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Study of biogas production from lagooning sludge by anaerobic digestion

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ABSTRACT — The aim of this study is to produce biogas by anaerobic digestion from lagooning sludge of Adrar city. The sludge used was characterized and the results show that this sludge is rich in organic matter which makes it more suitable for anaerobic digestion. In this study, the evolution of some parameters such as pH, total alkalinity (TA) and the volume of produced biogas, was followed for 55 days. The tests were carried out in a batch digester with a dilution rate of 5% in dry matter (DM) under a mesophilic condition (37 °C). The results obtained show that lagooning sludge with a dilution rate of 5% in DM gave a volume of 961.5 ml in biogas. The results of this study suggest that the lagooning sludge of Adrar city can be advantageously used as a low cost source for biogas production.

***Keywords**: Biogas, anaerobic digestion, lagooning sludge.*

I. Introduction

Among the different renewable energy sources used today, is that of biomass, which is in the form of solid or liquid products that can replace fossil fuels (natural gas, coal and oil) [1]. It is constituted by carbohydrates, proteins, and lipids that we can find in the organic matter available in an ecosystem [2].

Sewage sludge from treatment plants is industrial or domestic waste water treatment residues. Due to the increasing number of people connected to treatment channels and the increasingly strict regulation, the production of sewage sludge is only increasing over time [3].

Different sectors exist for the elimination of these sludges, but the choice must be based on the cost of installation, the origin of sludge, the resulting added value of the product and the impact that the chosen sector may have on the environment. Sewage sludge recovery processes involve renewable, inexhaustible and free energy. The production of biogas from sewage sludge offers an opportunity for the sustainable management of sewage sludge and energy as it is considered an adequate and promising method for the energy recovery of sewage sludge [4].

Biogas production is a widespread technique in the world. Clean energy must be an energy that protects the environment. So we mean that biogas is a clean energy when its use must be positive compared to a fossil gas with respect to greenhouse gas emissions or air pollution [5].

Anaerobic digestion or methanation is a natural biological process of carbonaceous organic matter transformation into biogas. This decomposition of organic matter is carried out in the absence of air and light in enclosures confined in liquid or dry media called 'digesters', within which fermentation reactions are optimized and controlled [6].

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The classical process of anaerobic digestion takes place in four main stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis [7, 8].

The biogas produced by anaerobic digestion is predominantly composed of methane (CH_4), carbon dioxide (CO_2) and water (H_2O). Traces of nitrogen (N_2), hydrogen sulphide (H_2S) and ammonia (NH_3) are also found [10].

The objective of this study is the production of biogas by anaerobic digestion from lagooning sludge of Adrar city. The experimental study consists in calculating the volume of the biogas, for this we launched a digester with a 5% dilution ratio in dry matter (DM). During this study, we also monitored the evolution of the pH, total alkalinity (TA) as well as the volume of the biogas produced as a function of the anaerobic digestion time.

II. Materials and Methods

II.1. Substrate

The substrate used in this study for feeding the digesters consists mainly of sludge, from the lagoon station in the town of Adrar. In order to optimize the biogas production kinetics and to reduce the residence time, the substrate was subjected to mechanical pretreatment (grinding and sieving) [11].

II.1. Analytical methods

Some physicochemical parameters of the substrate used were determined as pH, dry matter content (DM), organic matter content (OM). The pH is measured directly using a pH meter (HANNA HI 3220). Measurement of dry matter (DM) should be determined as quickly as possible, to limit losses by evaporation. The AFNOR standard method NF U 44-171 consists of a sampling of a maximum amount of sample, preferably a mass of 100 ± 0.1 g, by placing in an oven at 105 ± 2 °C. for 24 h until a constant weight is obtained [12].

The organic matter content (OM) was determined by the standard method [13]. This method consists of calcining a sample of used substrate in muffle furnace (Nabertherrm) at 550 °C for 12-18 h. The tests were carried out in batch-type digester. This digester is laboratory model, made of glass, very simple, allowing to ensure the anaerobic culture medium. This digester are equipped with two holes, the first for sampling liquid samples using a syringe and the other for gas exhaust to measure the volume of biogas produced. The useful volume of the digesters is 2.5 L. The simplified diagram of used device is illustrated in Fig. 1. The digester used is fed with the diluted sludge in order to obtain a concentration of the order of 5 DM %. The reactor is maintained in a mesophilic condition (37 °C.) in a heated and thermostatically controlled water bath.

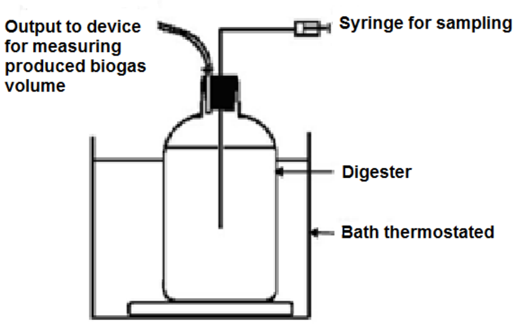

Fig. 1 Simplified diagram of used device [6].

The reactor is shaken manually by shaking them one to two times a day. The main physicochemical characteristics of used substrate in this study were determined. During the period of digestion, we have followed all the parameters that can inform us about the functioning of the digester such as pH, total alkanility (TA) and the produced biogas volume.

The follow-up of the total alkalinity (TA) requires the measurement of pH value, which is carried out using a pH meter (HANNA HI3220) equipped with a combined electrode. The pH is adjusted by adding sulfuric acid (H_2SO_4, 0.1N) and sodium hydroxide (NaOH, 0.1N). The volume of produced biogas is measured by hydraulic system means, in which the produced biogas at the outlet of the digester passes into a graduated test tube immersed in a liquid, which will displace the level of the liquid contained in the test piece and thus indicates the volume of produced gas [12].

