MICROBIAL FUEL CELL OPERATED ON SLUDGE FROM SEWAGE TREATMENT PLANT - A Case Study

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Abstract: The population explosion of the world demands large energy resources to meet its increasing energy demands, resulting into increased load on nature. Most of the population is driving their energy needs from fossil fuels, which lead to depletion of resources and affecting environment too. With the depletion of the traditional energy resources and their contribution to serious environmental hazards, It is well recognized that alternative energy source is the need of the hour. MFCs are the devices which use anaerobic micro-organisms to produce electricity in the process of chemical changes occurring during the process. The present study has showed that on the fifth day, it showed a Open circuit voltage (OCV) of 225 mV and current density of 32.87 mA/m^2 with tap water containing NaCl. But when the aerator was applied to the cathodic chamber, the increase in voltage was reported, and reached 248 mV and a current density of 43.14 mA/m^2 . With the wasted activated sludge, it showed a Open circuit voltage in the range of 282 mV current density of 57.53 mA/m^2 with tap water containing NaCl but when tap water is used the voltage was recorded in range of 329 mV current density of 80.13 mA/m^2 and the OCV reached to 639 mV with tap water provided with aerator and current of 0.5 mA with current density of 102.7 mA/m^2 and power density of 67.65 mW/m^2.

Key Words: *Microbial Fuel Cells, Anaerobic bacteria, Open Circuit Voltage, Current density and Power density.*

1.0 INTRODUCTION

Microbial production of electricity is one of the steps taken by the researchers to meet the increased energy needs in the sustainable manner. Electricity generated by the Microbial Fuel Cells may become an important form of bioenergy because it offers the possibility of extracting current from a wide range of complex organic wastes and renewable biomass. Microbial fuel cells (MFCs) are the devices that use microorganisms especially bacteria as the catalysts to oxidize organic and inorganic matter to generate current as addressed by Logan et al (2006). A microbial fuel cell (MFC) is a two-compartment arrangement separated by a cation-specific membrane or proton exchange membrane. Out of the two chambers, the anaerobic chamber is known as Anodic chamber while the other is cathodic, aerobic in nature. According to Allen and Bennetto (1993), the electrons produced through the oxidation of the organic or inorganic matter by microorganisms are transferred to the anode of the fuel cell and then to the cathode through the external circuit, where they reduce the oxidant, while the proton produced travel through the proton exchange membrane. The MFC's are of two types mediator based and mediator less MFC's. As suggested by Elakkiya et al (2005), in the case of the mediator based MFC's, the exogenous mediators are used as to aid in the production of electricity, while in the other type, there is no need to add mediators because microorganisms are self sufficient to transfer the electrons to the electrode. As stated by Debabov (2008), the discovery of bacteria capable of complete oxidation of organic compounds and of efficient electron transfer to electrodes via direct contact was a landmark in the history of MFC. According to Bond et al (2002), in most MFCs the electrons and the protons reaching to the cathode from anode the electrons combine with each-other and the resulting product is water. The microbes used in the MFC's are the key source in electricity production. As studied by Rabaey et al (2004 and 2005), the MFCs operated using mixed cultures currently achieve substantially greater power densities than those with pure cultures as mixed cultures contains mixture of microbial species which may form synergism. As microbial species are known for their ability to degrade a wide range of pollutants and wide range of organic matter too. According to Pant et al (2009) and Gupta et al (2012), Microbial Fuel Cell (MFC) is a novel method of directly generating electricity from organic matter in wastewater, simultaneously treating waste water solves issues of energy crisis and environmental damage. Kang et al (2003) and Chen et al (2013) studied anaerobic digestion in MFC for improved cathode reaction and performance of wasted activated sludge respectively. In the present study, the two chambered mediator less MFC has been studied for the electricity generation by using sludge from the sewage treatment plant situated in the campus of NITK Surathkal. The performance of MFC was studied with and without aeration.

