

# A Sustainable Approach In Managing Aquatic Ecosystems Of Koshi Region By Harnessing Thermal Energy From Water Hyacinth

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## Abstract:

Water hyacinth, scientifically known as *Eichhornia crassipes* is an invasive freshwater plant which disturbs water quality, ecosystem health, and livelihoods in aquatic ecosystems. Koshi region of Bihar state in India has several wetlands which are majorly used for the cultivation of foxnuts or Makhana. However, these wetlands are prone to the infestation of water hyacinth and pose a major ecological and economical challenge. However, biogas production from aquatic plants is gaining interest of many researchers of thermal engineering domain. The current work has been presented to demonstrate thermal energy potential of water hyacinth which otherwise considered as a water weed. The work involves collection, processing and generation of biogas through anaerobic digestion of water hyacinth. In house digesters have been made and used in this study. The anaerobic digestion process involves the decomposition of water hyacinth mixture by a consortium of microorganisms, resulting in the production of biogas. The current experimental results show that water hyacinth can be a potential constituent for biogas production. The results show that the digester mixture with water hyacinth as a cosubstrate has almost 96% higher amount of biogas generation than mixture with only inoculum as a substrate.

**Keywords:** water hyacinth, biogas, anaerobic digestion, thermal energy, inoculum

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## 1. INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is a floating aquatic plant known for its rapid invasive growth and lush green appearance. It is native to South America and spread to tropical and subtropical parts of the world since 1800s [1]. It is known as *Jalkumbhi* in Bihar, where *jal* means water and *kumbhi* signifies a pitcher like form. It thrives in freshwater bodies, such as wetlands, lakes, ponds, and stagnant rivers, where it eventually covers the entire water surface. It has the tendency to disrupt natural ecosystems by blocking sunlight from reaching submerged plants, depleting oxygen level in the water, and thus restricting the movement of aquatic organisms [2-3].

The proliferation and dense growth of water hyacinth (WH) has negative impacts not only on aquatic ecosystems but on socio economics of the region, and ecosystem too [4]. A household surveys and interviews with local communities in India presented the insights into the socio economic impacts of WH proliferation [5]. Their findings reveal how local fishermen are unable to navigate their boats in the river due to thickening of WH. The extent of livelihood disruptions, health concerns, and community perceptions regarding potential WH control strategies needs to be addressed. Various control mechanisms i.e., mechanical, chemical and biological control have been employed over the years to hamper the growth

of WH in the water bodies [6, 7]. Each method of control has their advantages and disadvantages. In mechanical control plants are cut or removed from the infested water bodies. However, cutting of the plants changes the dissolved oxygen and trophic structure leading to a subsequent increase in WH blooms [4]. On the other hand, chemical control is less labor intensive and but expensive than mechanical control. However, herbicides used to control can kill non-target algae and non-target macrophytes, resulting in adverse ecological impacts [8]. All the control methods have shown a strong effect on the ecological conditions of water bodies making them environmentally unsustainable. Some works has been reported in the potential of WH as a natural fiber in developing reinforced thermoplastic composites [9]. Some other uses are in the field of bio-fuel production, biomass and energy, waste water treatment, compost and fertilizer, animal feed, furniture [10]. Research and innovation leading to value added products from water hyacinth, emerges as a key element to achieve sustainable goal. It is suggested that the selection of a sustainable management strategy should be based on a comprehensive economic analysis of the benefits provided by the aquatic ecosystem [11].

