Conversion of Water Hyacinth Derived Biogas to Biomethane for Electricity Generation in Kenya: A Waste to Energy (WtE) Approach.

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Abstract— Water hyacinth a freshwater weed that thrives in polluted water was used as feedstock for Biogas production. The weed is removed from the water bodies by manual, mechanical, biological or chemical means. Manually and mechanically uprooted Water hyacinth poses a great environmental and public health challenge. This has developed an environmentally sound method of utilization of weed from Lake Victoria, Kenya as feedstock for biogas production. The uprooted weeds were pulped and mixed with water at a ratio of 1:1 and 1:3 with cow dung to supplement decomposition microorganisms. The mixture was loaded into bioreactor and gas yield, physicochemical parameters and bioreactor temperatures monitored during the production period. Gas compositional analysis of the biogas was carried out with a Gas Chromatograph coupled with a Thermal Conductivity detector (GC-TCD). The Biogas contained 49 - 53% methane, 30 - 33% carbon dioxide, 5 - 6% nitrogen and traces of Hydrogen sulphide. Optimal gas production occurs at the 21st day after feeding the digester. The biogas was upgraded into Biomethane using a series of cleaning devices; hydrogen sulphide scrubber, water scrubber and a carbon dioxide wet scrubber. Upgrading of the gas led to gas that that was of very high purity - Biomethane. The Biomethane was used to run internal combustion engine coupled with a generator for electricity production. Biomethane production from water hyacinth was found to be an environmentally and energy friendly project since it promotes Waste to Energy (WtE) technologies. Analysis of bioreactor effluents also produced a high quality bio-fertilizer.

Keywords— Biogas, Biomethane, Water Hyacinth, Gas Chromatography, Waste to Energy.

I. INTRODUCTION

Biogas is a clean and environment friendly fuel produced through the anaerobic digestion (AD) of organic wastes such as; cow-dung, vegetable wastes, municipal solid waste and industrial wastewater [1, 2]. It is increasingly becoming important in domestic and industry as fuel due to its costs and cleanliness. The main component of the gas is methane, carbon dioxide, hydrogen, nitrogen and hydrogen sulphide [3, 4]. Water hyacinth can be used as a potential feedstock for biogas production due to its abundance in polluted freshwater lakes and the high carbon- nitrogen ratio. It is harvested manually from L. Victoria, Kenya. This study aims at converting the water hyacinth produced biogas to biomethane for electricity generation. Water hyacinth was collected from Lake Victoria.

II. EXPERIMENTAL SET UP

A biogas plant constructed of 6 m^3 Flexible bag enclosed in Ultra Violet (UV) screen house was set up at Institute of Energy and Environmental Technology in Jomo Kenyatta University of Agriculture and Technology (JKUAT). Pulped water hyacinth (150 kg) was mixed with water at a ratio of 1:1. This mixture was seeded with cow dung at a ratio of 1:3 and loaded into the bioreactor digester and allowed to generate gas for a period of one month. Physical parameters of the water hyacinth that is Conductivity, Total dissolved solids (TDS) and pH were determined during loading and digestion.

The gas chemical parameters and composition was analyzed using the Gas Chromatograph and Thermal Conductivity Detector (GC-TCD).

III. RESULTS AND DISCUSSION

A. TEMPERATURE AND pH

Temperature and pH variations are illustrated in Figure 1 and 2. The two parameters varied widely during the biogas production period. The temperature varied within 17 and 32 oC, the fermentation process is an exothermic process and the variations could be attributed to the microbial action at various stages of decomposition. pH variations can be attributed to the bacterial action during the hydrolysis, acidification and methanization. The processes produce hydroxyl and hydrogen ions thus varying the pH. It ranged between 6.3 and 8.5 units.

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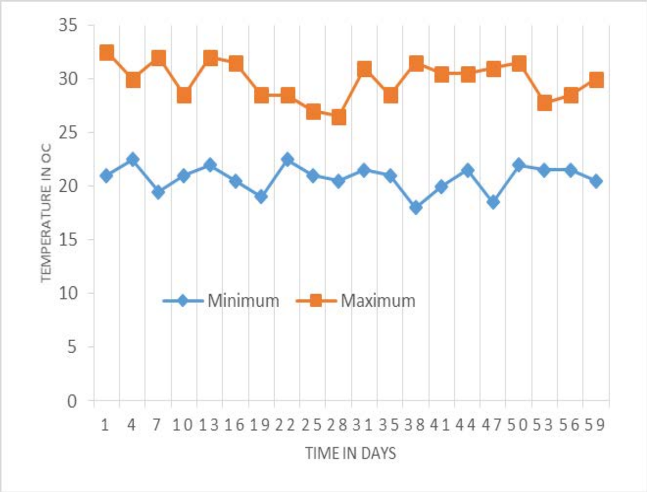


Figure 1. Temperature Variation within the Biogas Digester

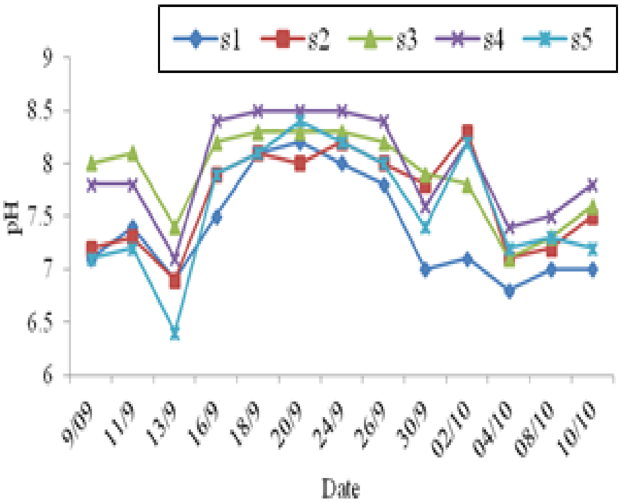


Figure 2. pH Variations Within the Biogas Digester

B. BIOGAS PRODCTION

Biogas production with time is presented in Figure 3. The gas production has a maxima on the 21st day. This can be related to the growth of bacteria within the digester after the 21st day the bacteria start to starve and competition for food and elimination. The reduced population of the microbes leads to a significant drop in gas production. This can be improved by periodic loading the digester with fresh feedstock.

