Production of Biogas at Wastewater Treatment Plant in Algeria: Case Study From W. Tissemsilt

Fatma Zohra Ferradji[1, 2], Nour El-imane Hamouche[1], Kamel Eddouaouda[2], Abdelmalek Badis[2]

[1]Department of Renewable Energies, Faculty of Technology, University of Saad Dahlab, Blida, Algeria
[2]Laboratory of Natural Products Chemistry and Biomolecules (LNSCB), Faculty of Scieces, Blida, Algeria
[*]Corresponding author; Email: ferradji_fatmazohra@univ-blida.dz

Article Info

Article history:

Received, 14/09/2023
Revised, 23/11/2023
Accepted, 05/12/2023

Keywords:

Biogas
Biomass
Renewable Energy
Treatment
Wastewater

ABSTRACT

In this present work is to study the efficacy and the evaluated of wastewater treatment process by analysis the quality of water before and after treatment by wastewater treatement plant of W.Tissemsiltin Algeria for year 2020 and to study the importance power treatment of wastewater by plant. The physico-chemical quality of the wastewater was analysed by potential hydrogen, biological oxygen demand and chemical oxygen demand and total suspended solids. On the other hand, the wastewater before treatment is very loaded with organic matter. For this purpose, we will use in the production of renewable energy. As well as to produce green energy this is biogas by wastewater treatement plant of W. Tissemsilt. The theatrical estimated global energy produced of wastewater during the year 2020 from W. Tissemsiltin Algeria is 8151655.33 kWh.

I. Introduction

In the recents years of the diminution of fossil energy and climate change, the most difficult demands to satisfy are providing electricity and fuels for transportation. So renewable energies are important solution can to be promoted to be able to replace fossil fuels in their current uses before several decades [1].

The wastewater cause pollution poses a threat to the environment. So, wastewater products by domestic in the world has expanded rapidly in recent years. However, these developments also cause an environmental problem due to the discharge of large quantities of wastewater with high biochemical oxygen demand (BOD), chemical oxygen demand (COD) and microbial pollution [2].

Hence, these wastes are now being channelized toward energy conversion. The energy drawn from a fuel that comes from biomass is referred to as “bioenergy” [1]. Organic wastes (biomass) are an important source of recoverable bioenergy is from agriculture, domestic wastewater. Hence bioenergy is associated with agriculture and with wastes from the urban sector (wastewater) give a large energy production. Wastewater is important mass of biomass [3- 6].

Biogas rich the methane (CH_4 > 50%). it is producted by anaerobic degradation (biodegestion) the organic material rich a carbon (biomass) in the absence of air. The biodegestion convert the energy contan in organic maters into biogas [8]. This biogas can be used as generating electricity and thermic energy. Today in Algeria, we must the use of methane (or biogas) producted by waste and wastewater urban. Where we give solution of many problems for exempl recycling of waste management, conserving of evironnement and energy production [7].

The wastewater and the waste activated sludge of wastewater treatment plants is rich in nutrients and organic matter. So, the essenteille objective of this study was to characterize the wastewaterin the treatment by plant of W. Tissemsiltin Algeria and to study the importance power of wastewater for production of biogas (methane).

In this sense, it is necessary to reflect of a way that allows us to recover another and clean energy, namely biomass, and in exacting the production of biogas.

In this context, we were to present the importance of renouvlable energy product by wastewater in our daily life, and then next we will focus on the evaluation of the potential energy of wastewater. We used different approaches: (1) the physical-chemical characterization of wastewater by certain parameters (TSS, pH, COD and BOD5), and (2) the ability of the treatment plant of W. Tissemsilt to product renewable energies by wastewater.

II. Research Method

II.1. Presentation of the plant of wastewater of W. Tissemsilt

The treatment plant of wastewater of W. Tissemsilt is located in the South West Algeria. We used wastewater from the sewage treatment plant in town of W. Tissemsilt. The plant located in towns of Tissemsilt and Oueld Bessem.

II.2. Physico-chemical characterization of wastewater

The physico-chemical parameters of wastewater of treated and untreated effluent were analysed by the laboratory in plant.

The principal parameters are BOD, COD and TSS analysied by using standard methods. The Standard Methods (NF EN 1899-1 -May 1998, classification index: T90-103-1 ICS 13.060) for BOD and for COD the method to be used follows the European standard: DIN 38409-H41 ISO6060-1989. The TSS, we measured by the method cite in Rodier [9].

For pH, we used the multiparameter and were tested the treated and untreated of effluent of wastewater.

II.3. Biogas production and simulation of electricity production

Hulshoff Pol presented important on the valuer of COD in the anaerobic degradation process. According to the author, the report of mater organic present in the wastewater can be orientated typ and vitess of biodegradation. According to several researchers show that the COD is the best criterion to calculate the volume biogas of wastewater given the concentration of substrate to be degraded by microorganisms.