2.0 MATERIALS AND METHODS

Various form of set up for microbial fuel cell has been studied. The Microbial Fuel cell used for the present study is two chambered made up of two plastic containers of 3l, connected by a solidified agar saturated with KCl in a PVC pipe. The two compartments of MFC are known as anodic chamber and cathodic chamber, they are anaerobic and aerobic respectively. The PVC pipe containing solidified agar saturated with KCl has dual function, one it acts as a salt bridge and other function is to act as a proton exchange membrane which help in the movement of protons coming from the oxidation of the organic or inorganic matter in the cathodic chamber. The agar filled inside the PVC was 10% (W/V) and to make it saturated with the 5 % (W/V) KCl was used. The electrodes are made of the graphite rods, of surface area of 48.67 cm^2. The two electrodes were connected to each other by a copper wire. The anodic chamber was sealed to make it anaerobic. In the cathodic chamber tap water was used. For the comparison the tap water filled in the cathodic chamber was added with the common salt, then tap water and at last the tap water provided with the aeration to analyze the impact of aeration on cathodic chamber and microbial fuel cell performance. The sludge that was added to the anodic chamber was collected from the sewage treatment plant, situated inside the campus of NITK, Surathkal. Firstly, the sludge coming from primary clarifier was collected and fed to the MFC. Second time, the sludge coming from the secondary clarifier was collected for the study. The voltage and current produced in the MFC were observed on the regular basis. The voltage and current mere measured by the help of digital multimeter in milli volt and milli ampere respectively. For voltage, the Open Circuit Voltage (OCV) was recorded. In the study the pH was maintained in the range of 6.0 - 6.5.

3.0 RESULTS AND DISCUSSIONS

The constructed MFC was studied for four parameters i.e. voltage, current, current density and power density. In the first cycle, the MFC was fed with the sludge coming from primary clarifier to the anodic chamber while cathodic chamber was filled with tap water containing NaCl and tap water with aerator to different set ups of MFC's. The second cycle was studied by using sludge from secondary clarifier to the anodic and tap water with NaCl , tap water alone and tap water with aerator to the cathodic chamber of different set ups of MFC's.

When Open Circuit Voltage (OCV) was studied against the time, it was observed that the OCV was increased from 0^{th} day to 3^{rd} – 4^{th} day, become stable then starts decreasing as the organic matter present in the sludge was being utilized by the microbes, so due to the decrease in the oxidation of the organic matter the production and movement of electrons and protons were also decreased. When tap water with NaCl was fed to the cathodic chamber, the OCP was recorded less in comparison to the tap water alone or the tap water provided with aerator. The aerator assisted cathodic chamber has given higher OCV in comparison to the tap water alone. The OCP recorded for sludge coming from the secondary clarifier has showed greater value than that coming from the primary clarifier. The MFC operated with anodic chamber filled with sludge from primary clarifier and cathodic chamber with tap water with NaCl gave peak value of 225 mV, but when the same

MFC was studied for the cathodic chamber containing tap water with aerator, it gave peak value of 248 mV.

In the second cycle, the secondary clarifier sludge containing anodic chamber has given different peak values of OCV for different cathodic electrolytes. The tap water conataing NaCl, the tap water alone and the tap water with aerator have given 282 mV, 329 mV and 639 mV respectively as the peak values of OCV. The OCP's plotted against the days are shown in the figures below.

