Experimental Factors Affecting the Production of Biogas during Anaerobic Digestion of Biodegradable Waste

Nabila Laskri, Oualid Hamdaoui, and Nawel Nedjah

***Abstract*—Biogas production by anaerobic digestion from biodegradable organic waste is increasingly seen as a viable renewable energy source. However, the efficiency of anaerobic digestion process is limited by a number of factors affecting mainly slow hydrolysis of complex organic matter.**

Operating conditions and digester power supply are among the main factors affecting the biogas production. The operating conditions are pH and temperature. However, disturbances caused by the power supply include the composition of organic waste, the concentration of substrate digested and toxic compounds, digestion inhibitors which are mainly volatile fatty acids (AGV) and ammonia (NH_4^+).

Throughout this experimental study we tried to establish the relationship between the volume of biogas formed with the pH, temperature, AGV, and the production of NH_4^+.

***Index Terms*—Anaerobic digestion, biogas, NH_4^+, AGV.**

I. Introduction

The anaerobic digestion process involves placing the waste organic material in tanks or digesters protected from oxygen and maintaining the digester temperature between 35 ℃ and 37 ℃ [1].

The gas produced has high energy content and can be used in many applications such as: heating, cooking, power generation, lighting and as a biofuel that can be injected into the gas network of city. Also, the digestate (or fermentation residue) produced by digestion is a good fertilizer (stabilized mud rich in nitrogen and low carbon) that can be used as manure to fertilize soils poor in organic matter [2]. This is the best form of energy for environmental protection.

Though, its development doesn't receive the desirable encouragement, it is considered as an important variable part in the worldwide energy balance. It should therefore in future co-exist with traditional energy sources, especially with the problem of global warming observed in recent years (global warming) [3], [4].

The methanation or anaerobic digestion is a biochemical phenomenon rather anaerobic fermentation of organic matter under the action of microorganisms. The transformation of organic matter in gas is the work of myriad bacteria. Indeed, it appears that using the methanation may be an interesting solution to provide energy from organic waste, while contributing effectively to clean up the effluent [5], [6].

Manuscript received June 13, 2014; revised August 8, 2014.

Nabila Laskri is with Preparatory School Science and Technology (EPST) Annaba, Algeria (e-mail: laskri_n@yahoo.fr).

Oualid Hamdaoui and Nawel Nedjah are with University Badji Mokhtar/ Faculty of Engineering Sciences/ Laboratory of Environmental Engineering, Preparatory School Science and Technology (EPST), Annaba, Algeria (e-mail:{ohamdaoui, nedjah_nawel}@yahoo.fr).

II. Materials and Methods

A. Materials

Experimental Predisposition

Our study consists of laboratory experiments on the process of anaerobic digestion, is available to monitor and control the factors involved during the course of the anaerobic digestion [7], [8]. For this, a specific material handling is necessary to know:

1) A digester with monitoring devices and sampling of;
2) A heating system.
3) A system for measuring the volume of gas produced.
4) Syringe to the sampling.
5) The batch type reactor, separated from each side of aluminum foil.
6) Immersion settled in the area mesophilic (35 °C).
7) Glass tube for the release of biogas.
8) Water bath.
9) Balloon to store biogas.
10) Thermometer.
11) Magnetic stirrer.

This dispositive is shown in Fig. 1.

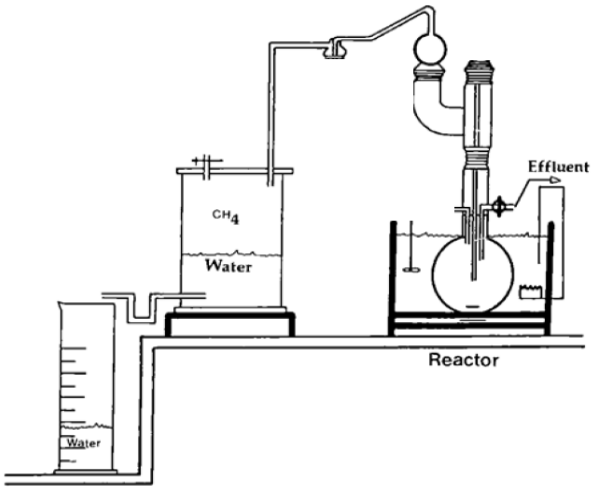

Fig. 1. Experimental device.

B. Methods

We conducted several experiments with different substrates of digestion namely:

- Sewage treatment plants for urban waste water by lagoon
- Fermentable organic matter of a dump of garbage.

The monitored parameters are: measurement of pH,

temperature, pressure in the digester and the volume of biogas produced.

