ENVIS RESOURCE PARTNER ON ENVIRONMENTAL BIOTECHNOLOGY

SUPPORTED BY:

MINISTRY OF ENVIRONMENT, FOREST& CLIMATE CHANGE

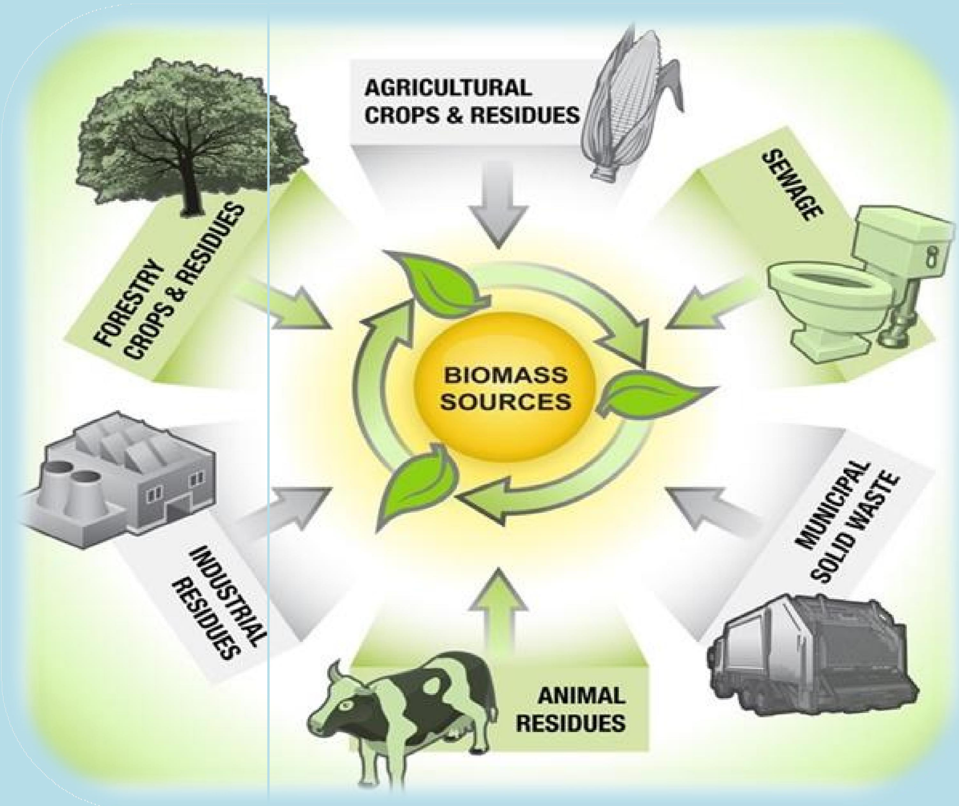
GOVERNMENT OF INDIA, NEW DELHI

ISSN : 0974 2476 Volume-35 Number-1, 2019

NEWS LETTER

ON

BIOENRGY FROM BIOMASS



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ENVIS Resource Partner on Environmental Biotechnology publishes two volumes (4 Nos.) of news letter in a year (**ISSN: 0974 2476**). The articles in the news letter are related to the thematic area of the ENVIS Resource Partner (see the website: **http://deskuenvis.nic.in**).

The format of the article as follows:

1. Font should be Times New Roman and font size to be 12 in 1.5 spacing with maximum of 3-4 typed pages.
2. Figures and typed table should be in separate pages and provided with title and serial numbers.
3. The exact position for the placement of the figures and tables should be marked in the manuscript.

Articles should be sent to
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EDITORIAL

Bioenergy is the energy derived from the natural and biological sources using different technologies, which are available on a renewable basis. The most commonly used biomass materials are crops, wood or forest residues, wastes from food crops, horticulture, food processing and wastes from sewage plants. Now days, these are the main sources of renewable energy which provides heat, electricity and transport fuel and is already making a substantial contribution to meeting global energy demand. This can contribute energy security and improving the management of resources and wastes. In addition to economic benefits, expanding bioenergy production can provide a number of environmental and societal benefits, such as job creation, improved access to energy, rural development and, more generally, new opportunities associated with the development. The bioenergy will fulfill a significant global energy demand in future.