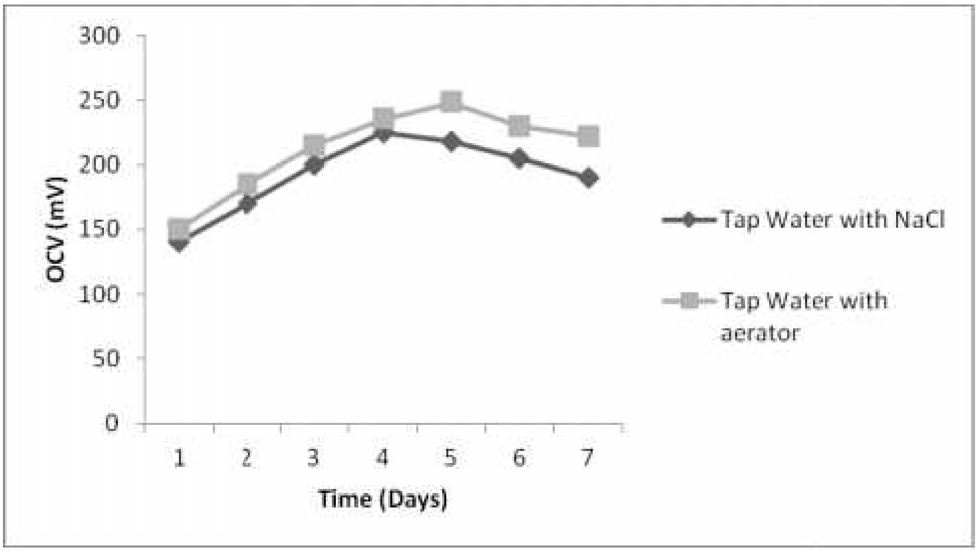

Fig.1 – Study of Max. OCV for Primary clarifier sludge.

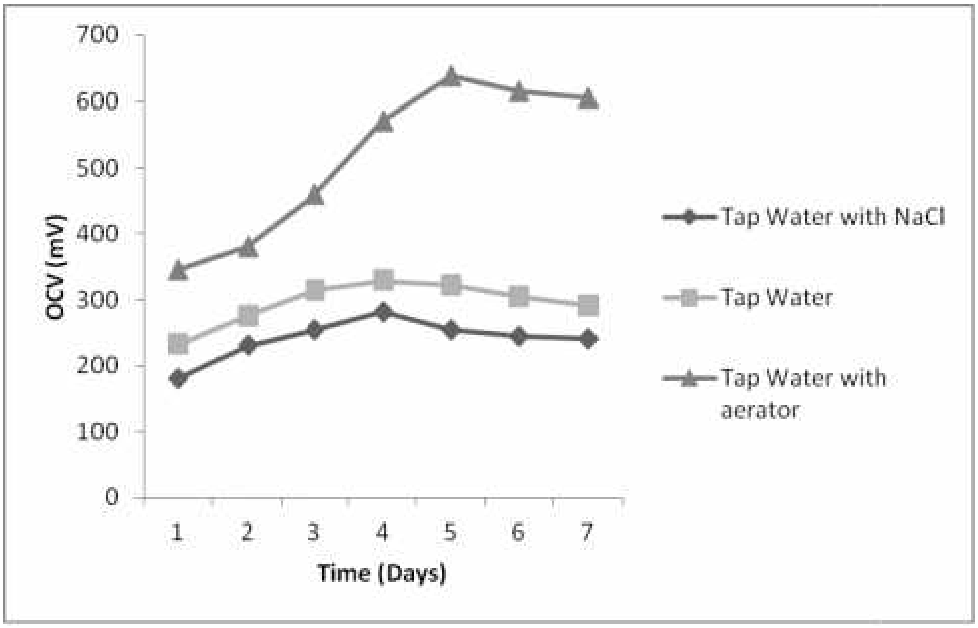

Fig 2 – Study for Max. OCV for Secondary Clarifier Sludge.

