International Journal of Research in Advanced Engineering and Technology
ISSN: 2455-0876, Impact Factor: RJIF 5.44
www.engineeringresearchjournal.com
Volume 2; Issue 2; March 2016; Page No. 40-44

Production of bio-hydrogen gas from Kshipra River water by anaerobic fermentation process

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Abstract

Kshipra is holy River that originate from the Kakri-Badi (indore) of Madhya Pradesh and flows across Ujjain city (23º18’N and 75º77’E). River flows across Malwa plateau to join river Chambal which later joins Gangetic system. In the present study, two study sites with high anthropogenic activities were selected on the banks of river Kshipra; they include Ramghat, and Mangalnath. Hydrogen is view as a very clean energy source, since its combustion release mainly dihydrogen monoxide as a reaction product additionally it has advantage of having the highest energy density when compared to any other fuel. This research deals with the fermentative production of biohydrogen gas and removal of pollution load from Khsipra River wastewater. In this study various parameters like contact time, pH value, reactor operating temperature are considered. An anaerobic batch reactor along with at magnetic stirrer having working volume of 1.5 litres was constructed and operated for 12 days. The temperature of the CSTR was regulated at atmospheric temperature. Biohydrogen gas obtained after 12 days about 92 ml at pH value 6.0-5.6, atmospheric temperature 26±2 ºC and colour of the substrate was Dutch white.

Keywords: Kshipra River water, Biohydrogen, Fermentation, Yeast, Dark-Fermentation

1. Introduction

One of the great challenges in the coming decade is how to get new renewable energy sources that are environmental friendly and to replace high dependency on fossil fuels. Almost all of the energy needed is derived from the conversion of fossil energy sources, such as for power generation, industrial and transportation equipment that uses fossil fuels as a source of energy. Fossil fuels are source of non-renewable energy and also have seriously negative impacts on the environment (Wahab *et al*., 2014) [9]. Hydrogen gas is a clean energy source with a high energy content of 122 KJg^{-1}. Unlike fossil, fuels hydrogen does not cause any CO_2, CO, SOx and NOx emissions producing water as its only by-product when it burns reducing greenhouse effects considerably. Hydrogen is considered to be a major energy carrier of the future and can directly be used in fuel cells for electricity generation. Biological method mainly includes photosynthetic hydrogen production (photo fermentation) and fermentative hydrogen production (dark fermentation) (González *et al*., 2011) [3]. Recent reviews on hydrogen indicated that the worldwide need on hydrogen is increasing with a growth rate of nearly 12% per year for the time being and contribution of hydrogen to total energy market will be 8-10% by 2025 (Pandu and Joseph, 2012) [8]. Biological production of H_2 is one of the alternative methods where processes can be operated at ambient temperatures and pressures, and are less energy intensive and more environmental friendly (Mohan *et al*., 2007) [7].

River Kshipra originates from a hill of Vindhya range, one mile south of Kshipra village lying 12 km south-east of Indore city (M.P.), India. It flows approximately between latitude 22º49 and 23º50 N, longitude of 75º45 and 75º35. River flows across Malwa plateau to join river Chambal which later joins Gangetic system. In the present study, two study sites with high anthropogenic activities were selected on the banks of river Kshipra; these include Ramghat, and Mangalnath (Bhasin *et al*., 2015) [1]. Most of the Indian towns and cities do not have access to safe drinking water. Naturally Ground water recharged through rain water. Ground water areas that are recharged at higher rate are generally more vulnerable to pollution. Kshipra River is situated in middle of the city but now a days it become partially contaminated with sewage water (nalla) and municipal wastewater. The wastewater that flows after being used for domestic, industrial and other purposes is discharge in the river. Sewage contains water as the main component, while other constituent, and include organic waste and chemical. Sewage discharges are a major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies. The wastewater is a mixture of sewage water, agricultural drainage, industrial waste effluents etc. it is well known that the wastewater from domestic origin contains pathogens, suspended solids, and other organic and inorganic pollutants. Industrial estates are established to fulfil the demand of the growing population in the country. The introduction of industries on one hand manufactures useful products but at the same time generates waste products in the form of solid, liquid or gas that leads to the creation of hazards. Most of the solid wastes and wastewaters are discharged into the soil and water bodies and thus ultimately pose a serious threat to human and routine functioning of ecosystem. Main contributors to the surface and ground water pollution are the byproducts of various industries. High levels of pollutants in river water causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni, Pb and fecal coli form and hence make such water unsuitable for drinking, It is found that almost all rivers are polluted in most of the stretches by various industries or by other activities (Dubey, 2013) [2].