(Ashis Kumar Panigrahi)

IN THIS ISSUE:

"**Bioenergy**" is use of any organic material, such as forest thinnings, residues, agricultural waste or urban wood waste, to generate heating, cooling and/or electricity. Though bioenergy is renewable energy created from natural, biological sources. Many natural sources, such as plants, animals, and their byproducts, can be valuable resources. Modern technology even makes landfills or waste zones potential bioenergy resources. It can be used to be a sustainable power source, providing heat, gas, and fuel.

Using bioenergy has the potential to decrease our carbon footprint and improve the environment. While bioenergy uses the same amount of carbon dioxide as traditional fossil fuels, the impact can be minimized as long as the plants used are replaced. Fast-growing trees and grass help this process and are known as bioenergy feedstocks.

Energy Generation from Wastes through Microbial Fuel Cells

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Ashis Kumar Panigrahi
ENVIS RP on Environmental Biotechnology,
University of Kalyani

Introduction

One of the major challengesof modern environmental biotechnologists or environmental engineers is waste and its degradation. Ahuge amount of organic and inorganic wastes generated worldwide, which is not easy to destroy. Although the present technologies for waste management, i.e. effluent treatment plant(ETP), trickling filter, landfill, anaerobic digester are require a huge amount of landmass, money. The microbial fuel cell (MFC) could play a main role as an environment-friendly biotechnological process for waste recovery. It was estimated that the organic fraction of wastewater contains a huge amount of unrecovered energy. Municipal, industrial, domestic, and animal treated wastewater contains approximately 17 GW of power (Logan & Rabaey, 2012). Along with this; forest and agricultural waste contribute to this insurmountable energy source. These sources were either received ill-treatment or remain untreated, but MFC could use these sources as its substrate to recover electrical energy or valuable chemicals. A microbial fuel cell is a device that microorganisms degrade substrates to recover electrons from there. A reactor is used in this method to convert chemically stored energy of various organic and inorganic substrates into electrical energy(Du et al., 2007; Logan et al., 2006, Majumder et al., 2014 a, b).

MFC comprises of two main chambers, one is the anode, and another is the cathode (Fig. 1). Microorganisms grow at the anode chamber and break down the substrate. Electron released from this process travels through the external resistor to the cathode, where it produces water with the reduction of a proton. During digestion, protons also produced in an anodic chamber, and the protons travel through a proton exchange membrane (PEM) to the cathode chamber, where it finally reduced. During this process, difference between anode and cathode potential produces electricity.

There are three types of bacterial culture used for MFC:

a) Mixed culture derived from sewage sludge.
b) Pure culture containing one type of bacteria, and
c) Bi-culture or Co-culture in which two types of bacteria applied.

Mixed culture is the most popular method because of its easy maintenance and availability. There are two types of MFC based on cathode chamber, one is a double chamber, and another is a single chamber, which does not have a cathode chamber. Despite its popularity, MFCs based on mixed cultures do not produce high power output compared to the pure culture, selection of biocatalyst is an important step to have a better efficiency. Thus, although the system follows a similar design to proton exchange membrane (PEM) fuel cells or polymer electrolyte membrane electrolyte fuel cells(PEMFC), the working principle of an MFC is not the same with PEM fuel cell. Microbial electrolysis cell (MEC) has dissimilar cathode reaction producing hydrogen compared to MFC, but MEC considers as a bioelectrochemical system (BES). Different groups call this process with different names, such as biocatalyzed electrolysis cell (BEC) and bio-electrochemically assisted microbial reactor (BEAMR). Unlike PEM fuel cells, the applications of MFCs are not constrained to electricity production. The applications of MFC system in waste management harvested bioenergy along with several environmental sustainable cost effective products, i.e. the recovery of nitrogen and phosphate, microbial desalination, conversion of carbondioxide to liquid fuels, wastewater treatment etc.