Biogas is composed of 60–65% methane, when it produced via anaerobic degradation of organic waste (humid biomass) by process conversion biochimic.

The methane fraction is considered important calorific power of biogas apart from other hydrocarbons. However, methane production through anaerobic degradationis affected by many factors such as pH, tempertur, DCO, mater organic, volatile solid content, etc. [11].

Based on literature research, we took equations to calculate the volume of biogas and the energy produced from effluent of wastewater require by treatment plant of wastewater.

The many studies have been quantified the potentialproduction of methane production can be using the COD during the anaerobic digestion. Where one (1) Kg of COD represents 0.35 $m^3$of methane production at standard temperature and pressure [11, 12].

$$\boldsymbol{V_{Methane} = COD_{Total} * 0.35} \quad (1)$$

$$E_{Methane} = V_{Methane} * PCI_{Methane} \quad (2).$$

Where:

$V_{Methane}$: Methane volume, in(m^3).

DCO_{Total}: Chemical Oxygen Demand in (kg).

$E_{Methane}$: Energy product by methane, in(kWh)

$PCI_{Methane}$= Pouvoir calorific inferior of methane $= 9.14\ \mathrm{kWh.m^{-3}}$
Equation 3 presented by Lemos Chernicharoand it calculated the total potential, wehen this energy formed by the anaerobic conversion factor of organic carbon to methane, where the 0.14 m³ of methane formed by one m³ of wastewater at tempertur mesophile (20°C), and the calorific value of methane is 35.9 MJ.m⁻³ [13].

$$E_{Methane}=V_{Wastewater}*\ 0.14*35.9\ (MJ) = V_{Wastewater}*\ 0.14*35.9*0.28\ (3).$$

III. Results and discussions

III.1. Physico-chemical characterization of wastewater

The result physico-chemical characterization annual (TSS, pH, BOD and COD) of wastewater treated and untreated effluent shows in Table 1.
After treatment process, the treated watewater represente about 6.9 mg. L^{-1} of the TSS. It is a concentration in untreated water is 369.82 mg. L^{-1}. The TSS potentially in the water body and cause depletion of oxygen. The TSS is essential for controlling the treatment process of effluent [9].
pH control is essential considering for treatment processes and activity of microorganisms such as autotrophic nitrifying bacteria i [14]. There is a fundamental relationship between pH and carbon which plays a major role in biodegradationl wastewater treatment, hence the need to measure and control pH for best results [15]. Thus, the high or lower pH at 7 measured requires a close attention to ensure hieght biodegradation. so, production biomethane (biogas).
Low pH level may be influenced by the methanogen bacteria activity (production biomethane). The results of the analysis show that the pH ranged between 7.8 and 8.2 for wastewater before and after treatment.
Since the value of BOD5 is an index of the bacterial activity and the biodegradable organic mater content of the wastewater. The BOD5 untreated represents the value 311.41 mg. L^{-1} and 10.57 mg. L^{-1} of waste water treated.

The COD is defined by the quantity of oxygen consumed for the oxidization of inorganic materials [16]. where the COD used as an indicator for the organic removal in most studies because it can be rapidly and easily analyzed [16]. The COD proved generally as indicator of treatment wastewater performance. The COD of waste water untreated and treated effluent respectively 555.87 and 52.40 mg. L^{-1}.
So, the values of BOD5 and COD of wastewater treated by plant of W. Tissemsiltare respects environmental norms [9].
The ratio between the BOD5 and the COD is an indicator and anature of the wastewater (effluent). We can predict the technic of the treatment will use. If ratio BOD5/ COD > 0.5 (before treatment of the wastewater), it is suitable for biological pretreatment, and if BOD5/ COD < 0.2 the treatment needs physico-chemical process application.
The ratio experimental between the BOD and the COD is between 0.6 and 0.48. This value gives the effluent good biodegradability and confirms that the wastewater is of domestic origin.
On the other hand, according to Nikiéma, the biodegradability of effluents is determined by the ratio BOD5/COD which gives a value allowing the classification of water and biomasse for choose the efficaceprocidingtreatment process, de plus evaluated biogas and methane production, etc. [17].

Table 1: Physico-chemical characterization of wastewaterof W. Tissemsilt.

Parameters	Wastewater untreated	Wastewater untreated
TSS	369.82 mg. L^{-1} ± 0.95	6.76 mg. L^{-1} ± 0.15.
pH	8.19 ± 0.2	7.84 ± 0.1
BOD5	311.41mg. L^{-1} ± 2.5	10.57 mg. L^{-1} ± 0.25
COD	555.87 mg. L^{-1} ± 1.5	52.40 mg. L^{-1} ± 0.85

The correlations between the various physico-chemical parameters give an idea of the chemical origin and the potential of the wastewater studied.

