Electricity Generation and Concurrent Desalination In 3-Chambered MFC using Domestic Waste Water as Substrate

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***Abstract*— In the present study, a 3 chambered Microbial Fuel Cell has been designed and adopted. Equal volume of waste water, salt water and potassium permanganate are used in the three chambers where graphite plates are used as electrodes at both ends. The system is operated for a single cycle covering a period of 24 hrs taking domestic waste water from two different points as substrate. The maximum voltage production and current production are 721 mV and 384 mA respectively. The power produced was stable for a short period. The experimental studies revealed two aspects: firstly there is a decline in the voltage as well as power production in both systems. However, a difference in the time taken by each system to reach maximum voltage varied; secondly, the electricity production is higher in the waste water collected from main sewage canal than waste water collected from domestic feeder canal. The reasons for such variations and ways to improve fuel cell efficiency are discussed.**

Keywords—MFC,waste water,voltage,graphite

I. INTRODUCTION

Water and energy are the two most pressing technological issues facing the world. The social and economic developments are driving the search for sustained supply of useable water and energy. To achieve sustainability in terms of useable water and energy supply, global scientific community is trying to find out ways and means to get new and renewable type of energy sources and cost effective desalination system. Recently developed Microbial fuel cell MFC) – a bio electrochemical system represents one of the newest approaches for generating useable water and renewable energy simultaneously. MFCs can generate electricity using microbial population in domestic wastewaters concurrently desalinating sea water using exo-electrogenic bacteria that produce electrical current from the degradation of organic or inorganic matter (Logan ,2008,2010 Logan et al ,2008., Logan and Regan,2006; Cao et al., 2009; Jacobson et al., 2011; Luo et al., 2011; Mehanna et al., 2010,2010b,.Liu et al 2010). Microorganism can also generate power by converting organic matter into electricity using microbial fuel cells (MFCs) (Logan et al., 2008; Logan and Regan, 2006; Mehanna et al. 2010; Rabaey et al 2004) and MFCs convert biodegradable organic material directly into bioelectricity using electrochemically active microorganisms as biocatalysts (Jeremiasse et al., 2010; Logan et al., 2008;Logan and Regan, 2006).

Visualising the importance and need for simple but advanced type of MFC, attempts have been made globally using a variety of substrates and techniques. Most of the systems are batch type (Luo et al 2012);recharging of analytic solutions (Luo et al 2011, Anup and .Oh, 2012); use of both organics like acetate , glucose and Phosphate and inorganics like Ferric cyanide (Mehanna and Liu ,2010); use of costly electrodes like Platinum (Luo et al 2011 ; Anup and .Oh, 2012); carbon tubes in cathode chamber (Wang et al, 2011).,bubbling of air into aquous medium at cathode chamber for oxygenation using external voltage for the MFC (Min et al 2005 ; Luo et al 2011; Liu et al 2010);use of varying volume of solutions (Luo et al 2011) in the MFC system as well . In the present study, it is aimed to design, construct and run to find out the actual efficiency of the presently designed simple MFC using domestic waste water from two different locations and Graphite electrodes at both ends and brackish water (15ppt) in single batch treatment keeping potassium permanganate as oxygen source. No external voltage or inorganic/organic salts or additional aeration of cathode medium has been done earlier. Moreover, this attempt is devoid of any recharging or recirculation of medium either in anode or in cathode chamber.

II. DESIGN OF MFC REACTOR

The presently designed MFC reactor contains intern-connected waste plastic containers separated by an anion exchange membrane (AMI:7001S) having 0.45mm thickness

between the anode and middle desalination chamber and a cation exchange membrane (CMI:7000S) with 0.45mm thickness. (Fig. 1). The membranes are made of Gel polysteryn cross linked with divinybenzene.. These ion exchange membranes are obtained from Membrane International Inc.,USA. The diameter of the membrane (both AEM and CEM) used in the system, is 5 cm. Activation is done as per the instruction given by the supplier. Heat treated graphite plates measuring 2.5 x 7.5 x 0.5 cm, are used as electrodes at both ends. The two terminals are connected to Digital multimeter (M830BZ). The anodic medium contained wastewater and cathode chamber is filled with 2% potassium permanganate solution as oxygen source. The middle chamber is filled with natural seawater diluted to get 15 PPT. The inside volumes of the anode, middle desalination, and cathode chamber are kept equal (350ml each). Domestic waste water as substrate are collected directly from household outlet feeder canals (WWH) and the other one from main sewage drain (WWM) canal which receives sewage from all domestic feeder canals. There is a visible flow of waste water in the feeder canal whereas there is no free flow in the main canal due to solid waste induced stagnancy. Voltage and Current parameters with two different waste water, has been recorded using digital multimeter for every hour for a period of 24 hours - one cycle. The experiments are conducted separately for each type of waste water and the values are taken for discussion.