(a)

(b)

Fig 1.1: sampling site of figure (a) Kshipra river Ramghat and figure (b) Kshipra River magalnath (Kumawat and Sharma, 2015) [6].

Dark fermentation, traditionally known as anaerobic digestion, is considered as a feasible process because it generates biohydrogen from carbohydrate substrates including biomass and organic waste materials and simultaneously reduces the pollution load of the river. However, the yield of biohydrogen is relatively low, since H_2 is produced as an intermediate and can be further reduced to methane, acetate and propionate by hydrogen-consuming bacteria (HCB) during dark fermentation. Critical factors in biological H_2 production are pH, temperature, feed concentration, bacterial population, retention period, etc., (González *et al*., 2011) [3].

The major criteria for the selection of waste materials to be used in biohydrogen production are the availability, cost, carbohydrate content, organic loading and biodegradability. Simple sugars such as glucose, sucrose and lactose are readily biodegradable and preferred substrates for hydrogen production. However, pure carbohydrate sources are expensive raw materials for hydrogen production. Major waste materials which can be used for hydrogen gas production may be summarized as follows. Some biodegradable carbohydrate containing and non-toxic industrial effluents such as dairy industry, olive mill, baker's yeast and brewery wastewaters can be used as raw material for bio-hydrogen production. Carbohydrate rich food industry effluents may be further processed to convert the carbohydrate content to organic acids and then to hydrogen gas by using proper bio-processing technologies (Kargi *et al*., 2006) [5]. Lactose-rich wastewater can be found in the cheese and dairy industry wastewater. Cheese whey contains about 5% lactose, which can be a substrate for fermentation purposes (Hassana *et al*., 2009) [4].

2. Material and methods

For conducting the experimental work Kshipra river water sample was collected from near Mahakaleshwar Temple and Mangalnath Temple Ujjain Madhya Pradesh, India. The wastewater can be considered as complex in nature due to the presence of organic matter.

Table 1: Characteristics of untreated water sample

S. No.	Properties	Values	
		Ramghat	**Mangalnath**
01	pH	7.5	7.4
02	Total Solid (TS)	975 mg/l	1022 mg/l
03	Biological Oxygen Demand (BOD)	150 mg/l	150 mg/l
04	Chemical Oxygen Demand (COD)	330 mg/l	349 mg/l

(Dubey, 2013) [2]

2.1 Reagent

All chemicals used in present work were either of analytical reagent (AR) or laboratory reagent (LR) grade. Orthophosphoric acid (88-93% w/w), Sulphuric acid (H_2SO_4, 98% w/w), Hydrochloric acid HCl (98% w/w, 36N) and Sodium Hydroxide solution was used to maintained pH in the reactor.

2.2 Sample Preparation Method

After collection, the wastewater was transferred immediately to the laboratory and stored at 4 ºC. A known volume 1000 ml of Kshipra river water maintain the fermentation process was mixed with 100 ml sewage wastewater, 10 gm Yeast culture and fungus added to the requisite organic loading rate (OLR) prior to feeding and pH adjustment. The experimental work was performed in the laboratory of Chemical Engineering Department, UEC Ujjain (M.P.) India and sample test were carried out in the laboratory of Pollution Control Board, Ujjain (M.P.). Test for the pollution load were conduct as per the standard method of testing APHA (Standard method for examination of water and wastewater, 20th edition, 1998).

2.3. Batch reactor experimental setup

Lab-scale apparatus was installed in the laboratory of Chemical Engineering Department, UEC Ujjain (M.P.) India. The reactor has a magnetic pellet at the centre of a 2 axial blade turbine, which rotates about its axis with the help of magnetic force developed by a magnetic stirrer. Batch anaerobic studies were conducted in borosil glass reactor with a liquid total volume of 2000 ml and working volume of 1500 ml.

2.4 Batch mode anaerobic studies

The production of biohydrogen gas and removal of pollution load were studied by batch technique. It is evident from experimental data that H_2 production was observed in conjugation. These indicate that the Kshipra river water participated as primary carbon source in metabolic reactions involving molecular H_2 generation. The substrate in borosil glass reactor placed on magnetic stirring device for known period of time. The substrate was checked daily for pH, temperature, colour and volume of gas obtain. The balloon test was applied for the analysis of biohydrogen gas. The pH value was obtained using pH meter.

