

Towards Deriving Renewable Energy from Aquatic Macrophytes Polluting Water Bodies in Niger Delta Region of Nigeria

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Abstract: This study was performed to derive methane rich biogas from biomass of harvested water hyacinth polluting water bodies in selected rivers of the Niger delta region of Nigeria. Field visits were undertaken on selected rivers in the Niger Delta region in which aquatic macrophytes were collected and inventorized. Also different types of aquatic macrophytes were surveyed. Control by harvesting macrophytes and deriving energy (methane-rich biogas from biomass of one (water hyacinth) was successfully carried out in this study. An initial test was conducted to evaluate methane rich biogas production from water hyacinth collected from the wild. After a successful production of combustible biogas, laboratory experiments aimed at generating biogas from harvested biomass of aquatic macrophyte (water hyacinth) cultivated under eutrophic and oligotrophic conditions were undertaken in the laboratory. The result of the study showed highest biogas yield of 22 L over a 40 day retention time for water hyacinth raised under eutrophic conditions. Biogas yield for water hyacinth raised under oligotrophic conditions recorded the highest yield of 53L over an 11 day retention time. The conversion of the biomass of harvested aquatic macrophyte (water hyacinth) from the Niger Delta into renewable energy, that is combustible biogas, demonstrated an inevitable option for the control and management of environmental pollution associated with aquatic macrophytes and their usability for poverty alleviation in the Niger Delta region of Nigeria.

Keywords: Biogas, from Niger delta aquatic macrophytes, produce

INTRODUCTION

Energy is a vital requirement in sustaining the ecosystem and it remains central to all human activities. Energy utilization in our daily activities ranges from domestic applications to sustenance of local industry and food processing. Access to energy is inevitable for poverty alleviation and for meeting the Millennium Development Goals (MDG). Energy is made available from the renewable and non renewable forms. The non renewable fossil fuel (wood, petroleum, coal, etc.) is used in the commercial, industrial, transportation and domestic sectors of the economy. Olaoye (2001) opined that the much dependable agricultural material for generation of energy in Nigeria is fuel wood. The uncontrolled level of wood for fire wood and charcoal, for combustion and for other domestic and industrial uses is now a serious problem in Nigeria. Umar (2000) reported that over 90% of the estimated values of fuel wood of the total energy are used by the rural people and urban "poor". There is rapid depletion of non renewable energy forms, hence the current attention to renewable forms of energy.

Renewable energies include biomass, solar, rivers, geothermal, wind, ocean wave and tides, etc. They are 'renewable' because they are regularly replenished by natural processes and are therefore in endless supply. They can operate without polluting the environment. The technologies developed to harness these are called Renewable Energy Technologies (RETs). The bioreactor used for anaerobic digestion of water hyacinth in this study is an example of RET; sometimes also called clean "technologies" or "green energy". Because renewable energies are constantly being replenished from natural sources, they have security of supply unlike non renewable fossil fuels which are negotiated on the international market and subject to international competition, sometimes may even result to wars and shortages. The concept of using aquatic plants such as macrophytes for water treatment and their harvested biomass as a renewable source is gaining attention throughout the world. Water hyacinth (*Eichornia crassipes*), until 1940's and 50's was considered an obnoxious weed clogging up agricultural canal systems, dammed streams and encouraging

mosquito breeding (Gopal, 1987). The prolific growth of water hyacinth and the ease of harvest techniques make it a suitable feed stock for biochemical conversion to methane rich biogas. It can be utilized in both the fresh and dried forms, serves as an alternative feed stock for biogas production and can also be employed for phytoremediation purpose (Marchaim, 1992). The non conventional plants such as aquatic macrophytes on waste lands, rivers and other water bodies of the Niger Delta are considered as veritable source of potential biomass to be used efficiently for recovery of reserved renewable energy, because:

- Weeds have ability to trap a significant amount of solar energy
- Weeds are capable of growing on soils and water bodies generally unsuitable for conventional crop production
- The genetic base of weeds is such that many can grow under a wide range of cultural and climatic conditions
- Weeds grow naturally without inputs and irrigation

Hence, the large scale utilization of aquatic weeds for renewable energy production is one of the best strategies for their control and management.

