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MUD POWER: HOW BACTERIA CAN TURN WASTE INTO ELECTRICITY

Monali Khadse and Shubhangi Warke*

Department of Veterinary Microbiology and Animal Biotechnology T&RC, Nagpur Veterinary College, Nagpur.

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***Corresponding author: Shubhangi Warke**

Department of Veterinary Microbiology and Animal Biotechnology T&RC, Nagpur Veterinary College, Nagpur.

ABSTRACT

Bacteria produces various types of diseases but there are some bacteria which are useful for energy production. Electroactive bacteria were unknown to science until a couple of decades ago. But now the scientists are looking for the natural electricity across the world, even on the ocean floor. It alters entire ecosystems, and may help control the chemistry of the Earth. Some anaerobic bacteria like *Geobacter* and *Shiwenella* species has the capability to harness the electricity which are present in the mud, sewage. These are the Electroactive bacteria. By linking bacterial metabolism directly with electricity production, the Microbial fuel cell (MFC) eliminates the extra steps necessary in other fuel cell technologies. It is based on the principle of redox reaction and the natural metabolism of microbes. There are different types of MFCs, but single chamber and two chamber MFC are used in mud power generation.In the MFCs there are two electrodes by which the electrons are transfer to the one anode to another anode.In single chamber MFC both electrodes are kept in one chamber in mud connecting with wires and resister,in two chamber MFC the electrodes are placed in different chambers filled with mud and water connected by the plain salt bridge. MFC act as an energy-saving technology.In other words, bacteria can be used to produce biofuels. Microbial fuel cell essentially is a solution for a renewable energy emitted by bacteria activity that need to be take a further attention , research and development.

INTRODUCTION

When we heard or read the word 'Bacteria' we may think of illness which is caused by the harmful bacteria but there are some bacteria which are useful to human being. Some bacteria which are responsible for energy generation are Electro active bacteria. These Electro active bacteria were unknown to science until a couple of decades ago. To overcome the various global challenges over the electricity, scientist are looking for the natural electricity across the world ,even on the ocean floor .It will alters entire ecosystem and may help control the chemistry of the earth.

Bacteria are present everywhere, some bacteria can respire with oxygen and some can respire without oxygen. Bacteria which are capable to produce electricity occur naturally in almost any type of mud, sewage or waste. Dry mud contains millions of bacteria. These bacteria which can generate energy that breathes without oxygen.

Naturally these bacteria, produces the energy and methane gas. To harness the electricity from bacteria there is one device called as Microbial Fuel Cell. Turning this natural process into a functioning Microbial Fuel Cell (MFC) is as simple as filling the MFC with mud, sewage or waste and waiting for the bacteria to grow. Microbial Fuel Cells (MFCs) are electrochemical devices that use Electro active microbes and mimicked bacterial interactions as biocatalysts to drive current of bioenergy. MFCs could provide a source of "green electricity" by exploiting domestic and industrial waste to generate power.

History of Microbial Fuel Cell

There are some inventers of microbial fuel cell in back ago. In 1911 B.H. Kim devoloped mediatorless MFC was a milestone in MFC,Enhanced the commercial viablity, by eleiminating costly mediator chemicals. In 1931 Burnett Cohen, created microbial fuel cells that, when connected in series, were capable of producing over 35 volts, though with a current of only 2 milliamps.In 1991 Lovley *et al*: they said that electron transport out of the bacterial cell via conductance "anodophiles".Then in 2004 Ieropoulos, Greenman, Melhuish: they invented the Stacks of small MFC to generate the energy.

Challenges

There are some global challenges over the electricity due to the increasing population, the challenges are the:

1) **Fuel issues**- In fuel issues there are failing fuel pump. The fuel pump is a non-serviceable part, meaning if it fails it will need to be replaced. There are some dirty fuel filters and some are faulty fuel injectors.
2) **Emission levels**-gloabally we emit over 36 billions tonnes of CO2 per year. CO2 concentrations in the atmosphere are at their highest levels in over 8,00,000 years.
3) **Water scarcity**- India's water crisis is often attributed to lack of government planning, increased corporate privatization, industrial and human waste and government corruption. In addition, water scarcity in India is expected to worsen as the overall population is expected to increase to 1.6 billion by year 2050.
4) **Poor quality of coal-** India's **coal**-fired **power** expansion plans are faltering, not over environmental high-ash fuel **causes** problems when it's used in state-of-the-art **power** plants. Energy Group, an Indian think tank that focuses on the issues of the poor. But those supplies generally are of low quality with high ash content.
5) **Lower performance of old power plants-** The efficiency of these plants gradually deteriorated and plant load factors (PLFs) of many units dropped to alarmingly **low** levels. Renovation of **old** thermal **power plants** is an economical and cost-effective.