III. Experimental Results and Discussion

A. Digestion of Sludge Lagoon Station

A sample of mud was removed from the wastewater treatment lagoons to proceed by an anaerobic digestion of such waste. This sample is placed in the digester by the following operating conditions:

Substrate concentration of mud: 100 g/l

Initial pH: 7,76.

Dilution rate: 90%

The following table gives the physico-chemical properties of the mud.

TABLE I: Physico-Chemical Wastewater Treatment

Physico-chemical	Upstream Station
T (°C)	18
ϰconductivity (mS / cm)	1,45
pH	7,76
BOD (mg / l)	120
COD (mg / l)	264,7

TABLE II: Anaerobic Digestion of Sewage Lagoons

Residence time (d)	pH	T (°C)	Nature of gas formed
0	7,17	36	-
1	6,99	36	Flammable
2	6,75	--	Flammable
5	6,68	--	Flammable
6	6,70	--	Flammable
7	6,74	--	Flammable
8	6,91	--	Flammable
16	7,12	--	Flammable
19	7,11	33	Flammable
26	7,18	36	Flammable
29	7,20	36	Flammable
30	7,25	36	- Flammable
31	7,25	--	Flammable

According to data from this table, the substrate is rich in organic matter and thus could easily promote anaerobic digestion. This digestion is done in a closed digester volume of 11. The result of this manipulation is given in Table II.

B. Anaerobic Digestion of Organic Matter of Fermentable Dump

8,5 million tons of waste including 1,5 million of industrial waste are discarded annually in Algeria is 0,75 kg per day per capita as the national agency of the waste "Study Day of the SEES / MS"(2003) [9], [10].There are 3,000 illegal dumps or 150 ha.

760,000 tons of wastes are likely to be recoverable. A study of DNA and from this figure:

- 1 ton of recycled steel,
- 1 ton of ore, recycled
- 1 tone of paper recycled
- 2 tons of wood
- 1 ton of plastic bottles recycled.

Organic waste, especially when they have a high water content, are not intended to be stored in landfills, or even to be incinerated. This requires a Strong and limited landfill waste fermentable [11], [12]. The samples were collected from several sites in the landfill where we have taken in each case a weight of 20 kg of mixed household waste. After sorting we weighed and selected component and each component of the sample. The characterization of samples from the dump is specified in the following Table III and illustrated on Fig. 2.

TABLE III: Characterization of Household Waste Dump

Composition (%)	Sampling Site				Moy
	1	2	3	4	
Organicmatter	63,0	55,0	72,00	57,3	61,86
Plastic	12,0	9,66	11,34	9,00	10,50
Cardboard and paper	7,66	26,0	6,33	6,33	11,58
Métaux Metals	13,0	7,66	7,33	7,00	8,75
Glass	3,60	0,68	2,33	11,3	4,50
Rags and other	0,60	1,00	0,61	9,00	2,83

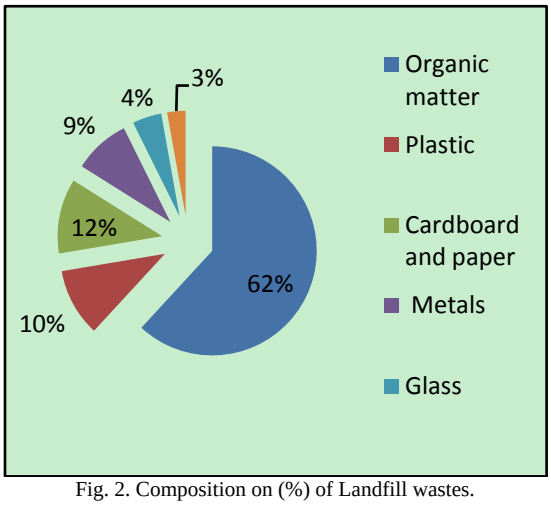

Fig. 2. Composition on (%) of Landfill wastes.

Achieving this goal requires significant efforts in three areas: reducing waste. The treatment of this important organic matter is energy recovery of waste by the anaerobic digestion process and represents a very interesting alternative [13], [14]. It is a source of "renewable" energy as we produce waste and the cost is low.

The results of anaerobic digestion of organic matter of Landfull are shown on Table VI.