Fig.1. Experimental Setup of 3chambered MFC

III. RESULTS

The maximum voltage produced during MFC operation with an initial salt concentration of 15 g/L (20 Ω external resistor) is 721 mV, with a maximum current of 385 mA in waste water from Main canal (WWM) and 585 mV and 296 mA in waste water from Domestic feeder canal (WWH). WWM has taken 18 hours to attain maximum output voltage and decline thereafter in a single cycle whereas WWM showed a maximum by 22 hrs. (Fig.2&3). The seawater in the middle chamber is efficiently desalinated from 15 PPT to 10.8 PPT and 15 to 8 PPT in WWH and WWM respectively .All these results are obtained in 24 hrs single batch without re-circulation or recharging of any of the medium at any stage of the operation. The values are taken for discussion.

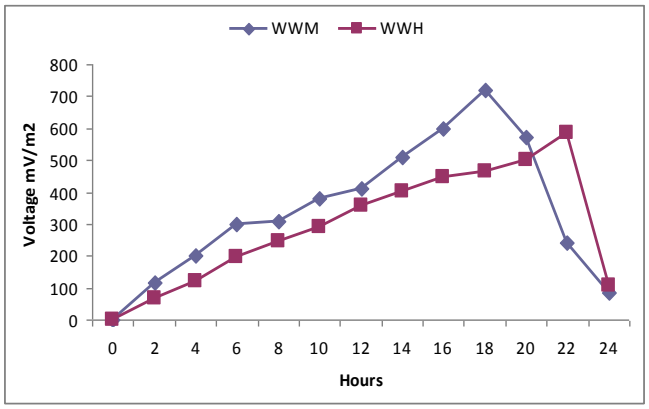

Fig.2. Voltage produced in Waste water from Main canal (WWM) and Household Feeder canal (WWH)

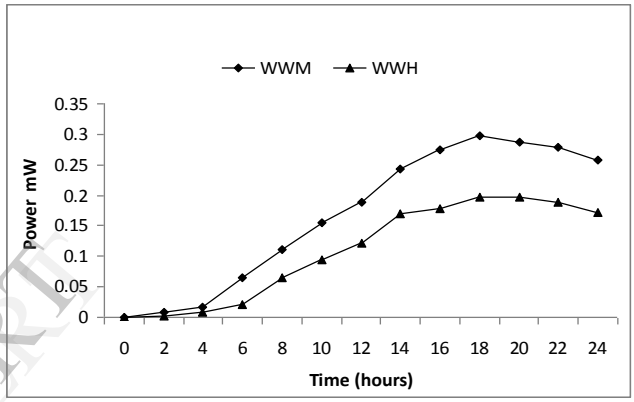

Fig.3. Power generated in Waste water from Main drain canal (WWM) and household feeder canal (WWH)

IV. DISCUSSION

In recent years, microbial fuel cells (MFCs) have emerged as a promising technology for harnessing renewable energy from waste biomass with seawater desalination. The quest for advanced type of MFC has been emerged internationally. To join this mission, presently an attempt has been by designing a 3 chambered MFC, for concurrent power production and desalination. The electricity production in the MFC is more reproducible and stable during single batch cycle. The maximum output voltage measured in the MFC for wastewater from main canal (WWM) is 712 mV (under 15Ω external resistance) and 385 mA where waste water from household feeder canal (WWH) showed 585mV and 256mA. From these results, two obvious observations are clear: firstly, there is a decline in output voltage within single cycle and secondly, there is significant difference in the output voltage and the time taken to reach maximum (Fig.3) between WWM and WWH. With regard to the voltage drop in a single cycle, it is already observed by Luo and Logan (2004);Cao et al., (2009) , Luo et al., (2011) Kim and Logan (2011b), Luo et al 2012 and Kim and Logan (2013) and it has been attributed to increase of the internal resistance during desalination . Besides, it is also understood that influx of additional ions in to anodic chamber is also one of the factors responsible for such voltage drop; secondly, the significant difference in

output voltage between WWM and WWH underlines the importance of quantity and quality of microbial consortia present in the waste water and organic load. It could be attributed from the present observations that variation in microbial consortia both in terms of quality and quantity between Household feeder canal (WWH) and Main sewage canal (WWM) might be one of the reasons for such variation in output voltage as well as time taken to reach maximum voltage. As Main drain canal (WWM) is receiving waste water from many feeder canals and low flow rate due to solid waste induced stagnation, there expected a rise in the diversity of microbial consortia with diverse physiological /metabolic pathways and increased organic load.; on the other hand, the feeder canals carry freshly formed waste water and the flow is also little faster without any stagnation which indicate the possibility of low level of bacterial concentration and organic load. It is reported that in a MFC, substrate is regarded as one of the most important biological factors that influence the integral composition of the bacterial community in the anodic bio-film and the MFC performance including power density and columbic efficiency (Chao et al., 2009; Liu et al., 2009; Lu et al., 2009; Oh and Logan, 2006; Pant et al., 2010). Present observation is also further substantiated by previous studies that addition of anolyte/ recharging of anolyte at the end of each batch cycle, once again increases voltage in MFC (Mennana et al, 2010; Luo et al 2011.2012). Addition or recharging of waste water into anodic chamber is nothing but addition of microbial flora as well as organic matter to restore the initial pH of the anode chamber. Therefore, it is presumed that type and age of organic waste water, microbial concentration and metabolic pathway of diversified microbial population and the quality of organic matter could be major factors influencing a drop in the electricity production