What is the microbial fuel cell?

Microbial Fuel Cells (MFCs) is a bio-electrochemical device that harnesses the power of respiring microbes to convert organic substrates directly into electrical energy. Microbial fuel cell technology represents a new form of renewable energy. A Microbial Fuel Cell (MFC) is capable of generating electricity directly from a large variety of organic or inorganic compounds, using a microbe as a catalyst. Conventionally, fuel cells convert chemical energy to electrical energy, by consumption of a fuel at the anode and an oxidant at the cathode. The electrons and protons released travel through an external circuit, producing electricity. In MFCs, the anode and cathode are separated by an ion exchange membrane, and a solution consisting of organic matter.

Principle

Microbial Fuel Cells (MFCs) works on the principle of-Redox reactions-it is the oxidation and reduction type of chemical reaction here, the chemical reaction involves in the transfer of electrons between two electrode. Harnessing the energy from microbes-it is very difficult to harvest the electricity from the tiny particles but the microbes itself expels electrons which are present in the mud. This electrons converted by the substrate through bacteria which is essential for the energy generation, when it get circulate from one electrode (anode) to another electrode (cathode) through the external circuit.

Mechanism

Bacteria get this energy in a two-step process. The first step requires the removal of electrons from some source of organic matter (oxidation), and the second step consists of giving those electrons to something that will accept them (reduction), such as oxygen or nitrate. If certain bacteria are grown under anaerobic conditions (without the presence of oxygen), they can transfer electrons to a carbon electrode (anode).The electrons then move across a wire under a load (resistor) to the cathode where they combine with protons and oxygen to form water. When these electrons flow from the anode to the cathode, they generate the current and voltage to make electricity. Microbial fuel cells work by allowing bacteria to do what they do best, oxidize and reduce organic molecules.

One can produce electricity in laboratory by the mechanism of microfluidic technique. Microbes have often prove to be gift of nature, from programmed biofertilizer to being used in metabolic production. They have great adaptability to servive in warmest to coldest depth of earth. They can respire with or without oxygen, by simply pumping out of electrons. So,does this mean they can produce the electricity? Scientist believe it can be done only hardle is to harness the power from the tiny cells. The MIT engineers developed the microfluidic technique which assessed bacterial polarizability. This technique quickly processed small samples of bacteria and measure the ability to produce electricity. There is a pure range of bacteria with this ability. Bacteria produces the electricity by (EET) Extra cellular Electrons Transfer. They generate electrons and transfer through the cell membrane this technique rupture the cell membrane and denatured the proteins. Microfluidic chip has the small channel through this they flow microlitres samples of bacteria. Each channel is pinched in the middle to form configuration. When voltage is applied across the channel, It squeezes the pinched section on the electric field. There is a gradient phenomenon known as the Dielectrophoresis it is force that pushes cells against its motion into electric field. They can repel a particle of different voltages. They can quickly sort the bacteria according to size, species. In the new technique this microfluidic setup to compare various strains of bacteria which included wild type of bacteria that actively produces electricity in MFC. Very small microlitres samples of each strain passed through the microfluidic channel, they slowly amped up the voltage across the channel i.e. 1 volt per second, from 0 to 80 volts. Through particle image velocemetry they observed that the electric field propelled bacteria cells through the channel until they approaches the pinced section. Here, the mud stronger field actively pushed bacteria via. Dielectrophoresis. Some traped at lower applied voltage and others at higher voltages. Higher polarizability higher will be the production of electricity or more electro chemically active. The microfluidic technique was concluded to be an efficient and non destructive way to gauge polarizability. This could be the 1st step for clean energy generation.1 day it can be possible that the electricity you use would have been generated from a

very tiny unicellular organs.

Bacteria Used In Mfc

There are some bacteria which are responsible for producing electricity they are *Geobacter* spp. ,*Rhodoferax spp.*, *Shewanella spp.* They are gram negative bacteria with rod shape morphology. This bacteria comes in the phylum proteobacteria. These are anaerobic respiration bacterial species. They can easily respire upon the graphite electrodes. They have been found in the anaerobic conditions in soils and aquatic sediments.These bacteria respire through Extracellular Electron Transfer (EET). They expels the electrons through their body. *Geobacter* is also called as Electricigens or Iron breather. *Shewanella* is also called as Mr. Clean.This gram negative bacteria has the thin layer of peptidoglycan layer ,here the electrons and protons can easily move in extra cellular layer.

