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Research Article

PRODUCTION OF ELECTRICITY FROM WASTEWATER USING A DOUBLE CHAMBERED MICROBIAL FUEL CELL CONTAINING GRAPHITE FROM PENCILS AS ELECTRODES

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ABSTRACT
Renewable and clean forms of energy are one of the major needs at present. Microbial Fuel Cells (MFC's) offers unambiguous advantages over other renewable energy conversion methods. Without any transitional conversion into mechanical power,fuel cells transmute chemical energy directly into electricity. Tests were conducted using Double Chambered-Microbial Fuel Cell (DC-MFC) containing graphite from pencils for both the electrodes in various numbers in anaerobic condition to find the amount of current produced, based on the increasing numbers of electrodes .The prime aim of this study is to construct a MFC'swithinexpensive materials and without using toxic mediators and thereby using them in wastewater treatment plants in the economical notion. The designed MFC (graphite electrodes from pencils) employing mediator less and membrane less anode and cathode was evaluated at conditions using anaerobic mixed consortia to specify the impact on the operation of the MFC in terms of current generation from anaerobic wastewater treatment.

Key Words: *Double Chambered Microbial Fuel Cell, Wastewater Treatment, Mediator Less*

INTRODUCTION
The need for energy in India increases every year, as there is continuous step up in the cost of fuels and also the depletion of fossil fuels to a higher extent. Microbial Fuel cells are categorized into two different types: biofuel cells that generate electricity from the surcharge of artificial electron shuttles (mediators) and microbial fuel cells that do not require the add-on of mediator. These fuel cells converts energy from one form to another and will continue to operate as long as fuel is fed to it .But a fuel cell does not store energy like a battery. Fuel cells convert chemical energy directly into electricity without a transitional conversion into mechanical power. The benefits of using fuel cells include: clean, safe, noiseless, high energy efficiency, low emissions, and ease in operating. Biofuel cells use biocatalysts for the translation of chemical energy to electrical energy (Allen *et al.*, 1993).The fuel cell is a device which uses traditional electrochemical technology to convert the energy produced either from a microbial metabolism or enzyme catalysis into electricity. The biological catalysts, say the microorganisms or redox-enzymes aids in the transfer of electrons between the inorganic or organic fuel-substrateand the surface of the electrodes, thereby enhancing the cell current.
The MFC usage in waste water treatment leads to two main benefits. Firstly, the contaminants present in the wastewater serves as an eternal source for carbon. Secondly, the diminution in energy consumption; as the energy obtained from the removal of contaminants could be used to power up the wastewatertreatment processes. With high prospective application of MFC's in wastewater treatment processes, remarkable work have been put in to increase the power output of MFC's. MFC's which has catalyst coated with specific substances such as platinum (Moon *et al.*, 2005) Mn (IV) and Fe (III) (Park *et al.*, 2003) are being developed and used for higher power output. The bacterial strains such as *Geobacter sulfurreducens* (Bond *et al.*, 2003), *Shewanella putrefaciens* (Kim *et al.*, 1999), *Rhodoferax ferrireducens* (Chaudhuri *et al.*, 2003), have been found to directly transfer electrons to anode surfaces without adding artificial mediators.There are three major obstacles for increasing the power generation in MFC's. First, the power generated inside MFC's are consumed by the internal resistance and thus it

causes low energy conversion efficiency (Mench *et al.*, 2001). Second, limitation in power generation due to low efficiency of electron transfer from bacterial cells to anode surfaces. Although several mechanism of electron transfer have been studied such as direct electron transfer to anode (Liu *et al.*, 2004), indirect electron transfer with soluble mediators (Kim *et al.*, 2002), there is no efficient method to improve the electron transfer efficiency inside MFC's. Third, the high cost of electrode materials, Proton Exchange Membrane (PEM) and electron donors/acceptors hinder the application of MFC's. Cost-effective materials should be explored to improve power generation of MFC's .

Mediator Less MFC

The microbial cells are inactive electrochemically. In this case, they require the aid of mediators to facilitate electron transfer from microbial cells to electrode. Therefore any organic or inorganic or a mixture can serve as a fuel given that they are oxidized by the appropriate organism (Jang *et al.*, 2004). The general reaction can be put forth as follows

$$C_6H_{12}O_6 + 6H_2O \; 6CO_2 + 24e^- + 24\,H^+ \qquad \longrightarrow$$

It has been shown that specific metal-reducing bacteria,belonging primarily to the family *Geobacteraceae* and *Shewanella* speciescan directly transfer electrons to electrodes using electrochemically active redox enzymes, such as cytochromes on their outer membrane (Dawn *et al.*, 2009). These microbial fuel cells does not need mediator for electron transfer to electrodes and are called as mediator less MFC's.Mediator less MFC's are considered to have more mercantile application potential,because mediators used in biofuel cells arecostly and can be lethal to the microorganisms. The schematic diagram of mediator less MFC is shown in the Figure 1. In a MFC, two electrodes (anode and cathode) are placed in two compartments separated by a salt bridge. Most studies have used electrodes of solid graphite (Bond *et al.*, 2003), graphite-felt (Chaudhuri *et al.*, 2003), carbon cloth (Liu *et al.*, 2004) and platinum coated graphite cathode electrode (Jang *et al.*, 2004). Microbes in the anode compartment oxidize fuel (electron donor) generating electrons and protons. Electrons are transferred to the cathode compartment through the external circuit, and the protons through the salt bridge.Electrons and protons are consumed in the cathode compartment reducing oxygen to water.