This study is aimed at identifying aquatic macrophytes in selected water bodies of the Niger Delta region which can be used for production of methane rich biogas, cultivate one of the aquatic macrophytes and evaluate its harvested biomass in anaerobic digestion for biogas production.

MATERIALS AND METHODS

The experimental studies were carried out at the Centre for Energy and Environment (2011) University of Benin, Benin, Nigeria.

The study was carried out in two phases, namely:

- Collection and inventorization of aquatic macrophytes in selected water bodies in the Niger Delta which can be used to generate biogas.
- Cultivation of one of the aquatic macrophytes (water hyacinth) and production of biogas from it.

Phase I:

Field study visits: Were made to selected water bodies in the Niger Delta region. A survey was carried out to obtain different types of aquatic macrophytes. This involved field collections of different macrophytes belonging to different life forms (submerged, free



Fig. 1: Bioreactor used for production of biogas by anaerobic digestion of water hyacinth

floating, floating-leaved and emergent). Field trips were undertaken to aquatic habitats both temporary and permanent. Such trips were made weekly for a period of 6 months.

Phase II:

Cultivation of aquatic macrophyte (water hyacinth) and production of biogas: A 50 L bioreactor (Fig. 1) was constructed in line with Badmus (1991). An initial test was conducted to evaluate methane rich biogas production from anaerobic digestion of water hyacinth collected from the wild. After a successful production of combustible biogas, laboratory experiments were initiated with the aim of generating biogas from aquatic macrophyte (water hyacinth) grown in the laboratory. Water hyacinth cultivated in experimental ponds under eutrophic and oligotrophic conditions was evaluated for production of methane rich biogas. The experimental ponds were constructed within Botanical Garden, Faculty of Life Sciences University of Benin, Benin City. Experiments were carried out during the wet season (20-30°C) and dry season (30-39°C) ambient temperatures and introduced into the bioreactor. Bacteria inoculum for bio-digestion was obtained from cow rumen. The volume of biogas was measured using the water displacement technique (Fig. 2)

Physico-chemical analyses: The pH of substrate in the bioreactor, influent and effluent, temperature, gas production volume was monitored daily on a regular basis. Total Solids (TS) were measured according to APHA (1975). Between 15-20 g of fresh feed stock was weighed (W2) in an empty crucible (W1) and dried in an oven maintained at 90°C for 24 h (W3).

Percent TS was calculated as:

$$\%TS = (W3-W1) / (W2-W1) \times 100 \quad (1)$$

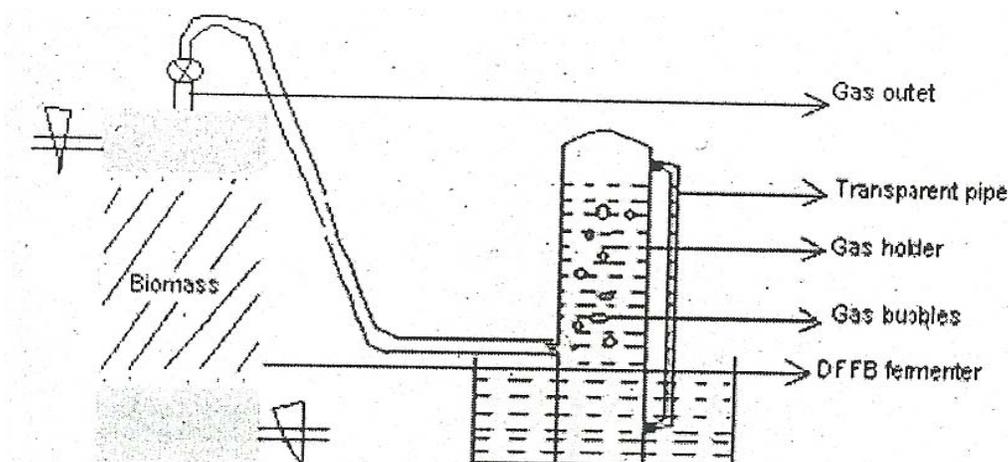


Fig. 2: A sketch showing biogas measurement by downward displacement of water

Volatile solids represent organic matter of the feed stock (excluding the inorganic salts ash). This was measured in accordance with APHA (1975), 2-3 g of oven dried sample was weighed (B) in an empty crucible (A) and heated to 550°C for 1 h in the muffle furnace to Constant weight (C).