Secondly, in the middle chamber, it is noted that about 60% of the salt was removed from the seawater (15 PPT to 10.8PPT) over a single desalination cycle with out any pressurized water or external source of electricity. This can be compared to traditional electrodialysis which is recommended for use at salt concentrations up to 6 g/L of dissolved. (Banasiak *et al.,* 2007). The basic mechanism involved in this magic of MFC is the transfer of negative and positive ions across AEM and CEM accordingly by processes of dissociation on side and ionic invasion in to other side. As stated by Cath *et al.,(* 2006), when current is generated by bacteria on the anode and protons are released into solution. AEM prevents protons and other positively charged ions from leaving the anode chamber; consequently protons tend to accumulate in the anode chamber itself creating ionic imbalance.. During the process of dissociation of sodium chloride in the middle chamber Cl ions move into anode through AEM, but sodium ions move into cathode chamber CEM. As a consequence of these two charge-transfer due to electrochemical processes, NaCl in the middle desalination operative. As rightly pointed out by Logan and Regan (2006) harnessing the metabolic activity of can provide energy for a variety of applications, once technical and cost obstacles are overcome. Kim et al (2007) and Jung & Regan (2007) in one of their reviews pointed one strategy to determine which microorganisms contribute to power chamber is dissociated and the water is desalinated.(Mehanna et al 2010, 2010b; Logan 2010 ,Logan et al 2008)**.** Similarly ,protons produced in the cathod chamber are depleted by combining with electrons and oxygen to form water in the third chamber which intern results in dilution of pot.permanganate and slowly the oxidation potential of pot.permanganate would be decreased. The MFC designed for the present study, is three chambered and all the chambers are loaded with equal amount of respective solutions/media similar to what Mehanna has done (2010) and desalinated substantial amount of (43–67%) water using three equal sized chambers.

Thirdly, it is observed that pH, one of the important chemical factors particularly in electrochemical processes, gradually decreases from 7.2 to 6.4 in the anode chamber during a batch cycle. Similar fall in pH during the cycle at the anode has been recorded by Liu et al, 2010, (pH decreased from 7.0 to 4.5) ; Mehanna et al 2010b (pH from 7.2 to 6.2) and Luo et al 2011 (pH from *7.2 to 5.4 ,).* It has been attributed that buffering capacity of the medium in the anodic chamber could not counter the pH change caused by the accumulation of protons in the anode chamber during concurrent desalination and electricity production (Ren et al ,2007 and Torres et al 2008). Besides, based on the results obtained, it is also attributed that in addition to the accumulation of protons chamber during electricity generation, cl- and hydroxyl ions along with bicarbonates from the middle desalination chamber are also fluxed in to anode chamber thro AE Membrane. Further, anions like NO_3^- SO_4^{2-} that migrated from saline water to the anolyte compete with the anode as the electron acceptors and cause electron loss and reduce system performance (Morris, 2009). Seawater contains bi carbonates of bivalents viz Mg and Ca. along with sulphate and chloride (Luo et al ,2012). During the process of desalination, the bicarbonate ions are also expected to be fluxed into anode chamber creating a overall internal impedance to the electrochemical processes in the MFC. These attributes are also further reinforced by Pant (2011) at molecular level that voltage production for each batch, the average increase of Na+ in the catholyte is 1.00(0.05 mmol, while the average increase of Cl- in the anolyte is 0.83 (0.03 mmol.).Thus, it is clear that anionic invasion from the middle chamber into the anolyte chamber significantly decreases pH from 7.2 to 6.4 which interfere with normal functioning of the MFC system as a whole.. Present observations are also in conformity with recent reports of Kim and Logan (2013).

Even though there are variety of factors that affect the overall performance of a MFC, such as performance of the cathode, solution conductivity, pH, alkalinity, circuit resistance, proton transfer through the membrane, it is learnt from the observations made in the preliminary experimental studies that type of microbial consortia and their concentration linked with organic content of the substrate are also the factors to be considered while designing highly efficient MFC as production from various fuel sources is to identify those microorganisms that selectively colonize anode surfaces and participate in extracellular electron transfer. Therefore, it is envisaged that future research on this specific parameter, would refine the functionality and sustainability of this scientific magic instrument (MFC) using biotechnology

optimistically for power generation involving tailor-made microbial consortia rather than waste water treatment using 3 chambered Microbial Fuel Cell.

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