Water hyacinth has enough amount of hemicellulose contents which can be used in biogas production [12]. Water hyacinth contains lignocellulose decomposable compositions which makes it suitable for biogas generation through anaerobic digestion [13]. Generally, Biogas as well bioslurry is generated by first chopping hyacinth into 5-10 cm pieces. Then this water hyacinth is fed into the digester where it is kept for 10-15 days by continuous daily feeding for the anaerobic digestion process to take place and the biogas generation starts eventually after the slurry formation [14]. Inoculums from different sources such as digested sewage sludge, digested food waste, fresh cattle manure and cow dung are being mixed with WH, in which inoculum acts as the initial source of microorganisms for the anaerobic digestion [15]. An active inoculum aids the success of organic matter degradation. A study was done to examine the impact of wood and faecal sludge biochar on the anaerobic digestion of cow dung and WH at a temperature of 37°C for 40 days. The cow dung alone produced the least methane ( $CH_4$ ), but adding 2 % wood and faecal sludge biochars significantly enhanced production of  $CH_4$  by 76.8 % and 94.0 %, respectively [16]. Experiments were conducted using 60 Liters batch digesters with WH, cow dung and chicken droppings. The best result was obtained for the mixture of WH (5 kg), cow dung (1.5 kg) and chicken droppings (1 kg) at 1/4 dilution, i.e. 179 L/kg of substrate. The WH alone produced the 70 L of biogas [17]. Operating temperature of digester plays a significant role in the production of biogas. Even after utilising only 30 % of the gas output, an approximately 40 % increase in net gas yield has been reported when operating temperature was at 35°C [18]. It is suggested to operate biogas plants at optimum temperature, instead of running at low environmental temperature. The calorific value of WH as a biofuel is almost similar and close to conventional fuels such as diesel and gasoline / petrol but has a very high viscosity [19]. Further, biofuel production is a complex chemical process which requires a large no of machinery setups [20]. Whereas, even with a lower calorific value than conventional fuels, biogas from WH can be an alternative to gasoline due to its simpler method of gas generation and it can further help to reduce the harmful effects of emissions and climate change. The present work has been focused on the viability of WH for an alternate source of energy considering the growing demand of energy and inevitable fuel crisis. Many wetlands of Katihar district are inundated with the WH as seen in the fig. 01. Many similar wetlands of this region are infested with WH, making them unsuitable for fisheries or foxnuts cultivation. It becomes a labour intensive job to remove WH from the infested area. Therefore, a sustainable process needs to be developed to thwart the menace of this challenge.



Figure 1 Proliferation of water hyacinth in (a) Kolashi and (b) Laliyahi village of Katihar, Bihar  
 The availability of WH as feed stock promises the potential of biogas generation in this region. In the current work, objective is to generate biogas from the WH collected from the nearby wetlands. The use of these aquatic plants as a feedstock for biogas production will not only help to control invasive plants in the wetland of Katihar but will maintain water quality and sustainability in the long term.

## 2. Experimental Methodology

In this section, a detailed description to generate biogas using WH available in the Katihar district of Bihar, India has been presented. It includes collection areas, preparation of mixture for digester, experimental setup and procedures.

### 2.1. Material Collection area

Water hyacinth has been collected from Kolasi and Laliyahi villages situated in Katihar which is near to Katihar engineering college. Both the villages have several open wetlands as shown in the fig. 1. Uprooted WH has been collected in several batches. Cow dung has been used as an inoculum in the present study. It has been collected from the nearby cattle owners.

### 2.2. Raw Mixture Preparation

Collected WH has been thoroughly washed to remove dirt and sludge. Root has been removed from the WH plant as it contributes to very low specific methane yield (litre/kg) compared to the rest part of plant [21-22]. Two batches of WH are prepared. One is cut into 8-10 cm pieces using hand held shearer. As WH has spongy interior, and has low weight to volume ratio. Therefore, it has been crushed using iron rammer. It has also been reported that how chopping and crushing significantly reduces the specific volume of the freshly harvested water hyacinth [23]. Another batch of WH has been grinded and made into a thick paste as shown in fig. 2.

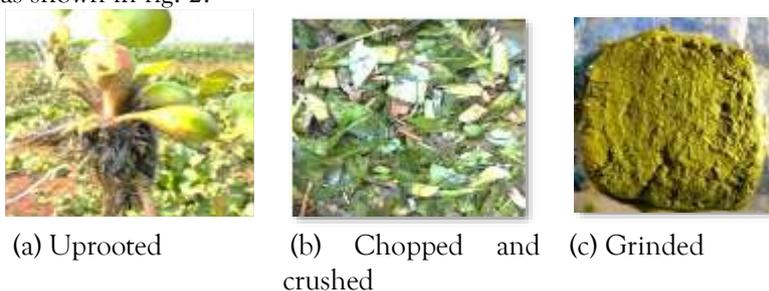


Figure 2 Different forms of water hyacinth

Mixture of substrates for the digester is prepared in four different compositions in weight/weight/volume ratio. Mixture description is given in the table 1. Four mixtures are

Table 1 Mixture composition used in digester

Name of the mixture	Weight (gm)	Volume (ml)	Mixture ratio (w/w/v)

	Form of the WH used in the mixture	WH	Inoculum (I)	Water (wt)	WH:I:wt
M1	-	0	3000	3000	1:1
M2	Paste	1500	3000	3000	0.5:1:1
M3	Paste	3000	3000	3000	1:1:1
M4	Crushed	3000	3000	3000	1:1:1

named as M1, M2, M3 and M4. In the subsequent sections of this paper, these names/labels have also been used for the four digesters. The composition of mixtures has been selected in a way to demonstrate the potential of WH as a co-substrate in the anaerobic digestion. Mixture M1 has only two constituents, i.e., water and inoculum. M1 mixture has been prepared without WH in order to compare it with the mixtures with WH constituent. Mixture M2 has been prepared with WH, inoculum and water. Mixture M3 and M4 have been prepared by using WH in paste and crushed form respectively. Both mixtures determine the suitable form of WH used in biogas generation.