3. Results and Discussion

This Section presents the results obtained from the batch studies of biohydrogen gas production and removal of pollution load by the Kshipra river water as substrates. Industrial effluents and wastewater are one of the significant environmental problems due to their highly toxic nature, so it is necessary to have treatment of wastewater and producing valuable biohydrogen gas. The parameters studied include pH, atmospheric temperature and colour of the substrate.

3.1 Effect of time and pH on production of biohydrogen gas by using Kshipra river water as substrate

Effect of various parameters like time, Avg. Temperature, pH and colour changes during reactor operation for production of biohydrogen gas from Kshipra river water as substrate (Table No. 2)

Table No. 2: Various parameters changes during reactor operation for production of bio hydrogen from Kshipra River water as substrate.

Time in Days	Avg. Temperature in °C	pH	Gas obtained in ml	Colour
1	27.2	6.0	Nil	Peach Yellow
2	27.0	6.0	Nil	
3	27.0	6.0	Nil	
4	26.8	6.0	20	
5	26.7	5.8	30	Dutch white
6	26.4	5.8	20	
7	26.0	5.7	10	
8	23.0	5.6	5	
9	20.0	5.6	5	Bone
10	19.0	5.6	2	
11	18.0	5.6	0	
12	18.1	5.6	0	Misty Moss

3.2.1. Effect of time

Since a high rate of methanogenic activity, the hydrogen gas production was very low in the initial period of reactor operation. After 72h (3 days) of initiation period the production of biohydrogen gas was found to be around 20 ml of the gas produced. Then the biohydrogen gas production was gradually increased and it reaches the maximum of 30 ml of the gas collected in the 5th day of reactor operation (Figure 1).

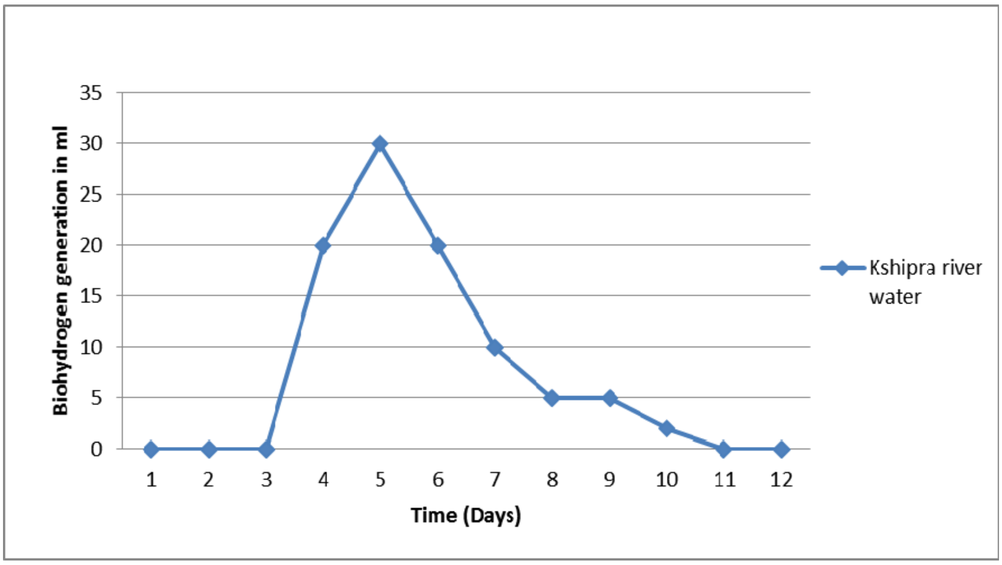

Fig 1: Effect of Time on production of biohydrogen from Kshipra river water.

The result obtained from this study effective for production of biohydrogen gas from Kshipra river water. The small Change in pH (decreases) with respect to time due to light acid formation into the reactor show in figure 2.