Types of Mfcs

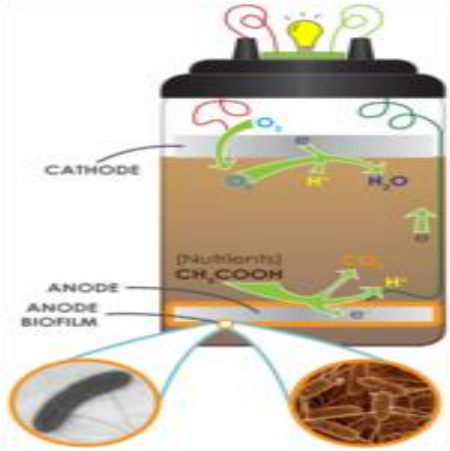
- Mediated
- Mediated-free
- Microbial Electrolysis
- Soil-based or mud based
- Phototropic Biofilm
- Nanoporous Membrane

These soil or mud based microbial fuel cell is one of the relevant and more efficient type among above all and it can set at small scale level.

MFC DESIGN

There are various designs and different configurations are possible of MFCs. Widely used is a two chamber MFC built in traditional 'H' shape various types of material can be used like plastic and stainless still with coating. Two chamber connected by a tube containing a seperator usually plain salt bridge. Material of the electrode can be of carbon or graphite.

Single chamber MFC



Mechanism of single chamber MFC- Anode and cathode separated by cathode specific membrane. Microbes at anode oxidize organic fuel generates electrons and protons. Protons move to the cathode compartment through the membrane.Electrons transferred to the cathode compartment through external circuit to generate current.Electrons and protons are consumed in cathode chamber, combining with O2 to form water.

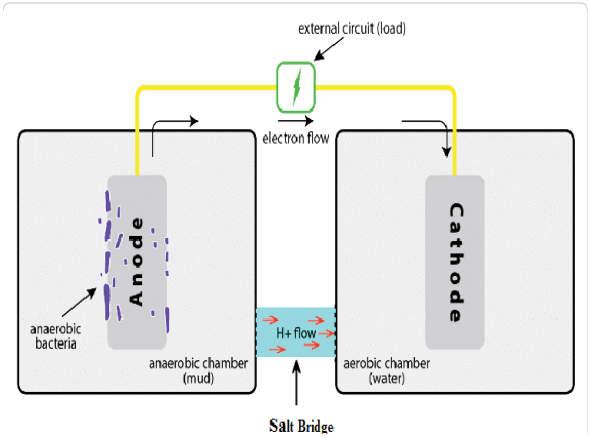
Anodic reaction

$CH_3COO^- + H_2O \rightarrow 2CO_2 + 2H^+ + 8e$

Cathodic reaction

$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$

Double chamber MFC



Mechanism of double chamber MFC – As the name indicate in this design there are two chamber which are connected by the plain salted bridge with each other. One chamber having one electrode i.e. anode and bacteria. The another chamber having 2nd electrode i.e. cathode. As the bacteria expels the electrons and protons, the protons move towards the cathode through the plain salted bridge and along with protons water is also produced. The electrons move towards the cathode through external circuit to produce the energy.

Application

1) Energy benefit

- Direct electricity generation
- Need no aeration
- Low sludge yield
- Adaptable to decentralized treatment

2) Operating stability

- Self regeneration of microorganisms
- Good resistance to environmental stress
- Amenable to real time monitoring and control

3) Environmental impacts

- Water reclamation
- Low carbon footprint
- Less sludge disposal

4) Economics

- Energy recovery
- Valuable products recovery
- Low operation cost

- Ease burden of subsequent treatment

Advantages of Mfc

- Generation of energy out of biowaste / organic matter
- Direct conversion of substrate energy to electricity
- Omission of gas treatment
- Aeration
- Bioremediation of toxic compounds

Limitations of Mfc

- Low power density
- High initial cost
- Activation losses
- Bacterial metabolic losses

Commercial available Magical Microbes Mudwatt Stem Kit: Clean Energy From Mud!

CONCLUSION

The MFCs have been explored as a new source of electricity generation. It can be used for production of secondary fuel. MFCs are individual kinds of FCs which use active biocatalysts such as microorganisms or enzymes to generate energy. Good alternative to Conventional Power Generation Systems.

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