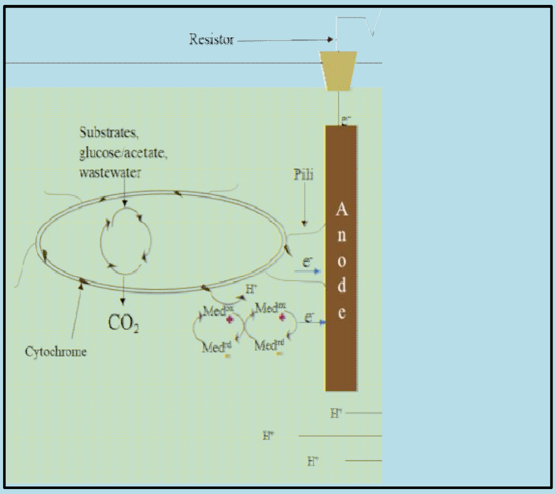

Fig. 1 Basic mechanism of a microbial fuel cell(MFC) and electron transfer process.

Scope of MFCs

The microbial fuel cell takes a multidisciplinary approach and is the confluence of electrochemistry, material science, microbiology, and environmental science. A combination of theoretical and applied science creates the research field of MFC. Basic elements of an MFC field are study of electrode material, recovery of resources, bio-catalytic study of biofilms, microbial electrosynthesis, and bioelectrochemical removal. For the study of electrode material, both the knowledge of chemical and material science is important for the fabrication of electrode. Various kinds of valuable resources and metals are possible to recover from domestic or industrial wastewater. The removal part is the biggest section of MFC research because it deals with the treatment and power production. MFC is so diverse that it could be modified to capture CO_2 from various sources. The majority of MFC papers deal with the electron recovery and treatment of wastewater, but some papers are describing the production of liquid fuel from CO_2. Anodic biofilm is the major player for the oxidation in the anode chamber, and multiple research groups focus on the study of biofilm. Some researchers study the cathodic biofilm as well.Most of the highly cited papers study the formation of biofilm and transfer of an electron from biofilm to an electrode (anode).

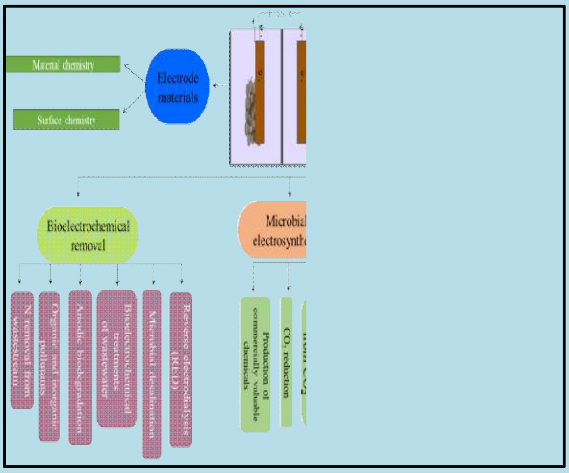

Fig. 2 Scope of MFCs

Architecture of MFCs

The basic architecture of an MFC is an H-type fuel cell composed of two chambers anode and cathode. A membrane, popularly known as cation exchange membrane (CEM), used to separate the two chambers. The most popular CEMs are nafion and ultrex. The protons that generated during the oxidation of substrates travel to the cathode chamber through the membrane leaving the electrons at the anode. The spacing of the electrode is one of the major issues.The spacing between the electrodes is a challenge for a double chamber MFC, but we can control the distance between electrodes in a single chamber. The larger the distance is less efficient. The electrodes compressed against each other to increase the surface area. Researchers found that the advantage of a large surface area is that it allows a bigger number of bacteria to colonize at the anode to increase the substrate oxidation rate. Basic components and their functionslisted in the table. 1.

