International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 3|| March 2017 || PP. 66-70

Electricity Generation from Biogas Produced in a Lab-Scale Anaerobic Digester Using Stirlingmotor

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ABSTRACT: *The sludge produced during wastewater treatment should be stabilized in order to minimize the damage to the environment. This study includes the evaluation of sludge stabilization and biogas formation by anaerobic digestion in order to generate electricity using stirling motor. The study was carried out with the raw sludge form the thickener of the waste watertreatment plant. The main aim of the study is to provide sludge stabilization resulting biogas production by reduction of organic matter and to generate electricity. Anaerobic digestion studies were carried out using a laboratory scale anaerobic reactor with a volume of 7L.Under themesophilic condition, the sludge age was maintained at 10 days during the first 20 days of operation, while the reactor was operated for 90 days until the end of the run, with a sludge age of 20 days.The results have changed in the range of 42-52% after the organic matter reduction obtained from the anaerobic digestion. Concentrations of 3735.7300 ppm, 5060.5768 ppm, and 6951.4013 ppm biogas were obtained. Biogas was turned on by mechanical energy with a Stirlingmotor and then turned to direct current and the lamps with 3V 20mA each were run for 60 minutes.*

Keywords: *Anaerobic digestion, stabilization,biogas, methane, electricity generation*

I. INTRODUCTION

In parallel with the widespread use of wastewater treatment plants to reduce the harmful effects of wastewater on the environment as a result of various activities, treatment sludge also increases. The dramatic increases in the production of waste sludge worldwide and the safe removal of sludge from wastewater sludge disposal sites are a serious challenge.Approximately 50% of the total cost of wastewater treatment is required for sludge treatment. Reduction of the amount of sludge at the source is very important in terms of minimizing the transportation cost and facilitating the disposal processes. The anaerobic digestion of sludge from domestic wastewater treatment accounts for a large majority of the energy required for the resulting biogas plant operation [1]In this context, biomass energy source is promising as a renewable energy source. Anaerobic digestion (AD), a very complex and sensitive process involving innumerable microorganisms with ultimate operational environmental conditions, is a suitable and efficient technology for the extraction of organic materials. However, the type and structure of the substrates in anaerobic treatment also affects the efficiency of biogas production. Organic materials are mainly formed by microorganisms in an oxygen-free environment, which are reduced to carbohydrates, proteins and lipid simple compounds. Anaerobic digestion involves hydrolysis, acidogenesis, acetogenesis and methanogenesis[2].

Many pathogenic microorganisms are rendered harmless during stabilization. The final product formed by anaerobic stabilization is a stabilized sludge which can be used as soil conditioner or fertilizer[3]. Also, the volumes of sludge that need to be removed are very low volumes. If the treatment sludge is to be stored in the field and eventually disposed of, it is necessary to treat them in order to minimize the problems that they can create before the final disposal and sludge stabilization is one of the biggest problems encountered in mud treatment. Anaerobic digestion is one of the oldest processes used for sludge stabilization. This process is defined as the disintegration of organic and inorganic substances in the absence of molecular oxygen.Anaerobic digestion process; Hydrolysis, fermentation and methane. These proesthetic organic materials are biodegraded into CO_2 and CH_4 in the final step[4].The most important advantage of the anaerobic digestion process is that the sludge is stabilized to reduce the content of organic matter and transform it into a substance that is harmless and easily dewaterable to the so-called biosolid [5]. Other advantages of the anaerobic digestion process include low energy requirements, low sludge formation, and the ability to utilize methane as an energy source in the biogas, the end product of anaerobic digestion.In this study, a laboratory scale anerobic digester was used for sludge stabilization and the electricity was produced by means of a stirlingmotor

II. MATERIAL

2.1. Sludge Properties

The study was carried out with the sludge from the thickener of the Wastewater Treatment Plant in Adana, Turkey. Thickened sludge characteristics were given in Table 2.1.In the startup period, the lab scale reactor was inoculated with thesludge from the anaerobic digester.

Table 2.1.Sludge characteristics

Parameter	Value (mg/L)
Total solids (TS)	55000
Volatilesolids (VS)	41780
Total COD	39760
Soluble COD	12500
pH	6,4

2.2.Experimental Setup

The study was carried out with lab-scaledigester illustrated in Fig.1a. This is a reactor controlled by a PLC unit with automatic heating and automatic mixer, and the temperature inside the reactor is fixed with a heat transfer jacket around the reactor.The pH of the system is automatically controlled by the pH probe in the reactor. The pH changes in the reactor were monitored regularly every day and were measured as values ranging from pH 7 to 7-40.The pH of the reactor was buffered by using 0.1 M NaOH through an automatic pump in the system. The reactor was started by adding 4 L raw sludge and 1 L inoculum sludge in the first stage. The sludge ageas maintained as 10 days for the first 20 days of operation and then for 90 days until the end of the studysludge age was 20 days. The reactor was operated under themesophilic (35 ° C) conditions.

