

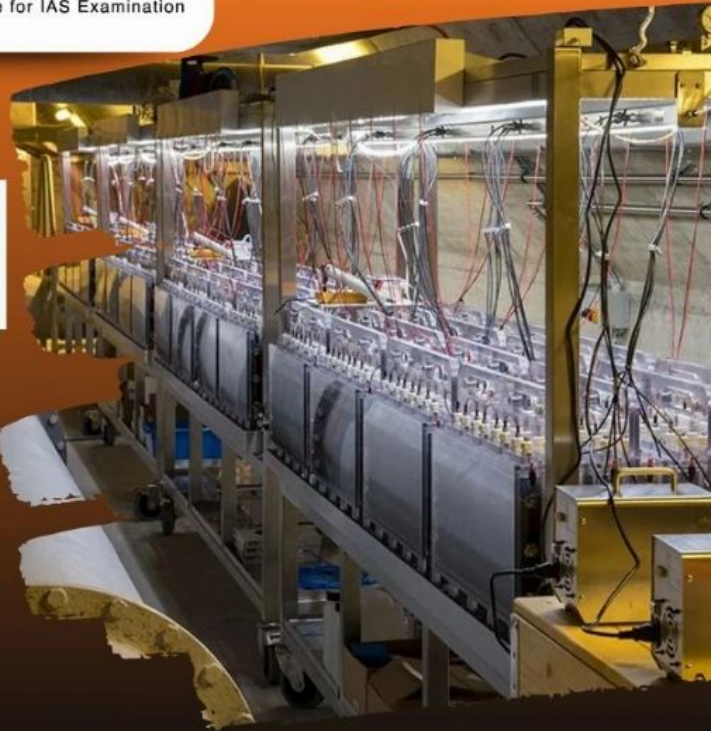
Microbial Fuel Cell

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VAJIRAM & RAVI
Institute for IAS Examination

Microbial Fuel Cell



Microbial fuel cells (MFCs) are the types of fuel cells that utilise microbial metabolism to produce electrical current using a wide range of organic substrates. They can be considered “the bioreactors that convert the energy in the chemical bonds of organic compounds into electrical energy through the catalytic activity of microorganisms under anaerobic conditions”.

Due to its potential in the production of sustainable energy from organic wastes, research on Microbial Fuel Cells has intensified in the last few years.

Microbial Fuel Cell Structure and Working Principles

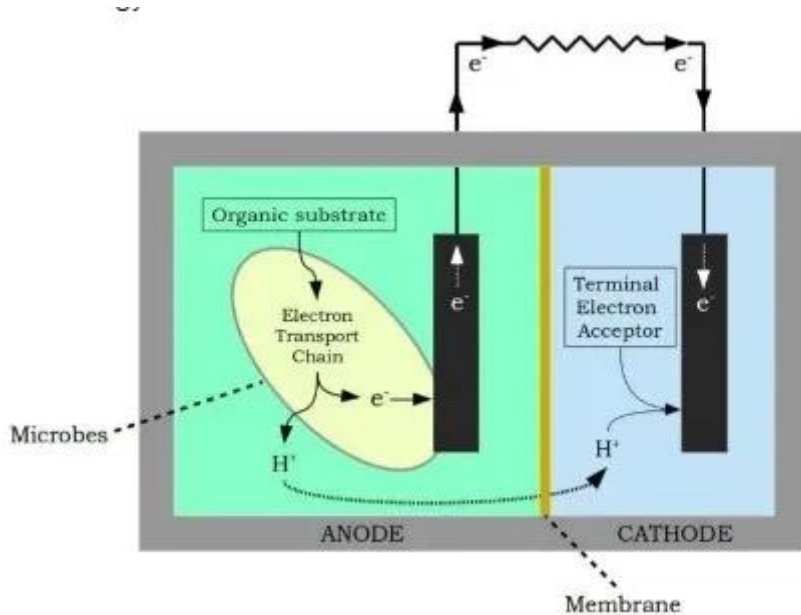
The workings of **microbial fuel cell (MFC)** technology are primarily based on the principle of redox reactions. In the MFCs, organic matter (generally waste materials) and microbes (generally bacteria) are used as substrates (electrolytes), in which electrons are generated through biochemical reactions.

- The natural metabolism of the microbes is used to generate electricity by releasing carbon dioxide (CO₂) and water in this process, which is similar to the aerobic respiration of living beings.
- MFCs can use agricultural byproducts and waste materials as a source of substrate.

- MFCs are generally **two-chambered**, but other variations such as single-chambered MFCs can be used.

The Two-Chambered MFC

The two-chambered Microbial Fuel Cell is shown below, which illustrates the workings of MFC technology.



- **Basic structure:**

- It is made up of two chambers, containing the anode and cathode separately.
- The anode is kept anaerobic and the cathode aerobic.
- The chambers are separated by a membrane, which is either a **cation exchange membrane** or a **proton exchange membrane**, as only protons are permitted to diffuse through it.

- **Working principle:**

- **Anode reaction:** At the anode, microorganisms anaerobically oxidise the substrate (fuel), thereby producing CO₂ along with protons and electrons. **Anodic Reaction:** $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} = 2\text{CO}_2 + 2\text{H}^+ + 8\text{e}^-$
- **Movement of protons:** The exchange membrane transports the protons to the cathode chamber.
- **Generation of electricity:** In order to create electricity, the electrons are moved from the anode chamber to the cathode chamber using an external electrical circuit.
- **Cathode reaction:** Protons (through the membrane) and electrons (through the circuit) are used up at the cathode, where they combine with oxygen (O₂) to form water.