Table:1 Essential components of MFCcell

Components	Material	Utility	Necessity
Cathode or Bio-cathode	Graphite rods, plates or carbon brush, cloth,	Counter electrode where terminal reaction takes place	Essential
Anode or Bio-anode	Graphite rods, plates or carbon brush, cloth	Working electrode where bacteria grows	Essential
Proton exchange membrane (PEM)	Nafion or ultrex CMI-7000	Uses for transfer of cations	Not-essential for single chamber
Electrolyte	Ferricyanide or oxygen (catholyte)	A conductive solution for submergence of electrode	Required
Cathode catalyst	Usually platinum based, but non-pt can be used	Using for increasing oxygen reduction rate at the cathode	Essential but expensive
Reactor architecture	Made of glass or plexiglass or plastics	Determines the fuel cell power output	Modified
Mediators	Anthraquinone-2,6-disulfonate (AQDS)	Facilitates electron transfer between biocatalyst & electrode	Essential or non-essential
Microbial catalyst	Microbes	Biocatalyst for degradation of substrates	Important

Types of MFCs

There are different types of MFCs designed according to the waste type and efficiency (Fig. 3). Some significant MFC types are, Single-Chamber, Double-Chamber, Upflow, Stacked, Microbial electrolysis, Soil-based, Phototrophic biofilm, Nanoporous membrane, Ceramic membrane etc. Moreover, two categories are depending upon the use of mediator, one is mediated, and second is mediator-free MFC. In the single-chamber, oxygen used as a terminal electron acceptor in the cathode chamber. Multiple units are connected either in series or in parallel in a stacked MFC. In the upflow systems, two electrodes placed vertically placing the anode at the bottom, and the influent stream passes from the bottom to top at the cathode chamber.

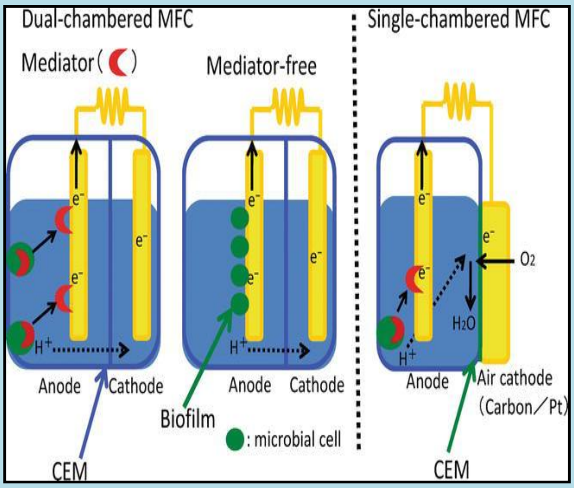

Fig. 3 Different types of MFCs (*Source:* Azuma & Ojima, 2018)

Bioelectricity or Electromicrobiology

This field of study is regarding to the special community of bacteria that transfer electrons to an electrode. This field of study focuses on electron transfer to a solid surface such as an electrode through bacteria and monitors the electrogenic performance of the bacteria. A wide range of microorganisms, including gram-negative and gram-positive bacteria, delivers electrons to the anode, listed in table 2. Researchers found this type of bacteria carries electrons to the electrode in a similar manner to the transfer of electrons to insoluble minerals. From this result, a few researchers hypothesize that bacteria derive extracellular electron transferability is a result of billions of years of evolution, which indeed opens up new fields of applications(Lovley, 2012).