Too the BOD5/COD ratio show that the wastewater studied is easily biodegradable. The value of ration BOD5/COD the wastewater before treatment equal 0.56 and higher than 0.5 (norm of nature of biodegradability). So, it is easily biodegradable and rich of organic matter.

Therefore, the significant presence of biomass, allows us which can be used in the production of renouvelabl energy by biochemical conversion means (production methane CH_4).

III.2. Methane production and Energy production:

Also, it has been reported by several authors [11, 18, 19] that wastewater biogas is of better quality than all other sources of biogas, its heat capacity is 8 $kWh.m^{-3}$ of biogas against 4.5 for landfill biogas and 6 $kWh.m^{-3}$ for bovine waste biogas.

We note a total annual for 2020 flow of wastewater is 5792490 m^3. This gave a total annual COD of 3219871.416 kg for wastewater.

So, equation 1 and 2, $V_{Methane} = COD_{Total} * 0.35 = 3219871.416*0.35 = 1\,126\,954.9956$ m^3 of Methane.

$$E_{Methane} = V_{Methane} * 9.14 = 10\,300\,368.659784 \text{ kWh.}$$

Energy recovery in wastewater of W. Tissemsilt by Equation 3 is:

$$E_{Methane} = V_{Wastewater} * 0.14*35.9 = 29113054{,}7 \text{ MJ}$$

$$E_{Methane} = V_{Wastewater} * 0.14*35.9*0.28 = 8151655{,}33 \text{ kWh}$$

Figure 1 show that 2020 total volume of wastewater treated and volume of methane estimated between January and December by plant of wastewater treatment of W. Tissemsilt. This represented important volume of methane in summer, in January and in February.

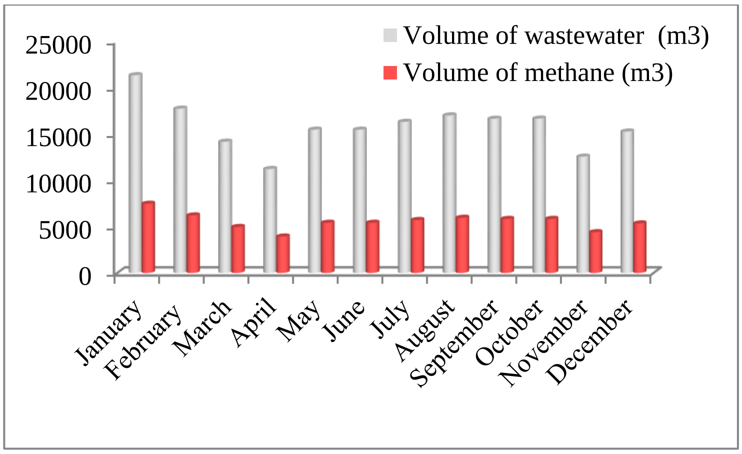

Figure 1: Volume of wastewater treated and volume of methane for year 2020.

For example, Equation 3 show the energy needs annual electricity consumption for an Algerian family of 4 people (100 m^2 house) is 350 kilowatts. Where 23290 family in town of Tissemsilt which corresponds to the quantity of biogas (methane) produced by at most 5792490 m^3 of wastewater for 2020 used.
Many researches in Algeria, for example two researchesTAHRI and KALLOUM used wastewater of slaughterhouse waste from the city of Adrar. They proved the importance power of biogas production [21].

IV. Conclusion

In Algeria, the politic of the renewable energy development strategy of adopted newly by the government has included bioenergy such as biomass.

The work presented here focused on energy recovery from wastewater, in particular wastewater in the Tissemsilt region (southwest of Algiers). Since the beginning of the 2000, the wastewater treatment plant is no longer perceived only as an industrial installation treating urban wastewater in order to minimize its impact on the natural environment, but also as a means of recovering resources: water, nutrients, energy. Therefore, we have treated a source of renewable energy such as wastewater. How to move towards the sewage treatment plant that is self-sufficient in electrical energy: Our study is specifically for the sewage treatment plant in the town of Tissemsilt (low load) for year 2020.

The results clearly show that the plant has an average energy potential for the production of biogas by effluents, which could be the subject of a self-sufficient station in electrical energy.

Acknowledgements

The authors express their gratitude and thank all personal of plant of wastewater treatment of W. Tissemsilt

References

[1] Beyene A, Yemane D, Addis T, Assayie A. A, Triest L, "Experimental evaluation of anaerobic digestion for coffee wastewater treatment and its biomethane recovery potential", *Int. J. Environ. Sci. Technol*, vol.11, pp.1881–1886, 2014, DOI 10.1007/s13762-013-0339-4.

[2] Srivastava*et a*l.,"Bioenergy Research: Biomass Waste to Energy", *Springer*, 2020.