Cathodic Reaction: $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- = 2\text{H}_2\text{O}$ (where $E^\circ = 1.23 \text{ Volts}$)

- **Role of Oxygen:** According to the above reactions, oxygen must be constantly consumed in order to maintain the potential for the production of electricity.

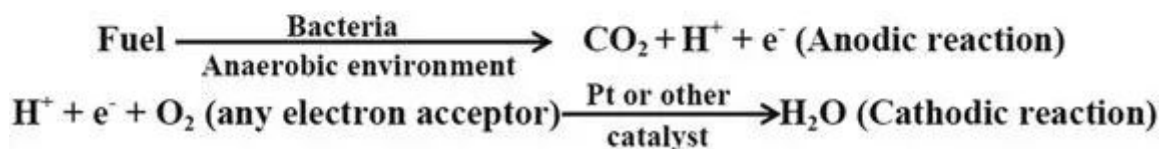
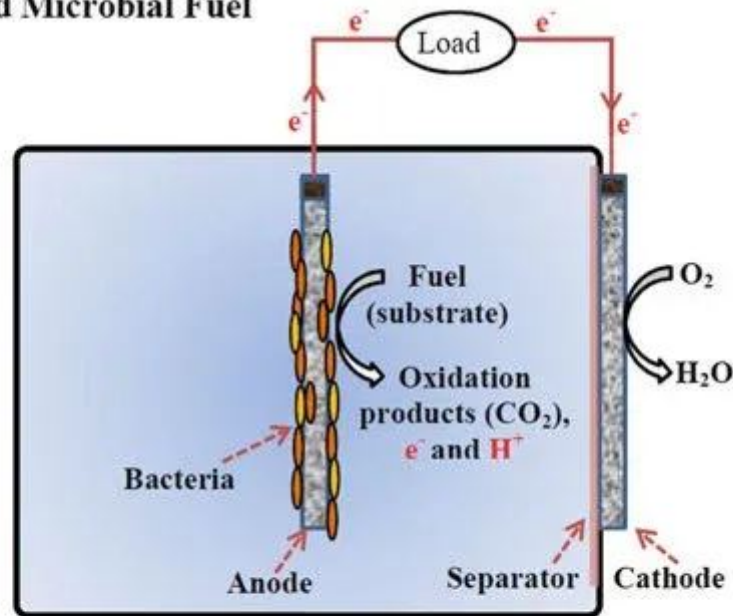
- The oxygen is supplied in the cathode chamber either by bubbling the water or by using an air cathode.
- Oxygen has the highest redox potential. As a result, it is regarded as a superior cathodic electron receiver.

Single-Chambered Microbial Fuel Cell

This microbial fuel cell design contains only one anode chamber, which is coupled with an **outer cathode (air-cathode)** to transfer protons and electrons.

- The figure below depicts a single-chambered MFC's design.

Single chambered Microbial Fuel



Advantages of Microbial Fuel Cells

The advantages and disadvantages of microbial fuel cells are described below.

- **Alternate source of energy:** MFCs use easily available **microbes as catalysts** and organic **waste materials as fuels**.
 - MFCs, therefore, can be proven to be an **alternate and renewable source of energy**.
- **Biodegradation/bioremediation of wastes:** The functioning of MFCs can be used as bioremediation or biodegradation.
- **Minimising wastewater discharge:** MFCs can address the issue of direct wastewater discharge into the environment.
- **No need for infrastructure:** Unlike other fuel cells, MFCs do not require dedicated infrastructure in production as well as distribution.
- **Better than enzymatic fuel cells:** Compared to enzymatic fuel cells, MFCs can harvest up to 90% more electrons from the bacterial electron transport system, demonstrating their high conversion efficiency.

Applications of Microbial Fuel Cells

The applications of Microbial Fuel Cells are limited to specific sectors now, which can be transformed to wide use as research and development proceeds. A few applications of MFCs are:

- **Powering underwater monitoring devices:** Devices intended to monitor underwater environments like rivers may be powered by Microbial Fuel Cells, where it is difficult to regularly access the system to replace batteries.
- **Power supply to remote sensors:** Chemical sensors and telemetry systems powered by batteries may be expensive and time-consuming. Using self-renewable power supplies, like MFCs, which can run for a long time using local resources, is one potential solution to this issue.
- **Biological Oxygen Demand Sensing:** Utilising Microbial Fuel Cell technology as a sensor for in-situ monitoring and controlling pollution is another potential application.
 - MFCs may be used as BOD sensors due to their efficiency in assimilating organic contaminants in wastewater.
- **Green-Hydrogen Production:** Modified MFCs that run on organic waste can be used to produce green-hydrogen.
 - The term "**bio-electrochemically assisted microbial reactors**" (BEAMR) refers to these modified MFCs.

Even though MFC technology holds great promise as a renewable energy source, it will take some time before large-scale and efficient MFCs are available for common usage. Given ongoing global endeavours for alternative energy, research groups across the world will definitely overcome the current limitations of Microbial Fuel Cells, like **low power output**.

Source: <https://vajiramandravi.com/upsc-exam/microbial-fuel-cell/>

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