(a) (b)

Fig.1.(a) Anaerobic digester (b) Gas collection unit

Fig.1. Lab-scale anaerobic digester

2.3.Analysis

The reactor efficiency was checked by performing total solid and total organic matter analysis in the sludge taken from the inlet and outlet three times a week on average. pH, temperature and biogas measurements were done daily. The biogas formed in the reactor operation process was measured with a Ritter brand flow meter in mL precision. The gas formed in the system is first collected at the balloon and then pressurized with a syringe using a three-way tap in the inner tube (Fig.1b). The methane content of the gas obtained from the reactor was measured by gas chromatography. The resulting biogas was converted into direct current by mechanical energy with Stirlingmotorand four leds were operated. The gas from the anaerobic digester was sent to the motor after it passed the Ritter brand flow meter. Sending of the gas to the tire after the initial operation of the reactor created a problem, and the problem was solved by attaching a balloon to the outlet of the flowmeter and the gas was collected daily at the ball and the gas was pressurized with the help of a three-way tap with a syringe.

2.4.Electicity Generation from Biogas using stirlingmotor

Today, pollution,global warming, reduction of fossil energy reserves increase energy demand. The machines that will convert renewable and alternative energy attract great attention .Stirlingmotors are one of the developmental motors that can work on open and closed systems with the ability to use many alternative and renewable energy sources. The Stirling motors are a motive that will be in the future, with a variety of applications, equal to the reversible Carnot cycle, and ongoing research around the world. A Stirling engine is a heat motor that works by compressing and expanding the air or other gas at different temperatures, and the heat energy is converted into mechanical work in a clear way. The Stirling motoris a closed cycle regenerative heat motor with a permanently gas working fluid. Closed cycle in this context means a thermodynamic system in which the working fluid remains permanently in the system and defines the use of a particular type of internal heat exchanger and thermal storage, known as regenerative regenerator [6].(https://en.wikipedia.org/wiki/Stirling_motor).The reserves of fossil energy resources in the world are limited, expensive and harm the environment, polluting the environment with pollutant emissions, especially SO_X, NO_X, and causing greenhouse effect by CO_2 emissions, which disrupt the earth's natural balance.To overcome these drawbacks will be possible especially by reducing external dependence, diversifying energy supply and more intensive use of renewable energy resources. Unlike other internal combustion motors, the Stirlingmotor does not depend on the power it uses, such as wood, coal, petroleum, natural gas, biomass, geothermal etc.Can be used with many sources of energy such as making these motors more promising for the future.

Until now, many researches on Stirling motors have been done by universities, research firms and commercial companies, and many different types of power generating models, different shapes and features have been manufactured. In this study, the operation of the Stirlingmotor will be monitored by the biogas energy obtained from the treatment sludge.The Stirlingmotor used in this study is a laboratory scale motor and can reach 1500 rpm. There is a LED that can work with the direct current that exists in the motor (Fig.2.).

Fig.2. Electiricy Generation with StirlingMotor

III. RESULTS AND DISCUSSION

Volatile solid (VS) represents the organic matter in a sample which is measure as solid content minus ash content.VS comprise the biodegradable fraction VS and refractory VS. High VS content with low refractory -VS is more suitable for anaerobic digestion.As seen in Figure 3.1, organic matter removal in the anaerobic reactor has increased since the 15th day of operation and has remained between 42-52% throughout the operation. Laboratory-scale anaerobic sludge digestion resulted in a removal efficiency of 42-52% after the organic matter reduction became stable

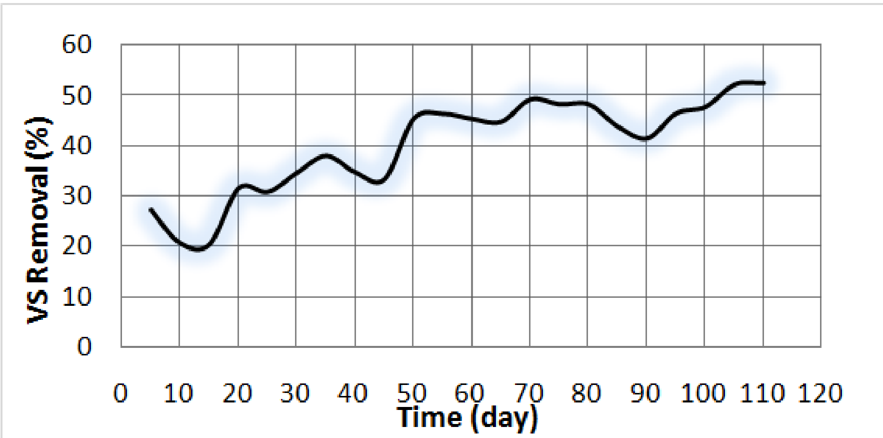

Fig.3.1. Changes of VS removal efficiency during the operation period.

