Bioelectricity generation by proton exchange membrane-based microbial fuel cell from sewage substrate

Electricity production from renewable resources without net carbon dioxide emission is much desired[1,2]. The microbial fuel cell (MFC) technology represents an alternative form of energy wherein wastewater and industrial effluents are used for electricity generation[3]. Microbial production of electricity may become an important form of bioenergy in the future because MFCs offer the possibility of extracting current from a wide range of soluble or dissolved complex organic wastes and renewable biomass[4]. It has been known for many years that it is possible to generate electricity directly using bacteria to break down organic substrates. The recent energy crisis has reinvigorated interest in MFCs among researchers as a way to generate electric power or hydrogen from biomass without a net carbon emission into the ecosystem[5].

Energy is stored by microorganisms and used for their growth. A typical MFC consists of anode and cathode compartments. In the anode compartment fuel is oxidized by microorganisms, producing electrons and protons. The electrons are transported to the anode from inside the microorganisms by a mediator, and flow to the cathode is through a copper wire[6]. A proton/cation exchange membrane (PEM/CEM) can be used to separate the cathode and anode liquids into different chambers, or to just act as a barrier that keeps materials other than protons from reaching the cathode[7]. Electric current generation is made possible by keeping bacteria separated from oxygen, but allowing the bacteria growing on the anode to transfer electrons to the counter electrode (cathode) that is exposed to air[8].

The present set-up consists of two chambers, one anaerobic (anode) and the other aerobic (cathode). In the anaerobic chamber, substrate is oxidized by bacteria and electrons are transferred to the anode directly from the bacterial respiratory enzyme to the electrode. The anaerobic chamber is connected internally to the aerobic chamber by PEM and externally by a wire that completes the circuit. In the aerobic chamber, electrons that pass through the circuit combine with the protons and oxygen to form water.

The dual-chamber MFC was constructed with anodic and cathodic chambers. Anode and cathode were made of carbon electrodes of the same size (8×1.5 cm) with a surface area of 123 cm^2. The two chambers were separated by a PEM (Nafion 117, Dupont Co., USA). The effective liquid volume of the anode and cathode chambers was 1000 ml. Cathode chamber was filled with 1000 ml of tap water. The MFC was operated in batch mode at room temperature. For quick start-up, the MFCs were inoculated with 1000 ml of sewage water obtained from the inlet of the primary filter with diverse electrochemically active bacteria. The anaerobic sludge was collected from the Sewage Treatment Plant (100,000 m^3 capacity) at SRM University, Chennai, India. The source of the plant includes waste from laboratories, toilets, etc. The natural consortium present in the sewage water was mainly used in all studies. The substrate was added to the anodic chamber and was completely sealed to maintain anaerobic condition. PEM of size 3.5 cm^2 was placed between two flanges in order to separate the two chambers of the bioreactor. A copper wire was used to connect the circuit and all exposed metal surfaces were sealed with non-conductive epoxy resin. An external circuit was established by connecting a multimeter which measures the voltage and current across the cell.

A batch configuration was employed. The set-up was left undisturbed for 30 days and the results were recorded once every 24 h for 25 days. Based on this prototype, five PEM MFCs were built and the current output of each set-up was recorded. Further, in order to increase the current and voltage output, five individual units were stacked in a series connection. The current and voltage readings were taken once every 24 h for 25 days.

The voltage output obtained from each MFC was in the range 0.6–0.85 V when measured individually. The maximum current obtained from PEM MFC was 0.55 mA at the maximum voltage of 0.85 V with the current density of 44.71 mA/m^2. Figure 1 shows current generation by the five PEM MFCs with respect to time in days, with a maximum current of 0.55 mA produced using sewage water as the substrate. The maximum current obtained in the series circuit was 0.45 mA, but the voltage produced was significant. The maximum voltage obtained after stacking five MFCs in series was found to be 3.54 V (Figure 2).