TABLE VI: ANAEROBIC DIGESTION OF THE FERMENTABLE PORTION OF HOUSEHOLD WASTE

Residence time (d)	pH	T (°C)	Nature of gas formed
0	8,01	34	-
1	7,01	34	-
2	6,97	34	-
3	6,83	34	-
6	6,97	34	-
7	6,76	34	-
8	6,97	34	Flammable
9	7,08	33	Flammable
13	7,14	28	Flammable
14	7,14	28	Flammable
15	7,01	33	Flammable
16	6,95	34	Flammable
17	7,08	34	Flammable
18	7,05	34	Flammable
19	6,95	34	Flammable
20	6,94	34	Flammable

IV. DISCUSSION AND CONCLUSION

The degradation of organic matter by methanation takes place in three stages. The first phase consists of hydrolysis of the substrate in simple molecules such as fatty acids. simple sugars and alcohol. Causing a decrease in pH of the substrate up to the second phase of degradation is a transformation product from the first phase acetates. This phase is indicated by a rise in pH. The last stage is the stage production of biogas from the products of the acetogenic phase and is performed using methanogenic bacteria. Each step of the biochemical process highlights the different bacterial populations. This result is shown of Fig. 3 and Fig. 4.

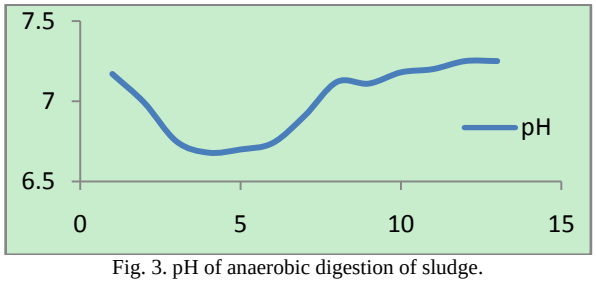

Fig. 3. pH of anaerobic digestion of sludge.

Experiments in the laboratory led to the following remarks:

- The digestion temperature is controlled in general in mesophilic digestion and varies between 33 ℃ and 37 ℃ [15], [16].
- The pH of the substrate decreases to remain constant thereafter. This drop in pH is usually produced during the acid formation. This acidic pH is due to an accumulation of volatile fatty acids in the substrate. The pH can inhibit the methanogenic phase. This remark is shown in Fig. 3 and Fig. 4.
- We obtained a specific production of flammable gas.

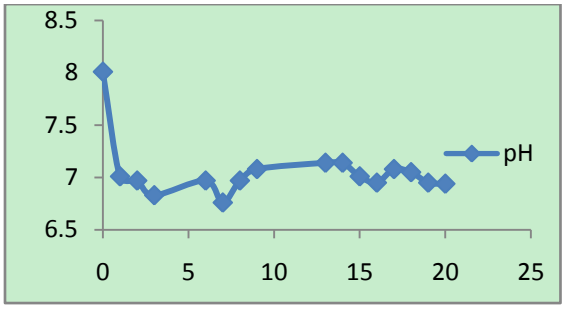

Fig. 4. pH of anaerobic digestion of organic matter from dump.

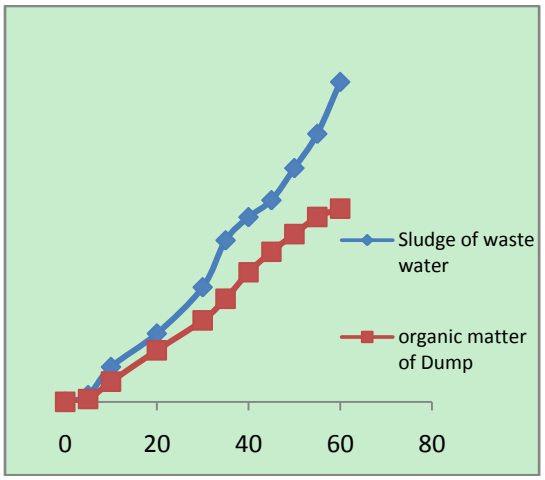

Fig. 5. The volume of biogas from the anaerobic digestion of the two substrates.

TABLE V: VOLUME OF BIOGAS FORMED FOR THE SUBSTRATES

Residence time (d)	V (ml) Sludge waste water	V (ml) Organic Matter of dump
0	0	0
5	45	19
10	233	135
20	456	344
30	765	544
35	1078	688
40	1233	865
45	1346	1002
50	1560	1120
55	1789	1234
60	2135	1290

To give an explicit comparison of the volume of biogas formed after digestion of wastes from the landfill and sludge from we do an anaerobic digestion of the two substrates during a period of stay of 60 days. For the two different substrates we found flammable biogas with different

production volume by the following Table V and illustrated on Fig. 5.

The volume of biogas increases with residence time and substrate concentration (Fig. 5).

Only high concentrations require time to stay very long for digestion [17]. Also the waste pretreatment promotes and enhances the biogas production [18]. The Anaerobic digestion is a method of treating organic wastes efficiently. Easily and economically exploitable [19]. This process reduces the use of fossil fuels especially in the regions or the connection of natural gas and electricity is very expensive and the production of energy which is recoverable biogas [20]. Also this process contributes to the pollution of organic loads [21]. Not to mention another advantage is the production of a digestate that can be valued as an organic soil poor in organic matter [22], [23].