Total solids changes in digesters as a function of operation time is given in Fig.3.2. During the operation, TS values decreased for thedigester. Depending on the organic matter reduction, the total solids in the digester decreased relative to the raw sludge and continued to increase for the first 80 days.

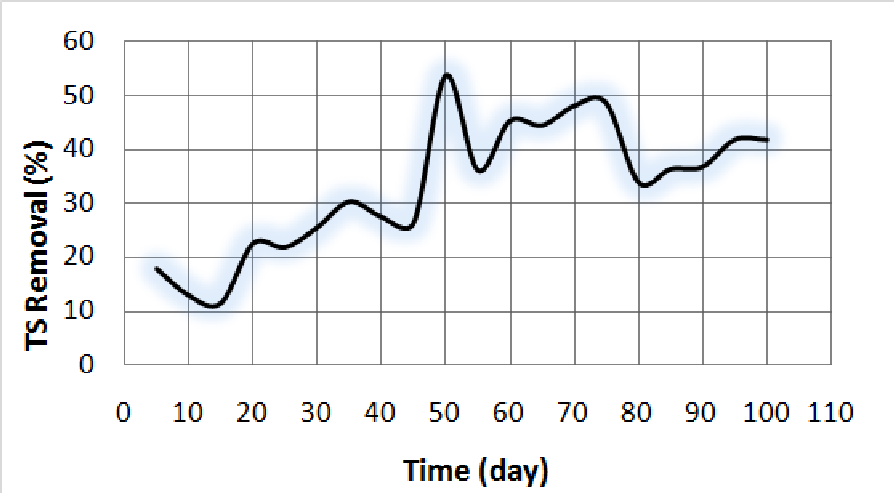

Fig.3.1. Changes of VS removal efficiency during the operation period.

Sludge gives a very good performance in biogas production. This is inevitably the biodegradable nature of the sludge. In the measurement of the resulting biogas concentrations of 3735.7300 ppm, 5060.5768 ppm, and 6951.4013 ppm were obtained and given in Fig.3.3. A total of 65 L of gas was obtained.

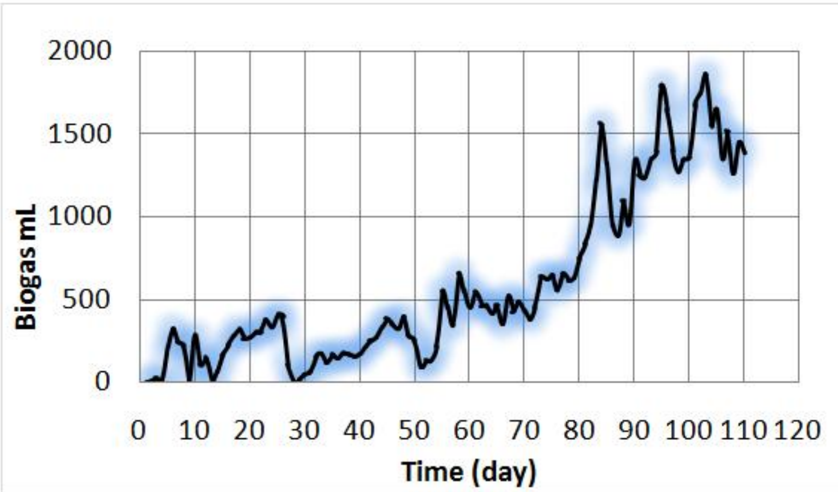

Fig.3.3. Biogas produced in the anaerobic digester

One of the easiest ways to control reactor efficiency in anaerobic digestion is to monitor the amount of biogas formed and the methane content in the biogas. One of the main advantages of aerobic treatment of anaerobic digestion is that it is the result of the process. The better the operation of the process, the more biogas it produces. The amount of biogas produced is parallel to the organic load removed in the system. As a result, the reduction in the amount of biogas indicates that the efficiency of the system to remove organic matter is reduced. One of the main reasons for this is excessive organic load. The distribution of biogas was surprising. Exceptionally, the concentration of CO_2 was higher than the CH_4concentration. The measurement of the biogas was not regular because of the insufficient analysis. All biogas measurements were given in Table 3.1.