The feasibility of operating an MFC has been demonstrated using a batch mode. In the present study, electricity was successfully generated with sewage

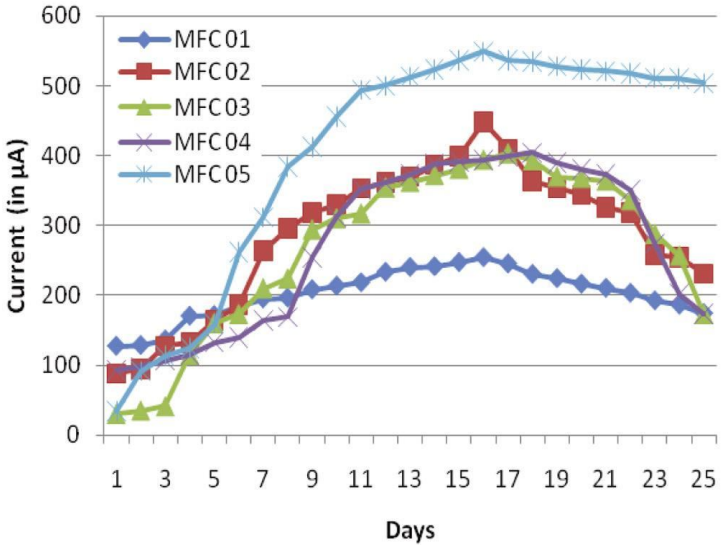
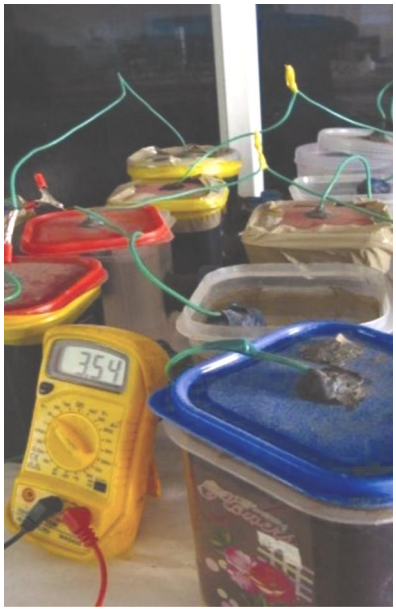


Figure 1. Current generation with respect to time in days by various photon exchange membrane microbial fuel cells.



Figure?????? Stacked microbial fuel cells showing 3.54 V.

water using MFC technology. The PEM MFCs constructed were able to efficiently utilize the sewage water for electricity production. The PEM MFCs showed better power output in comparison to the salt bridge, as PEM reduces the oxygen leakage.

When MFCs were inoculated with the sewage-water sample, there was about 24 h lag phase followed by an increase in the current output. The initial increase of current here can be attributed to the presence of components that are easily utilized by microbial consortia present in sewage water. When these easily degradable substrates were exhausted, the current output began to decrease. The fact that oxygen limitation was observed at high dissolved oxygen concentration is believed to be due to the poor oxygen reducing activity of the electrode used, i.e. graphite[9].

To increase the overall stack voltage or current, the five individual MFCs (MFC 01–MFC 05) were respectively connected in series circuit. Variation in the voltage after stacking the MFCs in series circuit was reported at regular time intervals. The amount of current obtained was less, maybe due to the internal resistance of each PEM MFC. The results have shown that MFCs are not dependent on mediator or any catalyst. Mediators were avoided due to their increased toxicity and to reduce addition of chemicals to the cell. Good performance of stacked MFCs is a promising result for employing them in practical applications. However, if more MFCs are to be stacked, bipolar plates will be required to provide electrical conduction and mass separation.

This paper demonstrated the use of stacked MFCs (in series) to produce power at enhanced voltages which could light a 3 V LED bulb. The high power output obtained could be maintained for at least 6 h under stacked condition. The MFC technology is still in the early stage of development. Further, efforts should be made for optimization of various parameters in order to enhance the power output.

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