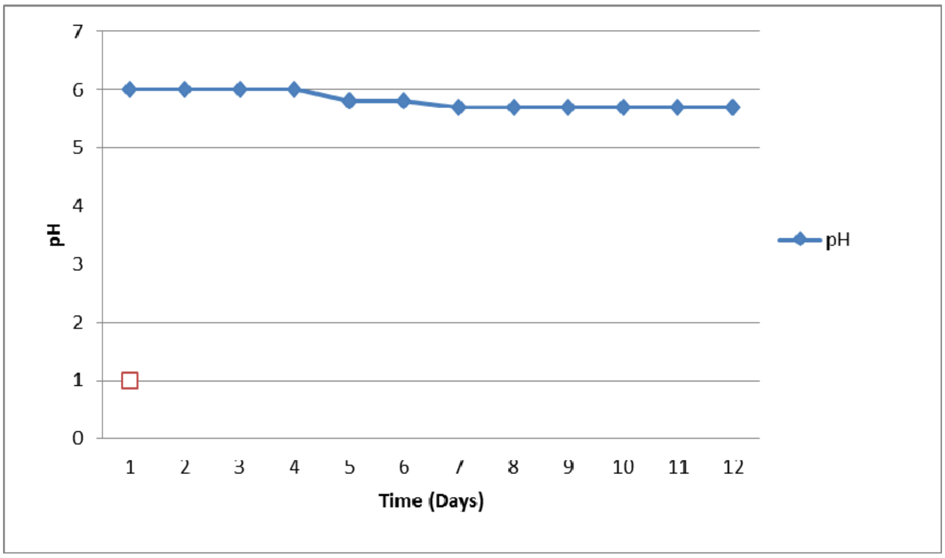

Fig 2: Change in pH with respect to time with Kshipra river water as substrate.

3.1.2 Effect of pH
Due to fermentative biohydrogen gas production where activity of acidogenic group of bacteria is considered to be crucial. pH value plays a crucial role in governing metabolic path way of organism. From literature the pH range 5.5-6.0 is ideal to avoid methanogensis.

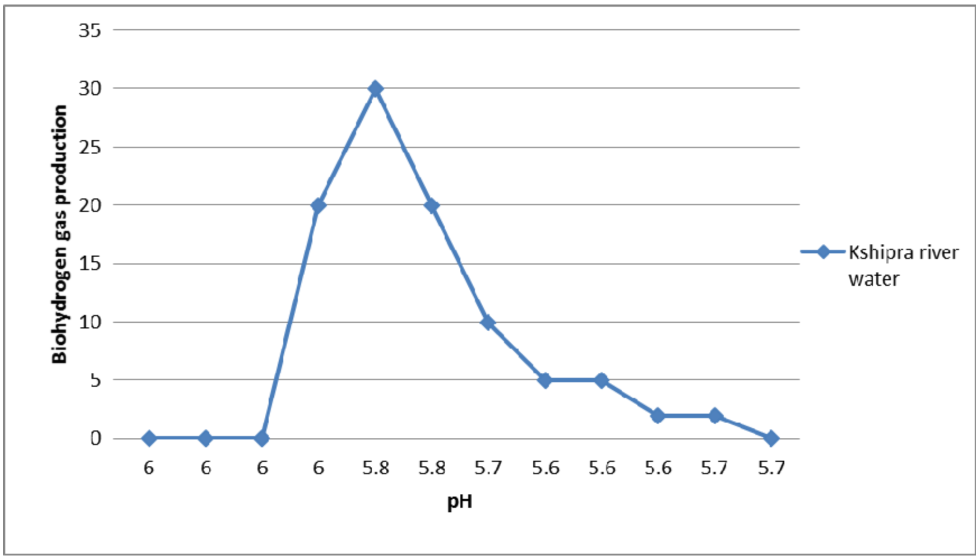

Fig 3: Production of biohydrogen gas with respect pH from Kshipra river water as substrate.

Conclusion
The study indicated that the feasibility of biohydrogen generation from Kshipra River water by anaerobic fermentation in a batch reactor. Production of biohydrogen gas and removal of pollution load is observed in Kshipra River water due to high organic matter. However, the process of hydrogen generation is found to be dependent on the OLR applied. The selected reactor operating conditions (acidophilic pH 6) were found to be for effective for biohydrogen production. The experiment results showed that maximum biohydrogen gas production (70 ml) at 4-6 days and pH value is 5.4-5.5, substrate colour show Dutch white and temperature was showed 28±2 ºC.

Acknowledgement
This work is supported by the Ujjain engineering College, Ujjain India and laboratory of Pollution Control Board, Ujjain (M.P.) India.

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