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Methanation of organic sludge from wastewater treatment plant and biogas production

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***Abstract*—The aim of our research work is the realization of anaerobic digestion by using the organic sludge of the urban wastewater treatment plant as a substrate.**
The biodegradable nature of the wastewater sludge allowed flammable biogas to be recovered after 24 hours of digestion and biogas production reached almost 5 liters for an initial concentration of 70 g / L
The rate of reduction in COD (chemical demand in oxygen) of the sludge was estimated at 87.3% .
For the good functioning of the digestion one must control the following parameters: type of substrate, pH of the medium, the organic load expressed in COD or BOD, the temperature. Once the operation is conducted we must follow the VFA / CAT (Volatile Fatty Acid/ Complete Alcalimetric Title) parameter which show if the process will continue or will be stopped. And finally, the C / N ratio gives us an indication if there is more carbon in the medium, this will indicate that the residence time is going to be very long in the reactor and if nitrogen is abundant in the organic matter it is will produce in the digestion medium ammonia which inhibits the degradation process and stops it in the acidogenic phase and the production of biogas.
The use of anaerobic digestion can be an interesting solution to dispose of energy from organic waste, while effectively participating in the remediation of these effluents. This renewable energy, inexpensive, non-polluting can replace conventional and non-renewable fossil fuels.

Keywords*— Biogas, anaerobic digestion, organic sludge, renewable energy, fossil fuels.

I. INTRODUCTION

The new sources of energy will have to have as main characteristic a near zero balance in CO_2 [1]. Among them, the pathways of bioenergy production from waste are particularly interesting.

A first, relatively old pathway is related to the production of methane by anaerobic digestion. A second possibility, much more recent and innovative, is the production of hydrogen by microbial ecosystems. The use of renewable energies such as biogas has become a necessity and is an integral part of the current strategy to mobilize all available resources.

Methanation or anaerobic digestion is a series of operations of biological degradation of organic matter by a microbial flora that occur in the absence of oxygen.

Products resulting from degradation can be classified into two categories, biogas and digestate.

Biogas is a mixture of methane (CH_4), carbon dioxide (CO_2) and water vapor (H_2O).

Methane is the main constituent of natural gas. The digestate is the liquid residue containing the non-degraded materials.

The process of anaerobic digestion is carried out in four stages [3]. These are the steps (**FIGURE 1.**):

Hydrolysis: macromolecules are gradually cut into soluble monomers by extracellular enzymes(cellulases, hydrolases, amylases, ...) ;

Acidogenesis: the monomers resulting from the hydrolysis step are converted into organic acids and alcohols with a release of ammonium (NH_4^+), carbon dioxide (CO2) and hydrogen (H2);

Acetogenesis: the products of acidogenesis are converted into acetic acid (CH_3COOH) but also into CO_2 and H_2 , the main substrates of methanogenesis .

Methanogenesis: last stage during which methane is formed in two main and distinct ways, that of acetate and that of the H_2 / CO_2 mixture.

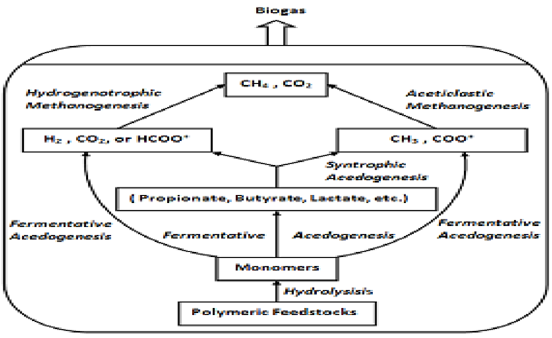

FIGURE 1. Anaerobic digestion steps [4].

II. MATERIALS AND METHODS

Our study includes laboratory experiments on the anaerobic digestion of organic waste. For this, a specific material for handling is necessary to know :

- A digester of 1 liter equipped with a sampling ;
- A water bath to set the temperature at 37 ° C.
- A system for measuring the volume of gas produced (measurement of volume by the method of displaced liquids) [5].

The parameters monitored are: pH measurement, temperature measurement, volume of biogas produced and chemical oxygen demand (COD) .

