Parametric Effect during Power Generation from Sewage Sludge Using Prototype MFC

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RECEIVED ON 03.06.2014 ACCEPTED ON 30.12.2014

ABSTRACT

Pakistan like other countries is also faced with energy crisis, for which there is a need to identify indigenous technologies along with renewable energy sources to satisfy the energy footprint of the country. Use of MFC (Microbial Fuel Cell) technique is currently a step towards this direction that can play an effective role in solving the dual problems of environmental pollution and energy shortage. In this study, sewage sludge from a wastewater treatment plant was collected and used as a substrate for electricity generation in association with other biomass sources. Effect of relevant parameters such as oxygen flow rate, pH and concentration on voltage generation was also analyzed. The experimental results yielded in voltage generation of 2500 mv/l for sewage sludge in comparison to that obtained using carbon manure (270 mv/l), wastewater (229 mv/l) and cow manure (330 mv/l) suggesting towards the potential of sewage sludge for power generation.

Key Words: **Sewage Sludge, Microbial Fuel Cell, Biomass, Power Generation, Renewable Energy.**

1. INTRODUCTION

The concept of renewable energy generation is pre-eminent nowadays and use of MFC technology is very popular in this regard. In MFCs various energy-containing waste materials are utilized to harness the leftover energy (mostly electrical), thus rendering the material as innocuous to the environment [1]. Energy reclamation from waste materials including sewage sludge is a definite solution to deal with the issues of energy shortage and environmental concerns regarding waste treatment [2]. MFC technology is also comparatively cost-effective, easy to operate and optimize the process parameters with higher scope for the process scale-up. Various parameters are worked upon during the running of MFC such as oxygen flow rate, pH and organic loading or substrate concentration, which is very much important as higher percentage of substrate will likely have negative effect on the power generation [3]. For oxidation reactions to occur in MFCs abiotic cathodes such as Platinum or catholyte are used. In addition, bio-cathodes along with potassium ferrricyanide as electron acceptor are also used especially in chamber MFCs for possible higher generation of electricity in relation to potential decrease in COD(Chemical Oxygen Demand) of sewage sludge [4-5]. In a typical two-chamber MFC consisting of cathode and anode chambers, the input

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waste material such as sewage sludge is introduced in cathode chamber first for sludge stabilization before its entry into anode chamber for the required function of electron transformation resulting in electricity generation. However, aerobic sludge pretreatment in the cathode chamber resulted in the increased profile of two MFC components such as power density and voltage output [6]. In case of an MFC with a single air-cathode chamber, the waste material was almost always pretreated first before its introduction into the said MFC. However, this pretreatment of waste material concomitantly resulted in the decrease of parametric concentration of TSS (Total Suspended Solids) and VSS (Volatile Suspended Solids)as well as increasing the pH, conductivity, soluble COD and volatile fatty acids. Considering this increased profile of pH and COD, and for optimized proportion of these parameters in sewage sludge the pretreatment supernatant is subjected to dilution with the primary effluent before it is processed in MFC. However, the addition of buffers such as phosphate buffer to the pretreatment supernatant results in increase in MFC power density [7].

The objective of this work is to study the potential generation of electric power from sewage sludge using double chamber MFC in comparison with other biomass sources including wastewater, cow manure, carbo manure to analyze the process efficacy in this regard.

2. METHODOLOGY

2.1 Materials

Sewage sludge was collected from local wastewater treatment plant. The amount of sewage sludge used in the MFC was one liter. The presence of autochthonous biota in the sludge along with the inoculum of allochthonous bacteria sp. saccharomyces cerevisiae was taken as a source of biocatalyst in MFC in terms of power generation as a result of their typical functional activities during the process. M9Saccharomyces cerevisia or baker yeast (Sigma Aldrich) was purchased from local market in Karachi from which the desired inoculum of 0.5N was prepared as per the standard method 110^0C [8].

2.2 Microbial Fuel Cell and its Operation

A lab-scale double chambered MFC was designed to carry out the relevant experimental work. Fig. 1 shows the real camera image of the MFC constructed in the lab. In the anodic chamber aerobic conditions were maintained containing substrate and biocatalyst in it, whereas cathodic chamber contained salt water [6]. Electrodes were used to transfer the electrons along with the salt bridge to transfer the protons from cathodic to anodic chamber. The salt bridge was made from agar and common salt. Air was supplied in the cathodic chamber to oxidize the proton coming from anode chamber. The external circuit was used for the transfer of electrons coming from anode chamber. Sampling holes were made on the lids of MFC containers for the collection of processed samples via pipetting from inside MFC for their analyses. Table 1 shows the characteristics of double chamber MFC.