### 2.3. Experimental setup and procedure

A 20 liters Polyethylene Terephthalate (PET) jar has been used for the digester. Experiments are conducted on four digesters. Mixture prepared as per the table 1 has been poured in PET jar. A thermocouple is inserted in each digester to measure the digester temperature during the experiment. Ambient temperature has been measured using another thermocouple kept outside digesters. A tube has been inserted into the jar to pass the gas to scrubber inlet. The scrubber outlet is connected with the gas storage tube which is fitted with a valve. The air inside the empty storage tube is sucked using a mini vacuum pump before connecting to the scrubber outlet. The setup has been depicted in the fig. 3. All the joints and connections are secured with a sealant. Water bubble test has been performed every day to check any air leakage in the system.

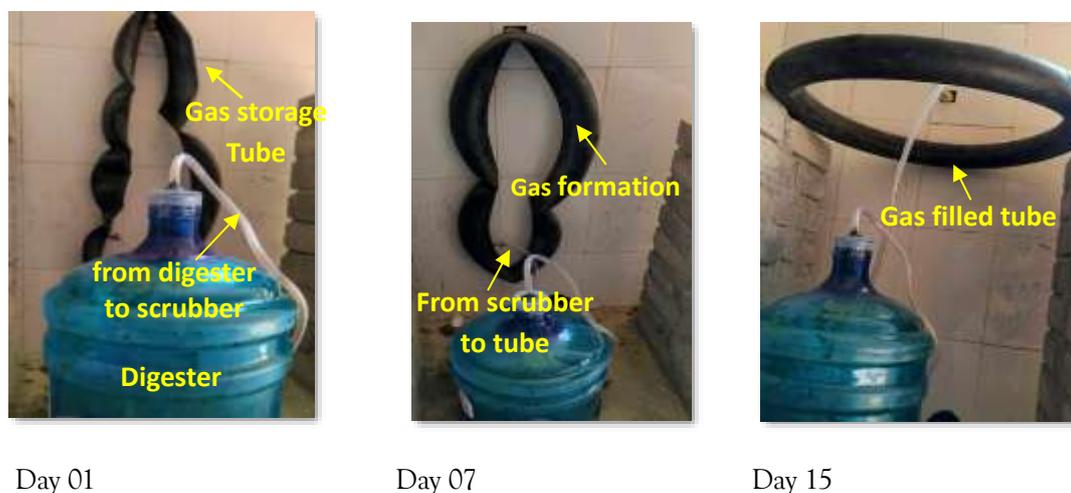


Figure 3 Different forms of water hyacinth

### 2.4. Biogas Scrubbing

Biogas generated by the anaerobic digestion needs scrubbing as it contains incombustible gases like  $CO_2$  and  $H_2S$  and water vapour. These gases reduce the calorific value of the generated biogas [24]. In the current work, a scrubber has been used as shown in fig. 4. The generated biogas is made to pass into water container through inlet tube. In this first container  $CO_2$  and  $H_2S$  both dissolves in water. The gas from water container is now passes into second container filled with iron wool where any amount of  $H_2S$  still present in gas reacts with iron oxide. This reaction forms iron sulphide ( $FeS$ ) and water. In the last stage, the gas from the second container passes into the silica gel container to reduce the water if any present.

Silica gel has its properties to absorb water. Thus, at the end biogas from the outlet has high amount of methane ( $CH_4$ ).



Figure 4 A biogas scrubbing system used in the present study

### 3. Results and Discussion

Experiments have been conducted using four closed and sealed digester for 15 days. Biogas obtained from the anaerobic digestion has been measured and results are presented in the subsequent sections.

#### 3.1 Temperature of digesters

A K type thermocouple has been installed in each of the four digesters to monitor the digester temperature. Temperature data recorded for 15 days of experimental run is shown in fig. 5. Temperature in all the four digester is between 29 to 32°C. The presented temperature data shows minimal variation in the temperature of digesters. It also shows the digester temperature is equivalent to the average ambient temperature of the lab (31°C) and very much near to the optimal temperature [18] required for the anaerobic digestion.