Table1. Biogas composition

Day	CH_4 (ppm)	CO_2 (ppm)	N_2O (ppm)
10^{th}	3735.7300	4020.0585	3.8650
20^{th}	2982.7985	2039.0520	-
30^{th}	4814.3679	5480.3592	2.1275
40^{th}	6951.4013	14077.4717	16.4282
50^{th}	6183.4462	11758.5001	12.5389
70^{th}	5054,4987	9605.8040	3.8650
90^{th}	5361,3087	9137.5226	5.1775
110^{th}	5060,5768	9182.2883	5.7236

The pH value is one of the main operational factors that greatly affect the digestive process. Anaerobic digestive microorganisms prefer a neutral pH range. There are many organisms that require different optimum pH in the biogas production process. The optimal pH range for achieving maximum biogas production in AD is 6.8-7.2. In the AD process, the methanogenesis microorganisms are very sensitive to pH changes and prefer to have a pH around 7.0. Asidogenesis microorganisms are relatively less sensitive to pH and can be poisoned in the 4.0-8.5 range. However, the optimal pH for hydrolysis and asidogenesis is between 5.5 and 6.5 [2]. The pH value of the digester content is an important indicator of the performance and the stability of an anaerobic digester. pH variations in the digester are greatly influenced by many aspects of the complex microbial metabolism In a well-balanced anaerobic digestion process, almost all products of a metabolic stage are continuously converted into the next breaking down product without any significant accumulation of intermediary products such as different fatty acids which would cause a pH drop. In this study, alkalinity and pH in anaerobic digestion were adjusted using several chemicals such as sodium hydroxide. The changes of pH during the operation time were illustrated in Fig.3.4. pH was changed between 7 to 7,4. However, a few peak was seen and pH was reached to 8 on 11th day and 68th day of the operation.

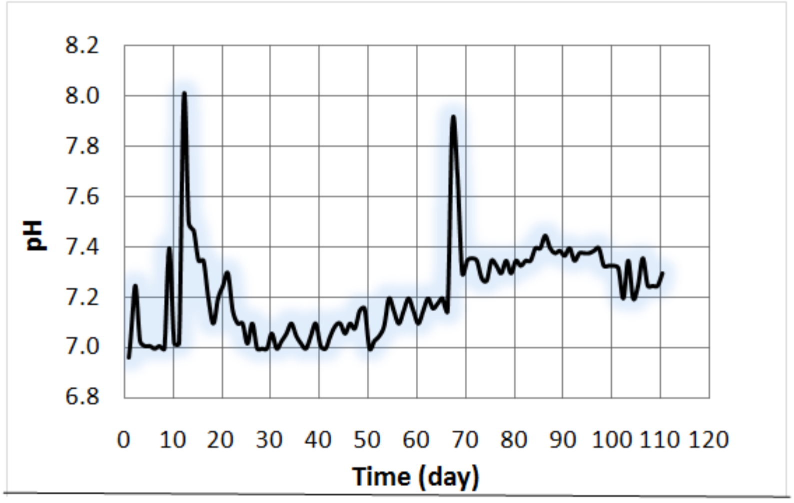

Fig.3.4.pH variation

With the biogas obtained in the study, the Stirling motor was started for about 60 minutes and the energy obtained was calculated as follows.
Oneled 3V x 20mA
3V x 20mA x 4 Led x 60 min x (60 s)/min= 864000 mW.s
864 Ws → 864 joule

IV. CONCLUSION

The results of the study confirm that organic matter removal (42-52%) and biogas elution can be achieved well with anaerobic digestion. The biogas from a laboratory-scale anaerobic digester was successfully converted to electricity. Biodegradation of organic matter can be increased by using mechanical disintegration, chemical disintegration, biological disintegration, thermal disintegration, etc. from pre-treatment methods before anaerobic digestion, and more biogas can be obtained by increasing the degree of stabilization.

REFERENCES

[1]. G. Tchobanoglous, F.L. Burton, H.D. Stensel, *Wastewater Engineering: Treatment and Reuse* (Metcalf & Eddy, Inc., 2003).
[2]. K. Hagos, J. Zong, D. Li, C. Liu, X. Lu, Anaerobic co-digestion process for biogas production: Progress, challenges and perspectives, Renew. Sustain. Energy Rev. (2016) 0–1. doi:10.1016/j.rser.2016.11.184.
[3]. İ. Öztürk, *Anaerobikarıtmaveuygulamaları*, (Su VakfıYayınları, İstanbul,2007).
[4]. A.Filibeli, *Arıtmaçamurlarınınişlenmesi* (DokuzEylülÜniversitesiYayınlarNo:225, ISBN 975-441-117-4.1998).
[5]. S.K., Dentel,*Sludge into biosolids: Processing, disposal, utilization*, (278-311, IWA Publishing, 2001).
[6]. https://en.wikipedia.org/wiki/Stirling_engine