2.3 Experimental Analysis

All the experiments, carried out in triplicate, were performed in the Department of Chemical Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan. Different parameters were analyzed to monitor the experimental process, which included the following:

2.3.1 pH

pH was analyzed using direct reading pH meter to maintain the desired conditions for microbial growth and their activity. In case of increase (>8.5) or decrease (>6) in the pH value, it was adjusted via the addition of an alkali or acid in the chamber.

FIG. 1. CAMERA IMAGE OF PROTOTYPE MICROBIAL FUEL CELL

TABLE 1. CHARACTERISTICS OF DOULBE CHAMBER MFC

Parameter	Height (in)	Dia (in)	Length (in)
Cathodic Chamber	14	8	-
Anodic Chamber	14	8	-
Salt Bridge	-	3	5

2.3.2 Oxygen Flow Rate

Oxygen flow rate was analyzed with the help of flow meter to maintain the aerobic conditions in the cathodic chamber of MFC.

2.3.3 Voltage Generation

Generation of current was monitored using a multimeter. Under varying concentration and changing pH, the process was monitored in terms of power generation. The calculations for current (I) values were based on the standard formula of I=V/Re, where Re stands for the external resistance, whereas, power (P) value was obtained with the help of equation P=IV [9].

3. RESULTS AND DISCUSSION

3.1 Electricity Generation from Sewage Sludge

Maximum power generation was observed after 140 min operation of the process when 2500 mv/l of the current was recorded followed by the gradual decline taking place after that (Fig. 2). This decline in power output was probably due to the decrease in the cell growth resulting in the likely decrease in their functional activity thus production of reduced current. The MFC treatment of sewage sludge likely resulted in the total organic carbon concentration to be utilized by the bacteria for the production of electric power [10]. In the anode chamber of MFC, inherent and/or inoculated biota oxidize the organics in the absence of oxygen resulting in the production of electrons and protons. The transformation of electrons take place in the cathode chamber via an external circuit inducing the production of water molecules as a result of the combination of electrons, protons and electron acceptor or external oxygen from air [11].

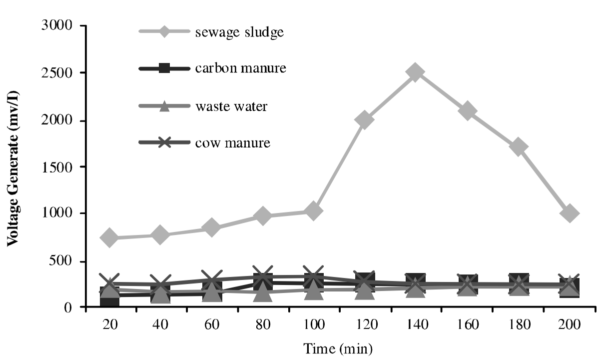

FIG. 2. POWER GENERATION PROFILE VERSUS TIME

3.2 Effect of Oxygen Flow Rate on Voltage Generation

Power generation was studied under different flow rates of oxygen to know about the effect of oxygen flow rate on electricity generation. Fig. 3 shows the voltage generation versus varying oxygen flow rate. The data in the Fig. 3 suggests that increase in voltage generation was recorded up to 2500 mv/l when the oxygen supply was in the range of 35-45 ml/min. This implies that almost 190% rise in the voltage production was recorded during this range when compared to the flow rate below this range. This increase in power generation with the increase in oxygen supply rate was likely due to the acceptance of protons from anodic chamber.

3.3 Effect of pH on Voltage Generation

Fig. 4 depicts the generation of voltage from sewage sludge under varying values of pH. The data in the graph suggests that voltage generation was slow when the pH value was in the upper acidic range until it became neutral. The sharp increase in the voltage generation was observed immediately when the pH became alkaline yielding in maximum yield of voltage (2500 mv) pH 8.5. However, after that there was again the fall in voltage generation probably due to the variation in ionic forms of active sites for the biota. This implies that both decrease and increase in the pH value results in the decrease of microbial activity.