#### 3.2 Biogas generation

Starting from day 1 mixture M1 and M2 starts generating gas. It shows the advent of anaerobic digestion in both the digesters. As depicted in fig. 6, the generation trend is almost linear in nature in both the digesters. However, mixture M2 is generating more gas and on the 15<sup>th</sup> day, it has generated approximate 18% more gas than M1 mixture. This comparison shows WH as a potential substrate in the anaerobic digestion. A comparison has been made

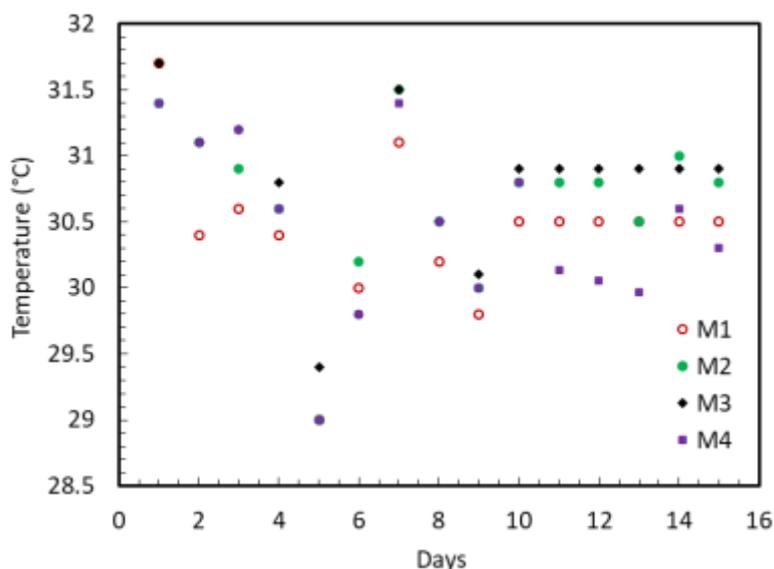


Figure 5 Temperature in all the four digesters during the experimental run.

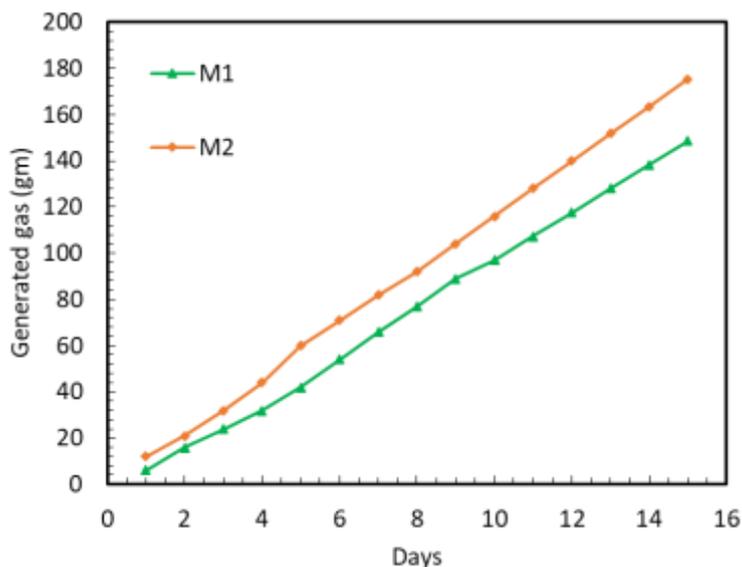


Figure 6 Comparison of biogas generation in the mixture with WH (M2) and without WH (M1) between biogas generated from mixture with WH in crushed form (M4) and paste form (M3). The comparison result has been presented in fig. 7. The amount of gas generated by M3 is considerably higher than M4. Mixture M3 has generated approximate 59% more gas than M4 mixture on the 15<sup>th</sup> day of anaerobic digestion. This result shows that the paste form of WH as a substrate is more potent than in crushed form of WH due to low specific volume of WH in the paste form. Anaerobic digestion starts in all the four digesters on day 1 and process continues in each digester for 15 days. The production of biogas has a linear trend for all the mixtures as shown in the fig. 8. All the four mixtures produce a similar amount of biogas