MATERIALS AND METHODS

Substrate Collection-Wastewater

The local domestic wastewater used as substrate in anode compartment of fuel cell was obtained from the SRM University's Wastewater Treatment plant (100000 cubic meter capacity). The source includes the waste from hostels, mess, toilets etc. The inlet of the lamellar filter served as the substrate. This phase was specifically selected to shun the coarse and large particles found in the raw waste water. Characteristically, pH of the waste water was 7.58. The natural microbial consortium present in the waste water was used in the study without any addition or inoculation of microbes into it.

Table 1: Composition of Domestic waste water as mentioned in *Treatment Disposal Reuse, Wastewater Engineering*

Contaminant :	Total solids	Solids	Volatile	Suspended	BOD	COD	Nitorgen	Phosphorous	Alkalinity
Domestic waste: Conc (mg/L)	720	365	220	165	220	500	40	8	

MFC Components

Microbial Fuel Cell is composed of various substances like electrodes, anode and cathode chamber and salt bridge. The substrate and the biocatalyst-microorganisms are part of the anodic chamber . The exchange of ions (protons) between cathodic and anodic chamber is aided by salt bridge. Graphite from pencils were used as anode and cathode.

MFC Construction

The Double-Chambered-Microbial Fuel Cell (DC-MFC)consisted of a plastic containers of capacity 1.2 liters served as the anodic and cathodic chambers (Fig 2).The anode chamber contained the substrate and the graphite electrode (anode ~9cm^2). A similar graphite electrode which was used as anode served as cathode. Salt bridge(Image not shown) used here was made with 5M NaCl and 10% Agar. The salt bridge were casted in a PVC pipe (12 cm X 2cm). Each chamber was provided with wire pointinputs (top).Electrodes were soaked in deionizedwater for 24 hrs.Copper wires were used as a contact from electrodes and connection between the electrodes and copper wires was sealed with adhesive tape.

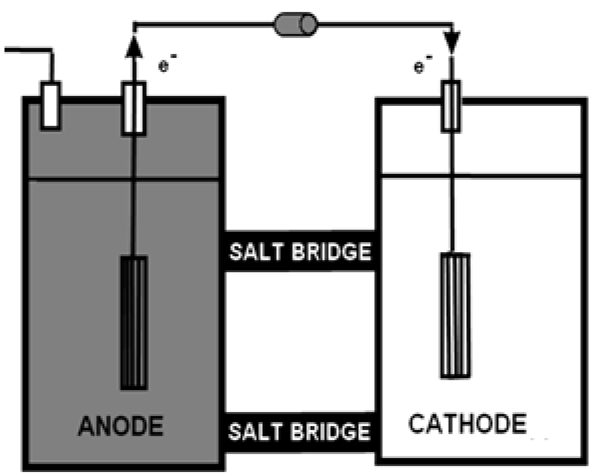

Figure 1: Schematic Representation of Dc-Mfc Using Graphite from Pencils as Electrodes

Figure 2: DC-MFC setup and the arrangement of graphite from pencils as electrodes

MFC Operation and Output Measurement

The substrate (waste water) was added in the anodic chamber.The anodic chamber was completely sealed to maintain anaerobic condition.A batch configuration was in use and readings were taken for a period of 30 days. The readings were taken on a daily basis. The output of the MFC was expressed by means of current (μa). A multimeter was used and was calibrated each time before use. Readings from the multimeter were noted only after a steady and constant value was obtained, which took 2-4 hours.

RESULTS AND DISCUSSIONS

The influence of MFC configuration is majorly on power generation. The physical characteristics of the MFC's (i.e., the size of electrodes, electrode spacing and presence of salt bridge) represent the MFC configuration. The modification of MFC configuration was aimed at increasing power generation. In this study, we have designed MFC's employing low-cost materials without using toxic mediators, which will have possibility to be put into operation in the wastewater treatment plants in the economical viewpoint. The designed MFC (graphite electrodes from pencils) employing mediatorlessand membraneless anode and cathode was evaluated at conditions using anaerobic mixed consortia to enumerate the influence on the performance of the MFC in terms of bioelectricity generation from anaerobic wastewater treatment.Therefore, three types of MFC design were compared in this study based on the variation in the number of electrodes used per operation. In the very first setup of 10 electrodes each in both anode andcathode, which resulted in the maximum current production of 226 µa and in parallel by using 20 graphite electrodes and 30 graphite electrodes, maximum current production was about 248 µa and 269µa respectively.