III. Results and discussions

III.1. Characterization of used substrate

Some physico-chemical properties of the used substrate are shown in Table I.

Table 1. Physico-chemical properties of used substrate [11].

Physico-chemical Properties	*Value*
pH	6,34
Humidity (%)	84,87
Dry matter (%)	15,13
Organic matter (%)	90,08
Minerals (%)	9,92

III.2. Evolution of operating parameters

a) Evolution of pH:

The pH is more important for the methanization process, it gives an idea about the acidity or the alkalinity of the medium, in addition, the microorganisms can only develop in a specific pH range [11, 14]. Fig. 2 shows the pH evolution curve.

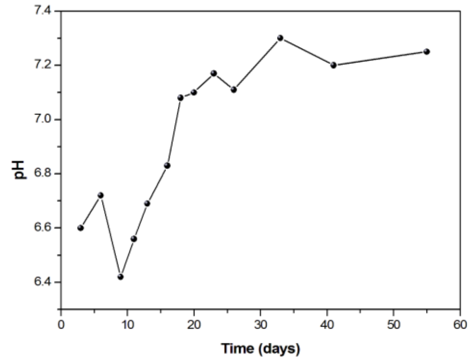

Fig. 2 pH evolution curve.

At the beginning of digestion, there is a drop in ph to acid values (from 6.72 to 6.42) this is observed from the 1st to 9th day, so it is the middle acidification. This can be explained by the decomposition of organic matter and the production of volatile fatty acids (VFA) and their accumulations in the medium. Then, it can be observed that the ph values began to increase gradually (from 6.42 up to 7.08) this is observed from the 11th day and continues until the 23rd day it is the alkalinity that begins to settle in the culture medium. This phenomenon can be explained by the beginning of consumption of volatile fatty acids (VFA) by other bacteria and by the increase in the alkalinity of the culture medium [6].

Finally, it can be observed that there is a stabilization of the pH values (between 7.08 and 7.3) this is observed from the 26th day to the 55th day. This stabilization can be explained by the stability of the process in general, that is to say that there is simultaneously a production of the VFA on the one hand and their consumption on the other hand.

b) *Evolution of total alkalinity (TA):*

This alkalinity allows the pH to remain around neutrality despite the presence of acids [11, 14]. Fig. 3 illustrates the evolution of total alkalinity (TA) for the various digesters.

At the beginning of the anaerobic digestion, low values of total alkalinity (> 1.2 g/L) were noted, which means that the pH of the medium undergoes undesirable variations towards the acid values due to the rapid production of the acids Volatile fatty acids, the same applies to the pH values at the beginning of methanization. After that, the values of the complete total alkalinity were increased to a maximum value of 2.2 g/L. These important values of the TA indicate good functioning of the digester and maintaining pH above 7.

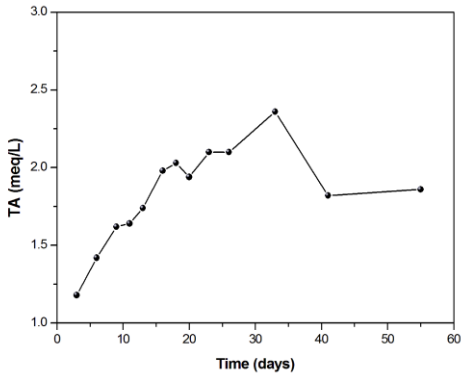

Fig. 3 Total alkanility (TA) evolution curve.

c) Development of produced biogas

Fig. 4 shows the evolution of the volume of biogas during 55th days of anaerobic digestion. Very low production of biogas has been observed at the beginning of anaerobic digestion, it occurs from the 1st to the 13th day, estimated at 20 ml. This low production, even in the presence of a high concentration of volatile fatty acids in the medium, may under inform the non-beginning of the methanogenesis. From the 16th to the 23rd day, we note that there is a start of significant production of biogas in variable proportions, so it is the transformation of volatile fatty acids into methane and carbon dioxide. From 27^{th} until the 55^{th} day, we can note a low biogas production identical to that observed in the first phase. This phenomenon can be explained by the depletion of volatile fatty acids in the medium and thus the depletion of the substrate in general and the imbalance of the culture medium.

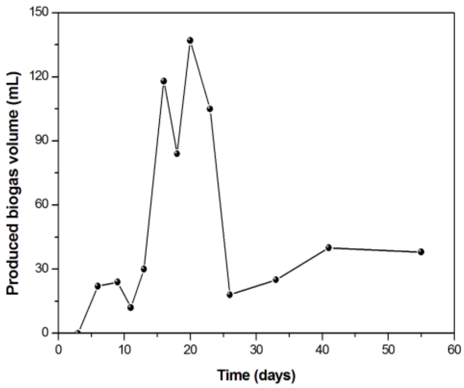

Fig. 4 Curve of produced biogas volume evolution.

III.3. Total volume of produced biogas

Biogas production is the main objective of the anaerobic digestion, but the quality of this biogas also plays a very important role in the subsequent recovery of this biogas. The total volume of biogas produced is 961.5 ml.

IV. Conclusions

The aim of this study is the recovery energy and biogas production from lagooning sludge of Adrar city by anaerobic digestion. The results obtained show that the maximum volume of produced biogas is 961.5 ml for 55 days by a digester with 5% in dry matter. This study is an opportunity to upgrade sludge from a lagoon station by biogas production that can be used for domestic purposes and the results of this work show that this waste can be advantageously used as a low cost source for biogas production.

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