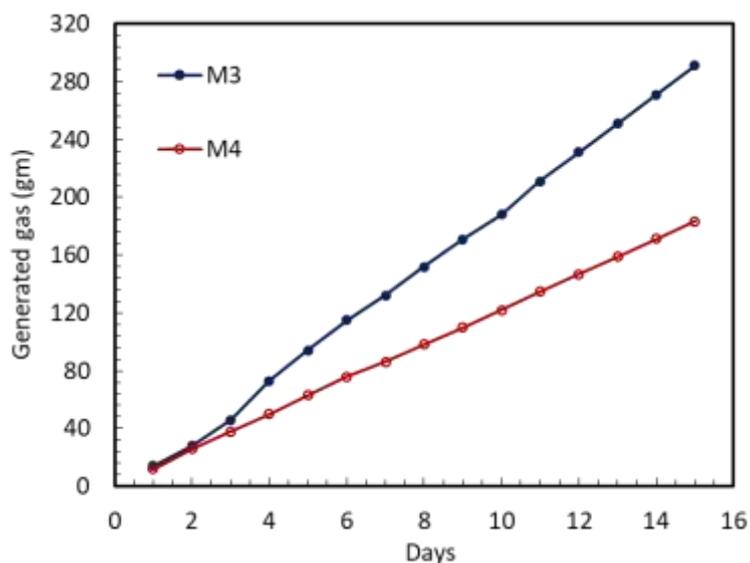


Figure 7 Comparison of biogas generation with WH in paste form (M3) and WH in crushed form (M4)

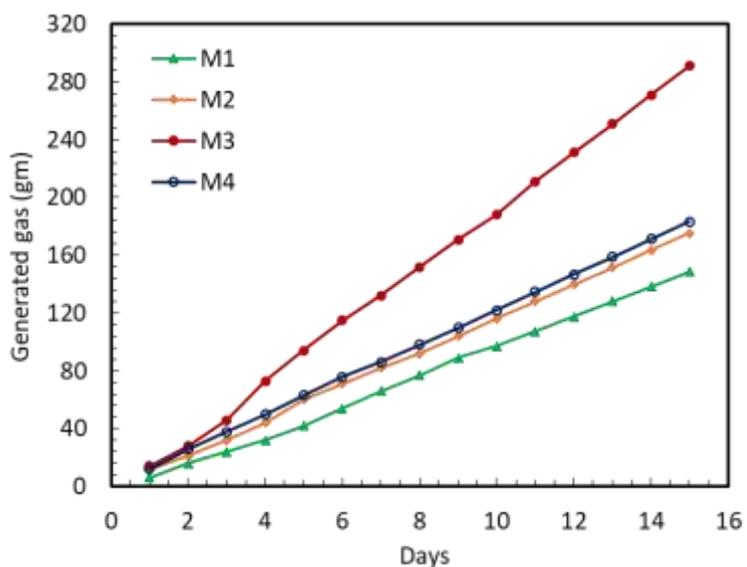


Figure 8 biogas generation in all the four digesters until day 3, but vary afterwards. Mixture with WH as a cosubstrate in the paste form has almost 96% higher amount of biogas generation than mixture with only inoculum as a substrate.

### 3.3 Combustion/Flame Test

A flame test has been performed by lighting the biogas coming out of the scrubber outlet. Gas coming out of scrubber has no combustible gas upto day 2. The burning of biogas starts after day 3 and has a very short bluish flame as shown in the fig. 9 and the colour of the flame corroborates with a previous finding [25]. The burning of biogas shows a large and continuous flame after day 10 onwards. The calorific value of biogas depends on the amount of  $CH_4$  presents in it [26], higher the value of  $CH_4$  higher the calorific value of biogas.



Figure 9 A representative flame test of biogas generated from a digester (M3)

It appears that from day 10 onwards, amount of  $CH_4$  considerably increases in the biogas which leads to a strong visible flame.

#### 4. CONCLUSION

The presented study shows the water hyacinth can be effectively used as a feedstock for thermal energy generation. The production of biogas from water hyacinth has been achieved using four different experimentations. Mixture M2 generating approximate 18% more gas than M1 mixture shows the potential of WH as a cosubstrate. Mixture M3 generates approximate 59% more gas than M4 mixture. It has also been observed that mixture with WH as a cosubstrate in the paste form has almost 96% higher amount of biogas generation than mixture with only inoculum as a substrate. Combustion test has also been performed to check the production of  $CH_4$ . The results obtained are promising in harnessing the thermal energy in the form of biogas using WH obtained from the Koshi/Katihar region. The present methodology can be further revamped and scaled up developing a state of the art digester for the production of energy, and control of water hyacinth towards managing the aquatic ecosystems of Koshi/Katihar region.

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