The anaerobiosis must be controlled very rigorously in the digester before the launch of the waste digestion reaction. The experiments are conducted with a residence time of 20 to 30 days.

A. SAMPLING

Substrate of choice : Sludge of wastewater treatment plant. A wastewater treatment plant is a set of facilities and processes where wastewater is directed to eliminate the various pollutants. We will be particularly interested in a natural lagoon type, used as a sludge producer in our study. It is the most used biological treatment for medium-sized stations (more than 2000 equivalent inhabitants). The sludge is taken from the settling pond n°3. The physicochemical characteristics are given s on average of the samples taken during one year (see **TABLE 1.**), the samples were weighed and then dried at 110 ° C for the total dry matter and at 550 ° C for the volatile material. Total nitrogen is determined by measurement of Kjeldhal nitrogen and measurement of mineral nitrogen as nitrite and nitrate. Phosphorus is measured spectrophotometrically by measuring orthophosphates.

TABLE I
COMPOSITION OF THE WASTEWATER SLUDGE

Parameters	Composition
DCO (mg /l)	1500
pH	8
DBO (mg/l)	750

The evolution of the organic load during digestion, expressed as the volume of biogas produced, is carried on the Figure 2. This clearly shows the relationship between the volume of biogas formed and the organic matter digested in anaerobic environment. Metanogenetic bacteria transform organic dry matter into biogas.

B. ANAEROBIC DIGESTION OF SLUDGE

A sample of sludge was taken from the third basin of the treatment plant by natural lagoon and this to carry out an anaerobic digestion of this waste.
This sample is placed in the digester according to the following operating conditions:
Concentration of the sludge substrate: 100 g / l
Initial pH: 7.76
COD : 760 mg / L
The evolution of the volume of biogas formed and the degradation of the sludge organic load of the wastewater treatment plant are shown in Table 1 . W e notice a biogas production from the 2 nd day of anaerobic digestion and this is very necessarily the biodegradable nature that sludge. This is proved by the volume of biogas produced during each experiment (see **FIGURE 2.**).
Anaerobic digestion degrades organic matter in sludge and produces flammable biogas efficiently and very quickly.
Thus, the more the sludge is loaded with organic matter, the more the methanation will be effective.

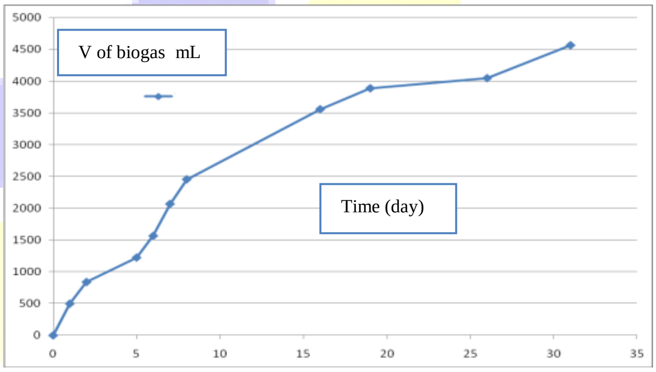

FIGURE 2. Evolution of biogas production

In general, the volume of biogas increases with the residence time and the concentration of the substrate. Only high concentrations require a very long residence time for digestion.

Time (day)	T (°C)	COD (mg/l) Sludge
0	35	543.54
1	37	487.6
2	37	458.8
3	37	402.3
5	34	385.8
10	34	321.4
13	37	267.7
16	36	202.3
19	37	178
21	37	132.55
25	36	111.50
28	34	103
30	34	86.9
32	37	80.5
35	37	74
40	37	73
50	36	70
60	37	69
Decrease Rate		87.3 %

Factors affecting the quality and quantity of biogas are: pH, temperature, substrate solids content, carbon / nitrogen ratio, residence time in the digester, homogeneity and particle size of the substrate.
The batch digester has the advantage of being simple.
This system has the advantage of treating solid waste, the production of biogas is not regular, it is slow then it accelerates and reaches a maximum rate in the middle of the degradation process and falls at the end of the cycle when only the elements with difficulty digestibles remain in the digester.
Sludge from sewage plants gives a very good output in biogas production. This is inevitably due to the biodegradability of this sludge.
The graph with the evolution of the chemical oxygen demand (COD) based on stays of time gives a decrease in organic biodegradable load based on the digestion of residence times as shown in **FIGURE 3.**