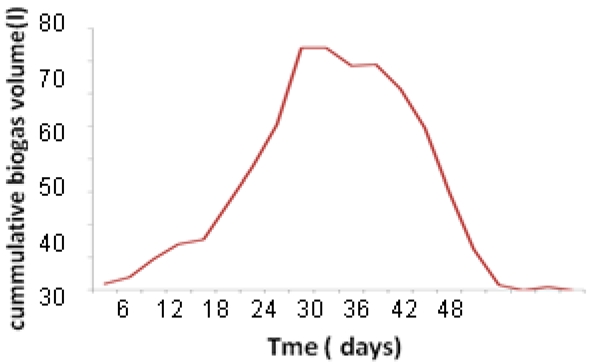


Fig. 3: Biogas Production with Time

C. BIOGAS COMPOSITION

Table 1. presents data on the retention times of the various constituents of biogas.

Biogas compositional data is presented in Table 2. The gas was found to contain a mix of gases. On average the biogas was found to contain between 49 - 53% methane (CH4), 30 - 33% carbon dioxide (CO2), 5 - 6% nitrogen (N2) and traces of hydrogen sulphide (H2S)

Table 1. Raw Biogas Composition

Composition	Retention time (min)	Percentage composition
Nitrogen	1.02	17.0 - 19.0 %
Methane	1.12	49.0 - 53.0%
Carbon dioxide	1.62	21.0 – 29.0 %.

Table 2. Biogas Composition after Upgrading

Composition	Retention time (min)	Percentage composition
Nitrogen	1.02	19.0 - 27.0 %
Methane	1.12	65.0 - 73.0%
Carbon dioxide	1.62	4.0 – 8.0 %.

D. BIOGAS UPGRADING

The gas was upgaraded by a series of cleaning devices, water vapour was removed using analytical grade sodium sulphate (NA2SO4), H2S removed using iron oxide and CO_2 using 15% sodium Hydroxide solution (NaOH). This increase the methane content by between 20 – 23 %. The chromatograms for the raw and upgraded biogas are presented in Figure 4 and 5.

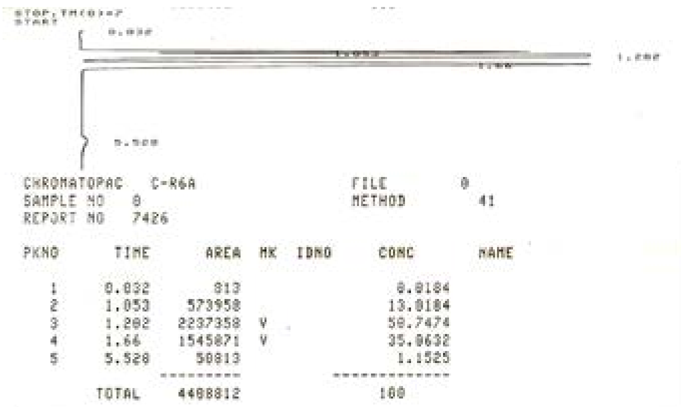
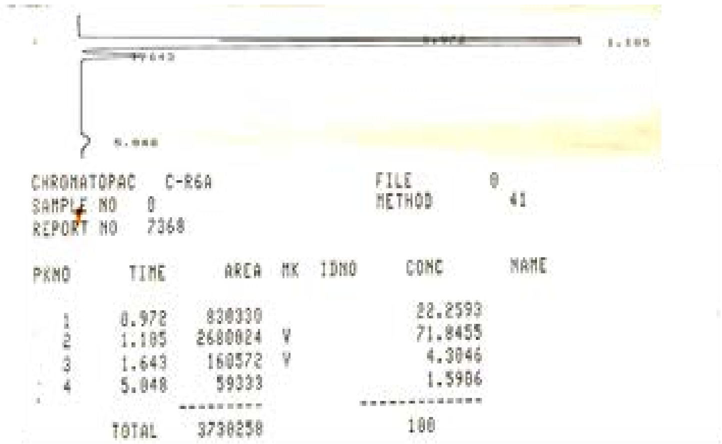


Fig. 4: Raw Biogas Chromatograms


CHROMATOPAC C-R6A FILE 0
SAMPLE NO 0 METHOD 41
REPORT NO 7368

PKNO	TIME	AREA	MK	IDNO	CONC	NAME
1	0.972	830330			22.2593	
2	1.185	2680024	V		71.8455	
3	1.643	160572	V		4.3046	
4	5.048	59333			1.5906	
	TOTAL	3730258			100	

Fig. 5: Upgraded Biogas Chromatograms

The biomethane was compressed into a biogas compressor and converted directly into electricity to run an internal combustion engine. However, very clean gas is necessary for this process. This is therefore still a matter for research and is currently ongoing.

The bioreactor effluents produced a high quality bio-fertilizer. The analysis of the composition of the bio-fertiliser nutrients is ongoing.

IV. CONCLUSION

The study shows that water hyacinth is a good feed stock for biogas production. This biomethane produced can be upgraded using available methods to improve the menthane content which can be utilized for electricity generation**.**

ACKNOWLEDGMENT

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