion of sewage treatment waste

· Self-production of energy for sanitation

· Production of biomethane to reduce greenhouse gas emissions

Keywords: Biogas; Biomethane; Electrical Energy.

INTRODUCTION

The main objective of the WWTP – Wastewater Treatment Plant, is the removal of polluting substances present in sewage, such as organic matter, nutrients (nitrogen and phosphorus), suspended solids, pathogens and other contaminants. Treatment may involve physical, chemical and biological processes. (VON SPERLING et al., 2014).

When, through the design of WWTPs, the solid organic matter contained in sewage, called sludge, is removed or reduced during the treatment process, it becomes essential to select the solid phase treatment process, capable of allowing handling and final destination , effectively meeting environmental preservation requirements, guidelines and standards. (JORDÃO et al., 2014).

Anaerobic digestion is a complex biochemical process where several groups of anaerobic and facultative microorganisms simultaneously assimilate and destroy organic matter, in the absence of oxygen, under conditions favorable to natural fermentation. Normally, this organic mass is removed from the liquid mass influent to the WWTP and processed in appropriate units called biodigesters. (JORDÃO et al., 2014).

A byproduct of this digestion process is sewage biogas, which consists mainly of methane (60-75%) and carbon dioxide (25-35%), with smaller amounts of carbon monoxide (2-4%) and trace gases like hydrogen sulfide, oxygen, nitrogen, and water vapor. This biogas can be captured and treated for use as a renewable energy source, helping to reduce greenhouse gas emissions, support urban waste management, and enhance energy security.

METHODOLOGY

The potential for production and use of biogas will be investigated in a wastewater treatment plant, called “ETE[1] Cabanga”, located in the city of Recife, Pernambuco, Brazil. UTM coordinates 609,280E and 9,106,242N (figure 1).

The Cabanga Sanitary Sewage System is made up of a 214 km long collection network, 17 pumping stations and a Treatment Station covering an area of approximately 1,718 hectares. Today, all treated effluent from ETE Cabanga is released into the Jiquiá River. The unit receives a load of sanitary sewage from approximately 500,000 inhabitants, and has an average nominal flow of 1000 L/s, digesting around 250 tons of sludge per day. The estimate was made in the digested sludge project with a solids content of 5% and density of 1.035 kg/m³, according to production data from the treatment unit itself. The calculation estimation methodology follows that described by Jordão et al., 2014.

[1] - ETE – In portuguese, 'Estação de Tratamento de Esgoto', or Wastewater Treatment Plant (WWTP).

RESULTS AND CONCLUSIONS

A simple utilization assessment is presented considering the data for "ETE Cabanga", as following:

Project Flow	1,000 L/s (86,400 m³/d)
Sludge substrate	250,000 kg/d
Solids Content	5%
Gas produced in the biodigester	1.1 m³/kg of solids destroyed
Calorific value of biogas	22,400 kJ/m
Biomethane generated	65%
Global yield of transformation into electrical energy	25%

Table 1: Electrical energy potential from biogas – 'ETE Cabanga'

Based on the data provided, the calculations for biogas production are as follows:

- Total Sludge Substrate = 0.05 * 250,000 (kg/day) = 12,500 (kg/day)

The biodigester produces between 0.8 and 1.1 m³ of biogas per kg of solids destroyed, depending on digestion conditions (Jordão et al., 2014). Assuming a production rate of 1.1 m³/kg:

- Flow rate of biogás produced = 12,500 (kg/day) x 1.1 (m³/kg) = 13,750 Nm³/day (5,018,750 Nm³/year).

The calorific value of biogas is 22,400 kJ/m³ (with 65% of this being biomethane, Jordão et al., 2014):

- Production of Electrical Energy = 13,750 (Nm³/day) * 22,400 (kJ/m³) * 0,65 = 200,200,000 kJ/day

Converting this to electrical energy, using a global efficiency of 25% and converting units from kJ/day to kWh/day:

- Production of Electrical Energy = 0.25 * 200,200,000 (kJ/day) / 3600 = 13,902.8 kWh/day (5,074,513.9 kWh/year)

The available electricity potential is:

- Electricity Potencial = 13,902.8 (kWh/day) /24h = 579.3 kW (Table 2).

The estimated cost of the Biogas Production Unit is R$ 19 million BRL. "ETE Cabanga" operates at a voltage of 69,000 V, with an average tariff of R$0.40/kWh. With the estimated annual energy generation, the potential energy savings from using the generated electricity for in-house consumption are approximately R$ 2,029,805.56 annually. The project has a calculated simple payback period of 9.36 years. This study highlights the potential of utilizing urban sewage treatment systems to enhance renewable energy production and reduce greenhouse gas emissions. By investing in clean, green energy sources, we can minimize environmental damage and promote sustainable practices.

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Figure 1: ‘ETE Cabanga’ location. Source: Google Maps (2024) and Compesa (2024).

ELECTRICAL ENERGY POTENTIAL FROM BIOGAS - ETE CABANGA					
Average Flow WWTP (L/s)	Digested Sludge Flow (m3/day)	Biogas - Flow (Nm3/day)	BioMethane (CH4) - Flow (Nm3/day)	Gross Energy Produced (kWh/day)	Available Electricity Potential (kW)
500.00	125.00	6,875.00	4,468.750	6,951.39	289.64
750.00	187.50	10,312.50	6,703.125	10,427.08	434.46
1,000.00	250.00	13,750.00	8,937.500	13,902.78	579.28

Table 2: Electrical energy potential from biogas – ‘ETE Cabanga’