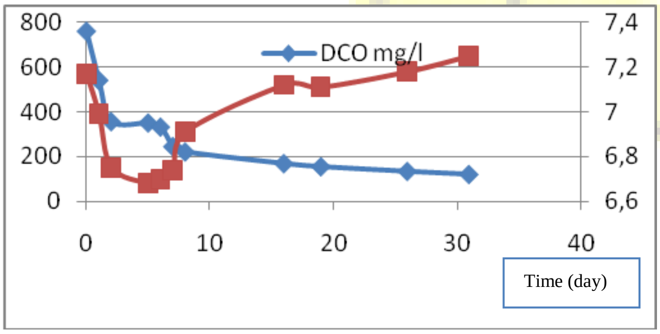

FIGURE 3. Evolution of Organic matter and pH during digestion

III. RESULTS AND DISCUSSION

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Anaerobic digestion tests carried out in the laboratory using a one-liter reactor have allowed the production of renewable and green energy with a CH_4 % greater than 70% [8]. This has been confirmed by the flammability of the biogas produced [9]. The digestion substrate is biodegradable and can be used for renewable and inexhaustible energy. TABLE. II gives the volume of biogas formed following the digestion of sludge waste from the treatment plant.

TABLE. II

Volume of biogas production

Time (day)	V of Sludge (ml)
0	0
5	112
10	315
20	567
30	897
35	1125
40	1220
45	1237
50	1258
55	1267
60	1267

The methanogenesis phase is the final and specific step of methane fermentation. It leads to the reduction of carbon to methane and is carried out by highly specialized microorganisms.
During this phase, the chemical oxygen demand decreases in order to produce biogas, the more the substrate is concentrated in biodegradable organic matter the more it produces biogas ; this was confirmed by the digest substrate during our study (see TABLE III.).
TABLE III. Amount of organic matter (COD) during anaerobic digestion
Sludge from sewage plants gives a good yield through anaerobic digestion [9,10] (see **FIGURE 4.).**

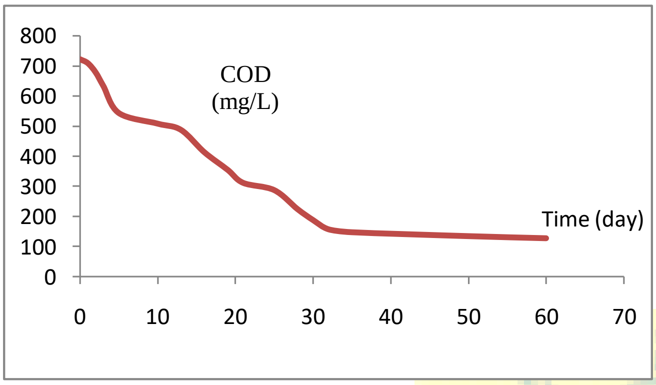

FIGURE 4. Evolution of organic matter during digestion

IV. Conclusions

Anaerobic digestion is an effective, easy-to-use and economical way of treating organic waste. This process makes it possible to reduce the use of fossil fuels, especially in regions where the connection of natural gas and electricity would be very expensive, as well as the production of valuable energy that is biogas. Also, this process contributes to the depollution of the organic charges. Not to mention another advantage that is the production of a digestate that can be valued as an organic amendment of soils low in organic matter.

Organic waste, especially when it has a high water content, is not intended to be dumped or even incinerated. This requires a strong limitation of landfilling of fermentable waste. Achievement of this objective requires significant efforts in three directions: the reduction of waste production, the increase in the recycled portion and the development of composting, whether or not anaerobic digestion is carried out.

The important treatment of this organic matter is the energy recovery of waste by the anaerobic digestion process and represents a very interesting alternative. It is a "renewable" energy source as long as we produce waste and the cost is low.

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