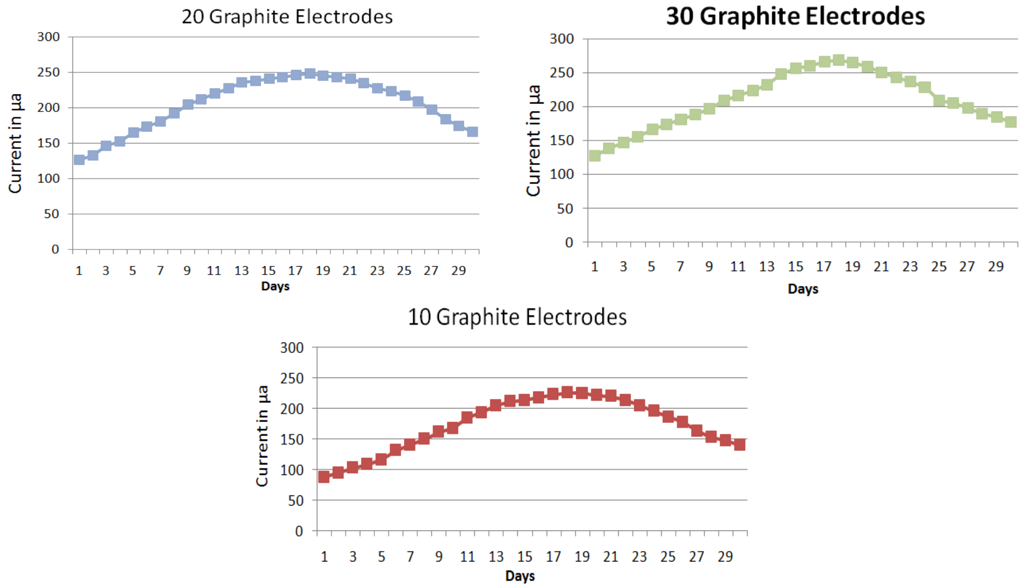

Figure 3: Graphical Representation of Current Generated from Dc-Mfc Using Varying Number of Graphite from Pencils as Electrodes with Respect to Time (Days)

Influence of MFC Configuration on Power Generation

The physical characteristics of the MFC's such as the size of electrodes, electrode spacing, and the presence or absence of membrane and mediators represent the MFC configuration. As mentioned earlier, we have designed this MFC with the absence of membranes and mediators. This modification ofMFC configuration was aimed at increasing power generation with economical viewpoint and to increase the time period of power generation.For the first 10 days, operation of MFC was without any modifications. After 10 days, the sludge was removed, heated and the same was added back into the anode compartment.The sludge was heated ina water bath at 90˚c for 5 minutes to curtail the activity of methanogens.More exactly,the growth of methanogens could be attributed to the deceleration, thus reducing the availability of electron and proton, hence reducing current. This particular step has boosted up and enriched the electrochemically active microbes for operating MFC. Moreover no microbial addition was carried out in either of the compartment in all cases.

Influence of Microbial Biomass on Power Generation

The latter plodding decrease in current production was observed after 23 days.This is because of the decreased activity of microbes due to the absence of nutrients or the decline phase of microbes life cycle.Several imperative questions remain unanswered concerning the activities in the anode compartment of MFCs. Consequently, what processes within the bacteria can be changed to perk up the MFC performance? Is the gush of electrons from the microbes to the anode limiting? Analysis of metabolic pathways in the microbes to increase electrical output can be aided through the use of metabolic engineering. Using metabolic engineering, it is possible to determine whether power enhancement is possible. If enhancement is possible, then metabolic engineering may be used to identify the pathways to be manipulated that are likely to provide the best results.

CONCLUSIONS

This peruse recognized the likelihood of bioelectricity generation from anaerobic wastewater treatment using a DCMFC fabricated with low-cost anode materials (pencil graphite as electrodes), without any toxic mediators. Moreover, power was generated utilizing low-cost and non-coated electrodes and mediator less anode. This process could be effectively integrated to wastewater treatment plant, wherein renewable energy could be generated from wastewater in addition to treatment. The ability to convert the organic material in wastewater directly into bio-electricity is striking phenomenon, but understanding of the microbiological fundamentals and further advancement of technology is required. With habitual and stable improvements in microbial fuel cell, it will be possible to increase power generation and their production and operating cost can be lowered. Thus, the grouping of wastewater treatment along with electricity production may help in saving billlions of money as a cost of wastewater treatment.

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