There are three possible ways for the transfer of electrons from the bacteria to the electrode, such as (i) electron transfer via soluble electron shuttles,(ii)direct transfer through membrane proteins, (iii)long-range transfer via pili. Flavin, which is a popular electron-shuttle, is secreted by *Shewanella oneidensis* for the electron transfer. *Shewanella oneidensis* is one of the bacteria that has studied widely to understand electron shuttle. Another model bacteria are*Geobacter sulfurreducens*, which do not use soluble mediators, instead, it uses membrane protein, for example, cytochrome. Numerous studies indicate that c-type cytochrome, which is a membrane protein, involves in direct electron transfer. OmcZ, OmcS are few of the studied cytochrome proteins. Another mode of direct electron transfer is through conductive pili.Although this mode attracts lots of focus, reviewers raise lots of questions, which is yet to be answered.

Table:2 Some electroactive bacteria used in a single chamber microbial fuel cell

Microorganism	Efficiency
Shewanella putrefaciens Ir-1	Dissimilatory metal reducing bacteria
Clostridium butyricum Eg3	First gram+ve bacteria used in MFC
Desulfuromonas acetoxidans	Isolated from sediment
Geobacter metallireducens	Used with poised potential
Geobacter sulfurreducens	Used with poised potential
Pseudomonas aeruginosa	Finding of a mediator, pyocyanin
Desulfobulbus propionicus	Deltaproteobacteria
Geopsychrobacter electrodiphilus	Deltaproteobacteria
Geothrix fermentans	Reporting an unidentified mediator
Shewanella oneidensis DsP10	Produce power density 2W/ m^2
Shewanella oneidensis Mr-1	Produce high power
Escherichia coli	Long acclimatization period
Rhodopseudomonas palustrisDX-1	Produce high power density
Ochrobactrum anthropi YZ-1	
Desulfovibrio desulfuricans	Grows on lactate and reduced sulphate
Klebsiella pneumonia K17	
Pichia anomala	Use of a yeast

Source: Logan, 2009

Applications of MFC

The major application of MFCs is to produce power from wastewater or sludge by oxidizing the organic fraction with the help of single species or mixed community of bacteria. Another focus of MFC is to remove the organic part from the wastewater because organic part is the major player for the eutrophication of water bodies. Brewery, dairy wastewater, sugar-mill wastewater, swine, and slaughterhouse wastewater are some of the major studied wastewater. Along with, MFCs are also useful for the recovery of valuable resource such as nitrogen and phosphate. Denitrifying bacteria applies to recover the nitrogen from domestic wastewater or agricultural wastewater, which considers as a major source. Denitrifying bacteria convert ammonia to nitrate then converts into nitrogen gas, which collects from the cathode chamber.Municipal or domestic wastewater contains a huge amount of phosphate, which requires treatment. The phosphate converted to struvite through a biocatalytic process and collected in cathode chamber.

Recently, a group of researchers recovered nitrogen as a form of total ammonium from urine stream. Another application is to produce hydrogen at the cathode chamber by applying an external voltage.

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Biohydrogen as a Potential Biofuel: Present Perspective and Future Prospect

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Introduction

At present the entire world is dependent mostly on fossil fuels to fulfill the energy requirements. The fossil fuels are categorized as non-renewable energy sources and their natural stocks are finite. Every unit of their consumption reduces the volume of their natural stocks. At the same time it has also serious negative impact on the environment. During the combustion of fossil fuels the emissions of gases like the oxides of carbon, sulphur and nitrogen along with other particulate matters into the atmosphere take place causing green house effect and climate change. Over dependence on fossil fuels as energy sources is not a sustainable approach. Therefore, to achieve sustainability in energy sector focus on the development and utilization of renewable sources of energy is highly essential. In fact, in this regard lots of work has been done throughout the world as a result of which technologies for development and utilization of different renewable sources of energy have come out. These non-conventional sources include hydroelectricity, solar energy, tidal energy, wind energy, geothermal energy and bioenergy. The most important aspect of these sources is that these are all renewable, non-polluting and do not have potential negative impact on the environment as it happens in case of fossil fuels. Because of its cost effectiveness and prospects for rural communities, the biofuel has emerged as an important renewable energy source. Biogas, biodiesel, bioethanol are the different forms of bioenergy which have drawn much attentions. But focus on biohydrogen, a form of bioenergy with tremendous potential and scope, is very limited. Therefore, in this article different aspects of biohydrogen technologies including its production and utilization are discussed. Since at present the world is facing with the challenges of population rise and increasing fuel price, any effort in bringing a renewable and cost-effective method of energy production bears much significance.