[3] Saber M, Aziza M, Yassaa N, "An overview of sustainable bioenergy potential in Algeria", *Algeria Renewable and Sustainable Energy Reviews*, vol.72, pp. 240-245, 2017.

[4] Khalid A, Arshad M, Anjum M, Mahmood T, Dawson L, "The anaerobic digestion of solid organic waste", *Waste Manag*, vol. 31(8), pp1737–1744, 2011.

[5] Saber M, "Designing biogas units for cleaner energy production from different wastewater effluents", *Desalin Water Treat*, vol.57 (12), pp.1–7, 2016, http://dx.doi.org/ 10.1080/19443994.2015.1022002.

[6] Bilandzija N, Voca N, Jelcic B, Jurisic V, Matin A, Grubor M, Kricka T, "Evaluation of Croatian agricultural solid biomass energy potential", *Renewable and Sustainable Energy Reviews*, Vol.93, pp. 225-230, 2018.

[7] Igoud S, Souahi F, Chitour, C.E, "Sustainable Management of Sewage Sludge Conditioning and Valorization", *Springer International Publishing Switzerland*, pp.685 -693, 2016.

[8] Maamri S, Amrani M, "Biogas production from waste activated sludge using cattle dung inoculums: Effect of total solid contents and kinetics study Energy", *Procedia*, vol.50, pp.352 – 359, 2014.

[9] Rodier J,"L'analyse de l'eau", *Technique et Ingénierie*, 2009.

[10] Hulshoff Pol L.W, "Waste characteristics and factors affecting reactor performance: process factors, waste characterization and pH related toxicity", *in international course an anaerobic treatment, Wageningen Agricultural University 1HE delft. Wageningen*, pp. 17-28, 1995.

[11] Prasad *et al*.,"Industrial Methanogenesis: Biomethane Production from Organic Wastes for Energy Supplementation",*chapitre 4 , Springer Nature Singapore Pte Ltd*. R. (eds.), *Recent Developments in Microbial Technologies, Environmental and Microbial Biotechnology*, 2021, pp. 99-115, https://doi.org/10.1007/978-981-15-4439-2_4- pp 99-115.

[12] Sasidhar K.B, Umaiyakunjaram R, Yogeswari S, Latha K, Shanmugam P, "Correlation between empirical formulae based stoichiometric and biochemical methane potential of sectorial wastewater from common tannery effluent treatment plant", *Bioresource Technology Reports*, Vol. 16, 2021.

[13] Lemos Chernicharo C.A, "Biological Wastewater Treatment Series: Anaerobic Reactors", *IWA, Publishing, London* V.5, 2007.

[14] Melcer H, "Methods for wastewater characterization in activated sludge modeling", *Water Environmental Federation*, New York, 2003

[15] Zvikomborero Hoko M, Nhapi I, "Characterisation of raw sewage and performance assessment of primary settling tanks at Firle Sewage Treatment Works, Harare, Zimbabwe" ,*J. Physics and Chemistry of the Earth, Parts* ,Vol. 67–69, pp. 226-235, 2014.

[16] Kawai M, Nagao N, Kawasaki N, Imai A, Toda T, "Improvement of COD removal by controlling the substrate degradability during the anaerobic digestion of recalcitrant wastewater", *Journal of Environmental Management*,Vol.181, pp.838-846, 2016.

[17] Maktabifard M, Zaborowska E, Makinia J, "Achieving energy neutrality in wastewater treatment plants through energy savings and enhancing renewable energy production", *Journal Rev. Environ. Sci. Bio/Technology*, pp1.17, 2018, https://doi.org/10.1007/s11157-018-9478-x

[18] Bennouna M, Kehal S, "Production de Méthane à Partir des Boues des Stations d'Epuration des Eaux Usées : Potentiel Existant en Algérie. In Production et Valorisation – Biomasse", *Centre de Développement des Energies Renouvelables, Bouzaréah, Alger*, 2001

[19] Jacob S, Upadrasta L, Banerjee R, "Bottlenecks in Biomethane Production from Agro-IndustrialWastes Through Anaerobic Digestion", *Springer Nature India PrivateLimited*, pp.75-104, 2020.

[20] Sheik S.K, Panneerselvam A, Ambikapathy V, Sathya R, Vinothkanna A, "An investigation of sewage water treatment plant and its physico-chemical analysis", *Journal Biocatalysis and Agricultural Biotechnology*, Vol. 35, 2021, https://doi.org/10.1016/j.bcab.2021.102061.

[21] Tahri A, Kalloum S, "Energy Recovery by Production of Electricity from Anaerobic Digestion of Organic Waste in the Saharan Environment ", A*lgerian Journal of Renewable Energy and Sustainable Development*, Vol 3, (1), 2021, DOI: 10.46657/ajresd.2021.3.1.7