Percent Volatile Solid (VS) was calculated as:

$$\% VS = (B-C) / (B-A) \times 100 \quad (2)$$

RESULTS AND DISCUSSION

Phase 1:

Field study visits: Were made to the following selected Niger Delta water bodies: River Ethiope, Fishing camp near Koko, River Osse, the Benin River and a navigated water way in Delta State. Mat of water hyacinth on the Benin River was extensive. The water way in Delta State had navigation hindered by the very thick mat of water hyacinth. Similarly, access to an oil well head was blocked by a thick mat of water hyacinth. Luxuriant growth of *Vossia cuspidata* on River Ethiope and mat of water lettuce (*Pistia stratiotes*) evidence the growth of different types of aquatic macrophyte on the same water body environment. Luxuriant growths of different types of aquatic macrophytes were recorded at the front yard of a fishing camp near Koko. Mat of water lily was observed on Osse River.

The occurrence of 24 different types of aquatic macrophytes identified in the Osse and Ethiope Rivers with level of abundance in each case is as shown in Table 1 The occurrence of *Eichhornia crassipes*, *Sacciolepis africana* and *Vossia cuspidata* were most abundant among the 19 species of aquatic macrophytes

Table 1: Occurrence of quatic macrophytes in Osse and Ethiope river

S/no	Plant name	Occurrence in Osse rivers	Occurrence in Ethiope rivers
1	<i>Rhynchospora corymbosa</i>	+	+
2	<i>Scirpus cubensis</i>	+	+
3	<i>Aeschynomene indica</i>	+	+
4	<i>Hydroclea glabra</i>	+	-
5	<i>Nymphaea lotus</i>	+	+
6	<i>N. maculate</i>	+	+
7	<i>Ludwigia abyssinica</i>	+	+
8	<i>Acroceras zizanioides</i>	+	+
9	<i>Echinochloa obtusifolia</i>	+	-
10	<i>E. pyramidalis</i>	+	+
11	<i>E. stagnina</i>	+	+
12	<i>Leersia hexandra</i>	+	+
13	<i>Penicum laxum</i>	+	+
14	<i>Sacciolepis africana</i>	++	++
15	<i>Vossia cuspidata</i>	++	++
16	<i>Polygonium lanigerum</i>	+	+
17	<i>Eichhornia crassipes</i>	++	++
18	<i>E. natans</i>	+	
19	<i>Petondon petandrus</i>	+	
20	<i>Salvinia nymphellula</i>	+	
21	<i>Sphenoclea zeylanica</i>	+	
22	<i>Cyrtosperma</i>	+	
23	<i>senegalense</i>	+	
24	<i>Lemna sp.</i>	+	++
	<i>Azolla africana</i>		

++: Abundant



Fig. 3: Water hyacinth (*Eichhornia crassipes*) grown under eutrophic condition

Table 2: Methane gas production from water hyacinth raised under oligotrophic condition

Time (days)	Methane gas production (L)
1	40
2	53
3	41
4	32
5	41
6	25
7	19
8	40
9	28
10	18
11	18

Table 3: Methane gas production from water hyacinth raised under eutrophic conditions

Time (days)	Gas production (L)
1	4.0
4	4.0
6	6.0
8	7.0
10	10.0
12	8.0
14	14.0
16	20.0
18	18.0
20	16.5
22	17.0
24	16.0
26	16.0
28	16.5
30	17.0
32	20.0
34	22.0
36	22.0
38	15.0
40	14.0