Hydrogen as a green fuel

Hydrogen is a clean and renewable energy carrier. It has high energy content properties and has promising prospect as a future fuel. The molecular hydrogen has the highest energy content per unit weight (i.e., 143 GJ/ton) among the other gaseous fuels (Boyles, 1984). Since it ultimately oxidizes to water as a combustion end product, hydrogen is a carbon-free fuel. Thus, it does not contribute to greenhouse gas emission and other environmental problems like acid rain or ozone layer depletion. But the challenging issue in establishing the H_2 as a potential source of energy is the way it is produced commercially at present. According to a report H_2 is produced from natural gas reforming, refinery/chemical off-gases, coal and electrolysis in the proportions of 48%, 30%, 18% and 4% respectively (Hemaiswarya *et al.*, 2012). The classical methods that produce hydrogen for commercial uses are the steam forming of natural gas, coal gasification and electrolysis of water. All these processes are highly energy intensive and require very high temperature (>840 °C) and are also not environment friendly. Because of such predicament, there was a necessity to produce hydrogen from alternate sources that would not only be economical but also environment friendly and biohydrogen is the outcome of such needs.

Biohydrogen production processes

Biohydrogen is the H_2 that is produced biologically. The major processes through which the bio-hydrogen is produced are outlined in Fig. 1.

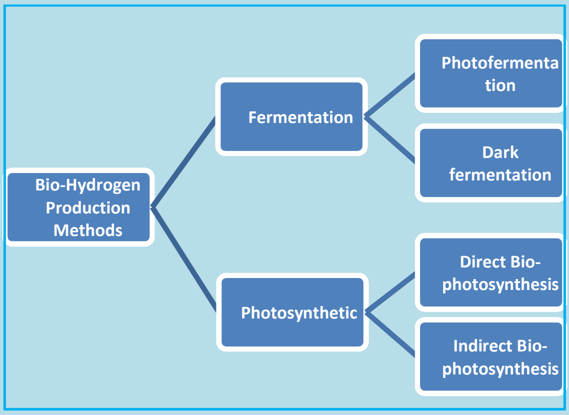

Fig.1:Methods of biohydrogen production

The major processes through which the bio-hydrogen is produced are bio-photolysis of water by algae, dark fermentation, photo-fermentation of organic materials and the sequential dark and photo-fermentation processes (Das and Veziroğlu, 2001). Different microorganisms are able to convert diverse types of renewable biomass into hydrogen. Some of these microorganisms include green algae (*Chlamydomonas reinhardii* and *Chlamydomonas moewusii*); blue-green algae (*Anabaena variabilis*, *Anabaena cylindrical* and *Oscillotoria miami* BG7); photosynthestic bacteria (*Rhodobacter sphaeroides*, *Rhodobacter capsulates*, *Rhodobacter palustris* and *Rhodospirillum rubnum*) and fermentative bacteria (*Enterobacter aerogenes*, *Enterobacter cloacae* IIT-BT 08, *Clostridium butyricum*, *Citrobacter* spY19, *Bacillus coagulans* and *Clostridium acetobutylicum* ATCC 824) (Saifuddin and Priatharsini, 2016 and references therein). The biological process of hydrogen production is fundamentally dependent on hydrogen producing enzymes which catalyze the chemical reaction $2H^+ + 2e^- \leftrightarrow H_2$. Three enzymes are known to catalyze this reaction. These include nitrogenase, Fe-hydrogenase and NiFe-hydrogenase (Hallenbeck and Benemann, 2002). In bio-photolysis processes, Fe-hydrogenase is used whereas photo-fermentation processes utilize nitrogenase.