REFERENCES

[1] ADEME, *The Agricultural Use of Sludge from Municipal Sewage Treatment Plants: Techniques of Water Management and Prevention of Pollution and Hazards*, no. 23, 1988.

[2] J. F. K. Oilor, "Biogas energy use in Nigeria: current status. Future prospects and policy implications," *Renewable and Sustainable Energy Reviews*, 2000.

[3] A. Lallali and G. O. N. Mura, "The effects of certain antibiotics on biogas production in anaerobic digestion of pig waste slurry," *Bioresource Technology*, 2001.

[4] A. Tekin and R. Coskun, "Biogas production from olive pomace," *Resources Conservation and Recycling*, 2000.

[5] K. S. Sreekrishnan and R. Vineet, "Enhancement of biogas production from solid substrates using different techniques," *Bioresource Technology*, 2003.

[6] R. Gourdon, "Biodeterioration microbial waste: Definitions, principles and methods of evaluation," *Waste Science and Technology*, no. 1, 1996.

[7] J. Quart, C. O. Prevot, and J. Oliva, "Methanizer in fluidized bed reactors treatment of waste water at the El Aguila Brewery," in *Proc. Symposium IAWPRC - CFRP NICE 4-6, Technical Advances in Biofilm Reactors*, 1989.

[8] V. Andreoni, "Anaerobic Digestion of Swine Slurry and agro-industrial Wastes in fixed bed up - flow digesters," in *Proc. NICE Symposium on s*, 4-6 April, 1989.

[9] A. Touzi, S. Igoud, and I. Tou, "Production of biogas from animal dung," *Review of Renewable Energy*, pp. 103-108, 2001.

[10] Study Day of the SEES/MS, *Importance of Biomass in the Sustainable Development of the Sahara, Adrar, Algerie*, 2003.

[11] E. Whiteandal, "Methane fermentation of woody biomass," *Bioresource Technology*, 1994.

[12] Cheremisinoff, *Handbook of Solid Waste Management and Waste Minimization Technologies*, Elsevier Science (USA), 2003.

[13] C. H. , *Fermentation and Biochemical Handbook: Principles. Process Design and Equipment*, Second Edition, Publications West Wood Noyes, New Jersey, USA, 1997.

[14] Demeyer, *The Bioenergy Conversion*, TEC and DOC, pp. 214-220, 1982.

[15] R. Scriban, *Biotechnology*, 4th edition, TEC and DOC, pp. 701-707, 1984.

[16] M. Murat, *Recovery of Waste and Industrial by-Products*, 1981.

[17] R. Gourdon, *Biological treatment of waste Techniques of Ingenious*, 1990.

[18] J. and V. Laforest, "Salaries physico-chemical and chemical waste," *Techniques of Ingenious*, 1990.

[19] J. Bebin, "State of the purification of urban wastewater and industrial," *Water Technical*, no. 269, May1969.

[20] C. Chitour, *Energy: The Challenges of 2000*, vol. I OPU, 1997.

[21] C. Chitour, *Energy: The Challenges of 2000*, vol. II OPU, 1997.

[22] R. Perrin and J. Scharff, *Industrial Chemistry*, 1997.

[23] K H. A. Weissermel, *Industrial Organic Chemistry: Main Commodities and Intermediate*, 1981.

Nabila Laskri was born in Annaba, Algeria, she held a magister degree in chemical engineering in 2000 at the Department of Process Engineering and currently she is conducting her PhD studies. From 2003 to 2005, she worked as a researcher in renewable energy center, and then she moved to the university as a lecturer until to 2012. Now she occupies the position of a professor at the Preparatory School of Sciences and Technology, Annaba, Algeria.

Nawel Nedjah was born on December 29, 1970 in Annaba, Algeria, she held a magister degree in chemical engineering in 2002 at the Department of Process Engineering and currently she is conducting her PhD studies. From 2003 to 2006, she worked as a researcher in renewable energy center, and then she moved to the university as a lecturer until to 2012. Now she occupies the position of a professor at the Preparatory School of Sciences and Technology, Annaba, Algeria.

Oualid Hamdaoui graduated with his engineering degree at the Department of Process Engineering, University of Annaba and received the magister and PhD degrees at the same department in 1997 and 2004 respectively. He is working as a senior lecturer at the Process Engineering Department since 2005. He is a member of the Laboratory "Molecular Chemistry and Environment", University - SAVOIE, France, as well as a conference session chair and technical review committee.