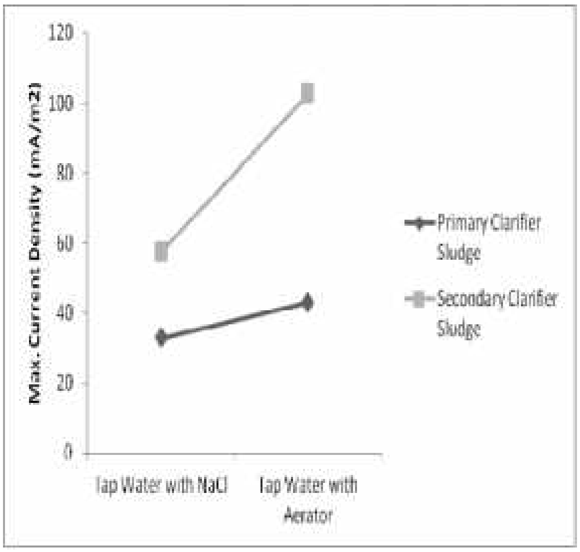

Fig 3(a) – Max. Current Densities

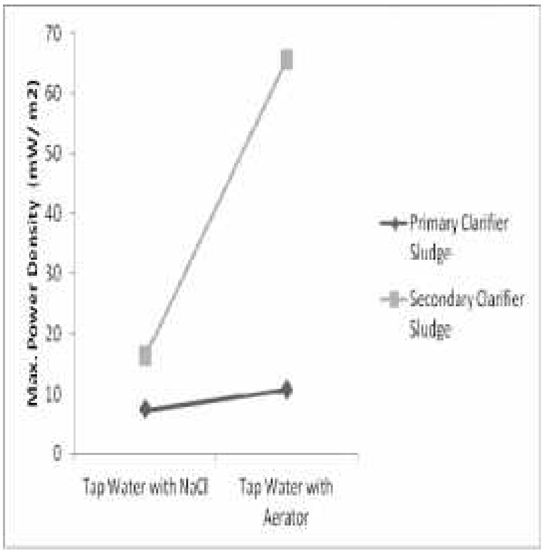

Fig 3(b) – Max. Power Densities.

Current measured and recorded voltage were used to calculate the Current densities and the Power Densities in (mA/m^2) and (mW/ m^2) respectively. The MFC operated with primary sludge in anodic chamber and tap water with NaCl has showed current densities and power densities as 32.87 (mA/m^2) and 7.39 (mW/ m^2) respectively. The same MFC with Tap water with aerator has showed 43.14 (mA/m^2) and 10.7 (mW/ m^2) respectively. The MFC fed with secondary clarifier sludge to anodic chamber and tap water with NaCl to the cathodic chamber showed current densities and power densities as 57.53 (mA/m^2) and 16.22 (mW/ m^2) respectively, while for cathodic chamber containing tap water alone the readings were 80.13 (mA/m^2) and 26.36 (mW/ m^2) respectively. The values showed by the tap water with aerator were as 102.7 (mA/m^2) and 65.65 (mW/ m^2) respectively

Anodic Sample	**Cathodic Electrolyte**	**Max. Open Circuit Voltage(OCV) (mV)**	**Max. Current (mA)**	**Max. Current density (mA/m^2)**	**Max. Power density (mW/ m^2)**
Sludge from primary clarifier	Tap Water with NaCl	225	0.16	32.87	7.39
Sludge from primary clarifier	Tap Water with aerator	248	0.21	43.14	10.7
Sludge from secondary clarifier	Tap Water with NaCl	282	0.28	57.53	16.22
Sludge from secondary clarifier	Tap Water	329	0.39	80.13	26.36
Sludge from secondary clarifier	Tap Water with aerator	639	0.5	102.7	65.65

Table 1 – Measure of Voltage, Current, Current density and power density for all the samples by using graphite as an electrode.

Fig. 4 - Peak value of OCV with secondary clarifier sludge as cathodic chamber and tap water aerator as an anodic chamber.

Fig. 5 - Peak value of OCV with secondary clarifier sludge as cathodic chamber and tap water aerator as an anodic chamber.

4.0 CONCLUSION

The study has showed that the aerator assisted cathodic chamber gives better performance for MFC than the NaCl containing tap water or tap water alone. The secondary clarifier sludge has proven to be better than that of the primary clarifier sludge. The peak values of voltage, current , current densities and power densities were showed by the MFC working on secondary sludge and tap water assisted with the aerator. The value were found to be 639 mV, 0.5 mA, 102.7 (mA/m^2) and 65.65 (mW/m^2) respectively.

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BIOGRAPHIES

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