***Biophotolysis of water by algae*:** This may of direct or indirect types. In direct biophotolysis the PS I and PS II of photosynthetic process convert the solar energy to chemical energy which is used to break down the water molecule to produce hydrogen molecule (reaction 1 mentioned below)

$2H_2O$ + light energy $\rightarrow 2H_2 + O_2$ (1)

Oxygen is a potent inhibitor of hydrogenase. Therefore, oxygen content is maintained below 0.1 % in order to increase the efficiency of the enzyme. But in case of indirect biophotolysis, the oxygen production process and hydrogen production process are separated into two stages as mentioned below in reactions 2 and 3.

$12H_2O + 6\ CO_2$ + light energy $\rightarrow C_6H_{12}O_6 + 6\ O_2$ (2)

$C_6H_{12}O_6 + 12\ H_2O$ + light energy $\rightarrow 12\ H_2 + 6\ CO_2$ (3)

***Dark fermentation*:** In this case the fermentative microorganisms hydrolyze the complex organic polymers to monomers. These are further converted to organic acids of lower molecular weight and alcohols by hydrogen producing bacteria. With carbohydrate as the feed stock, acetic acid and butyric acids are produced along with generation of hydrogen in dark fermentation process (reactions 4 and 5).

$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2$ (4)

$C_6H_{12}O_6 + 2H_2O \rightarrow 2CHCH_2COOH + 2CO_2 + 4H_2$ (5)

A variety of carbon sources can be used in this process to produce hydrogen in absence of light. Valuable byproducts like acetic acid, lactic acid and butyric acid are also produced in this process along with hydrogen. The product gas is a mixture of CO_2 and H_2 and hence it has to be separated. Further, the H_2 yield is also very low. These are the disadvantages of the dark fermentation process.

***Photo-fermentation*:** This is a fermentation process in which the organic substrates are converted into hydrogen and carbon dioxide in presence of sunlight (reaction 6). Oxygen is not involved in this process.

$CH_3COOH + 2H_2O$ + light energy → $4H_2 + 2CO_2$ (6)

The advantages of this process include removal of environmental pollutants, use of organic acids produced in dark fermentation and the industrial waste as feed stock for production of H_2. But some time the industrial effluents become toxic to the fermentative microbes which warrants it's pre-treatment.

***Two-stage dark/ photofermentative hydrogen production*:** This is a hybrid technology in which the organic acid produced during the dark fermentation is further processed through photofermentative reactions using photoheterotrophic bacteria yielding hydrogen and CO_2. In comparison to dark fermentation this process is more beneficial.

Challenges of the technology

Even though the biohydrogen has a great potential for its use as an effective alternate of the fossil fuels, there are many challenges for its production and utilization (Seshadri and Shashirekha, 2012; Gupta *et al*., 2013). The important among them are the selection of microbes (with their molecular understanding), feedstock types and their availability. The low yield and high production cost are two major challenges of biohydrogen production systems. Since the growth of the microbes inside the bioreactors is controlled by several factors, formulating the right conditions for increasing the efficiency of the processes is vital. Designing of the bioreactors with proper engineering applications for high production efficiency is equally important. After production of biohydrogen, its proper storage and efficient utilization are also challenges of this technology. During the production, carbon dioxide is also produced along with hydrogen. Therefore, there is a necessity of safe integration of hydrogen production system with hydrogen purification. Addressing all these issues is very pertinent at present to make biohydrogen as an effective alternative to fossil fuels.