3.4 Effect of Concentration on Voltage Generation

Voltage generation profile versus substrate concentration is highlighted in Fig. 5, which shows that the amount of substrate concentration applied during

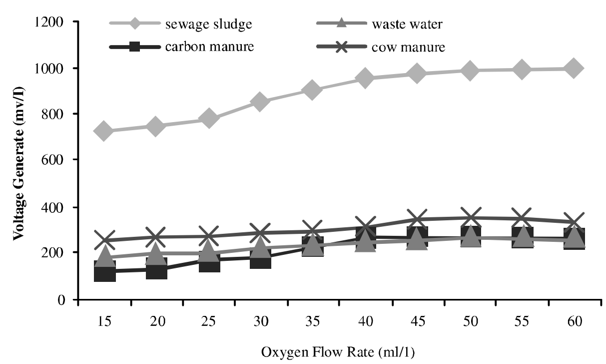

FIG. 3. VOLTAGE GENERATION PROFILE VERSUS OXYGEN FLOW RATE

the process will have an effect on the power generation. This could be due to the decreasing purity level of the organics present in the sewage sludge. The data in the graphs indicates that substrate concentration needed to be increased from its original concentration by 40% in order to achieve maximum power output of 2500mv/l at 140%, when microbial activity was perhaps at its peak.

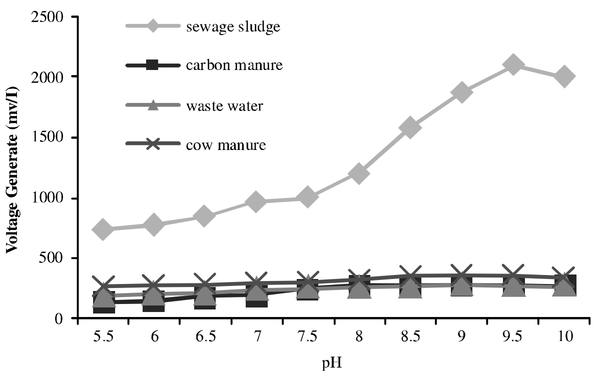

FIG. 4. VOLTAGE GENERATION PROFILE VERSUS pH

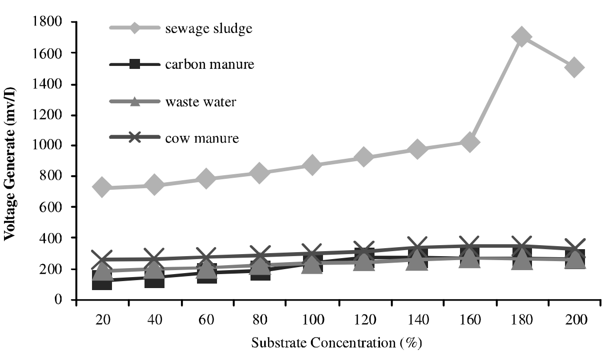

FIG. 5. VOLTAGE GENERATION PROFILE VERSUS SUBSTRATE CONCENTRATION

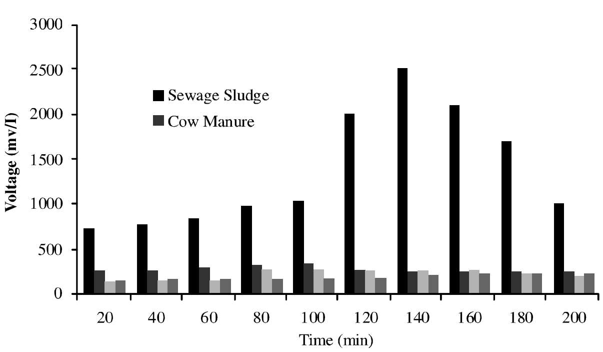

FIG. 6. POWER GENERATION WITH SEWAGE SLUDGE AND DIFFERENT BIOMASSSOURCES FOR POWER GENERATION

3.5 Power Generation Comparison between Sewage Sludge and Other Sources

Energy recovery from waste materials can simultaneously address energy crisis and associated environmental concerns [12]. Pre-treatment of the waste material has shown significant improvement in MFC electricity productivity. Variety of biomass sources is utilized as substrates in MFCs to produce electricity such as algae biomass, cattle dung, etc. Different biomass samples were used for power generation during this study shown in Fig. 6. However, all the tested biomass samples gave lesser power output likely due to the insufficient footprint of organics or glucose available in them. In this study separate samples of cow manure, carbo manure, waste water and sewage sludge samples were used .The maximum power generation of 2500 mv/l was obtained using Sewage sludge in comparison to 270 mv/l from carbo manure, 229 mv/l from cow manure and 330 mv/l from wastewater.

4. CONCLUSION

Sewage sludge was found to be a potential source for power generation via MFC technology as compared to other biomass resources such as cow manure, carbo manure and wastewater. The maximum electricity generation recorded using sewage sludge was found to be much higher than that obtained from the other sources of biomass. These results suggest that MFC technology is a viable solution for recycling of the sewage sludge and associated problem of environmental pollution.

ACKNOWLEDGEMENT

The authors are thankful to the facilities offered by the Department of Chemical Engineering, Mehran University of Engineering & Technology, Jamshoro, Pakistan, to carry out this research work.

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