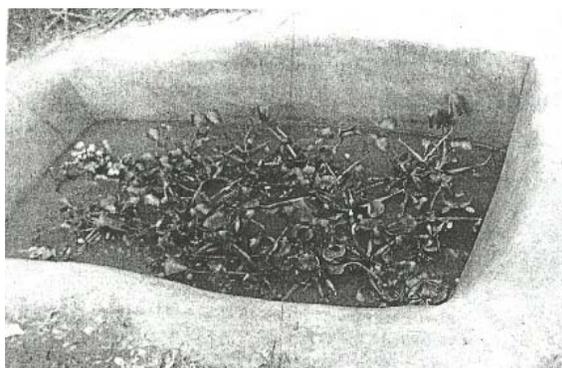


Fig. 4: Oligotrophic pond containing population of water hyacinth

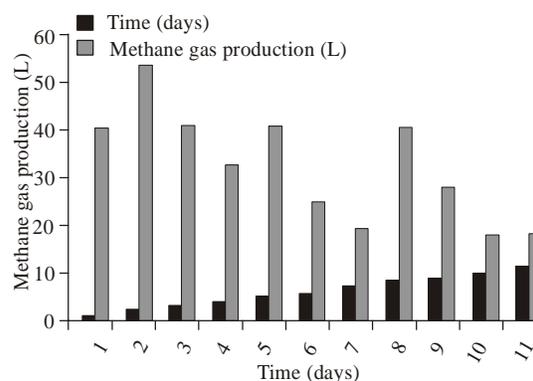


Fig. 5: Methane gas production from water hyacinth raised under oligotrophic condition

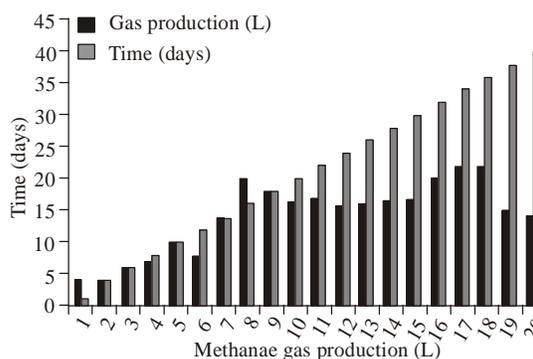


Fig. 6: Methane gas production from water hyacinth under eutrophic condition

naturally growing in Osse and Ethiope Rivers of the Niger Delta region of Nigeria.

Phase II: Methane rich biogas production through anaerobic digestion of biomass of water hyacinth (*Eichhornia crassipes*) grown under eutrophic condition (Fig. 3) ranged from 4 to 22 L/day (Table 2), while the volume of biogas produced in water hyacinth cultivated under oligotrophic (Fig. 4) ranged from 18 to 53 L/day condition as depicted in Table 3. Table 4 shows the chemical analysis of effluent from the bioreactor. There was a significant difference in the amount of biogas production under the two regimes. More biogas was generated from the water hyacinth raised in oligotrophic condition (Fig. 5). Indeed, the initial experiment using water hyacinth grown under eutrophic condition (Fig. 6) was carried out during

Table 4: Chemical analysis of effluent from the bioreactor

Parameter /Code	Total solids	Org. C	N	P	SO ₄	K	Ca	Mg
	mg/L	%		mg/L				
Effluent	12.570	5.0	0.3	30.1	1.380	85.34	61.82	9.90

the rainy season while the latter experiment using oligotrophic condition took place in the dry season. Temperature is known to have a significant effect on biogas yield; hence the significant increase in biogas production may be attributable to temperature effect.

A survey of literature showed that water hyacinth has been previously used for biogas production in Sokoto with an energized system, yet the gas produced by the energized system is lower than our system reported above. Our system was operated under ambient condition and we succeeded in getting more quantity of biogas.

It is noted that there are several other aquatic macrophytes in water bodies of the Niger Delta region which biomass can be aerobically digested for the production of abundant quantities of biogas as a result of their prolific growth, wide distribution and abundant availability. There is need to evaluate the potential biogas yield of such aquatic macrophytes as: *Sacciolepis africana*, *Vossia cuspidata* and *Pista* sp.

CONCLUSION AND RECOMMENDATIONS

The availability of abundant feed stock (biomass) material of aquatic macrophytes usable for renewable energy (i.e., biogas) production occurs in water bodies of the Niger Delta region of Nigeria. However, quantum estimate of each of the 24 identified macrophytes and their biogas production potential need be undertaken to compare them with non renewable energy reserve of the region. Effort should be made to acquire at least 4 units of the bioreactor and of increased volumetric capacity to translate the current 50 L laboratory scale bioreactor to a small industrial scale system producing sufficient biogas for the powering of

the systems of the Centre for Energy and Environment (2011) University of Benin, Benin, 2011 City, Nigeria.

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