Indian scenario

The prospects and potentials of hydrogen as a fuel was realized in India long back. In 2005 India's first hydrogen fuelling station, owned by Indian Oil Corporation Limited (IOCL) was installed in Faridabad. Prior to that, three wheelers were manufactured to run with compressed hydrogen gas with technical input from IIT, Delhi. In International Partnership on Hydrogen Economy, India is a founder member along with 15 other countries including USA, Japan, UK, the European Union, China and Brazil. Through the National Hydrogen Energy Road Map Programme, India has successfully demonstrated the use of hydrogen in three wheelers, motorcycles, power generators, catalytic combustion and air conditioning (Hemaiswarya *et al*., 2012 and references therein). Biological production of hydrogen from organic wastes has also been done at the laboratory scale. The Ministry of New and Renewable Energy (MNRE), Govt. of India has also been supporting R & D programmes on different aspects of hydrogen fuel technologies (Nouni, 2011). With the financial support from MNRE, Govt. of India the researchers at Defence Research and Development Organisation (DRDO) and Department of Biotechnology have developed customized bioreactors that can produce hydrogen from agricultural residues for use in fuel cells and other applications (Athalye, 2018). The researchers are now working hard for the large scale production of biohydrogen on commercial basis. However, all these achievements of India are far behind the developments on hydrogen technologies that are taking place in rest of the world.

Conclusion

The increasing energy demand of present has put tremendous pressure on the fossil fuels reserves which may create severe energy crisis in near future. To achieve sustainability in the energy sector and to control the environmental pollution caused due to fossil fuel burning, much emphasis have been given on the development and utilization of renewable sources of energy. Although hydrogen has emerged as a potential renewable energy, the conventional methods of hydrogen generation are neither sustainable nor environment friendly. In this regard, the biohydrogen has a promising prospect. It will not only reduce the cost and the pollution caused due to the conventional hydrogen production processes but also effectively use the organic wastes as raw materials. Therefore, much works have to be done to meet all the challenges of biohydrogen technology so that it can be a potential renewable and green fuel of the future creating job opportunities for the youth.

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Report of GSDP Course on People's Biodiversity Register (PBR)

ENVIS Resource Partner on Environmental Biotechnology, University of Kalyani, Nadia, funded by MoEF&CC, GoI was conducted certificate course on People's Biodiversity Register (PBR) under Green Skill Development Programme (GSDP) from 14th Nov,-20th December, 2019. The course was completed successfully under the leadership of Prof. Sankar Kumar Ghosh, Hon'ble Vice Chancellor University of Kalyani and Prof. Ashis Kumar Panigrahi, Coordinator and Training Incharge of GSDP Certificate Course. ENVIS RP, K.U trying best for the placement of participants in different organizations.

A total of **20** participants trained through the course and out of which more than **60%** were from rural West Bengal. The participants are comprises of **35% female** and **65% male** with science graduate and post graduate students. Among the students **45%** are **reserve categories.** After completion of the course, out of 20 participants there are **four participants** were already got engagement in different sectors like Instructional project work, NGO and higher studied.

Inauguration of GSDP course on Peoples Biodiversity registers

Photographs during GSDP course on Peoples Biodiversity registers

Inaugural session of GSDP course on Peoples Biodiversity registers

Prof. Ashis Kumar Panigrahi, Coordinator introduce about the course

Selection of participants for PBR course

Experts discussing about PBR in class

Experts preparing PRA tools for PBR-students

Field visit to Bethuadahari forest

Field visit by PBR students at BCKV farm

Meterological station visit at BCKV field

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FORTHCOMING EVENTS		
Events	**Date**	**Place & Correspondence**
ICEBP 2020: 14. International Conference on Environmental Biotechnology and Phytotechnology	August 27-28, 2020	Paris, France https://waset.org/environmental-biotechnology-and-phytotechnology-conference-in-august-2020-in-paris
ISER-788th International Conference on Nanoscience, Nanotechnology & Advanced Materials (IC2NAM)	July 2-5, 2020	Okinawa, Japan http://www.iceeb.org
5th International Conference on GIS and Remote Sensing	September, 16-17, 2020	https://gis-remotesensing.environmentalconferences.org/ Rome, Italy
3rd International Conference on Nanomaterials and Biomaterials (ICNB 2019)	September 10-11, 2020	https://earthscience.conferenceseries.com/about-us.php 47 Churchfield Road, London, W36AY, UK

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