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Performance of microbial Fuel cell under air Pumping to the cathode side

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Abstract

Pumping air to the cathode chamber and its effect on the microbial fuel cell performance was detected. It was detected that increasing oxygen concentration has a positive value on the cell performance accompanied by increasing of chemical oxygen demand COD which is attributed to the growing of cultures that are nourished by oxygen in the cell. Generally, the performance of the cell was better in case of air purging with respect to the case of without purging.

Keywords: *Microbial fuel cell, Cyclic voltammetry CV, COD, LSV, Cell potential*

1. Introduction

A microbial fuel cell (MFC) is a bio-electrochemical system that produces current from oxidation of biodegradable organic compounds using microorganisms, called exoelectrogens that are capable of transferring electrons outside their cell. At the anode of MFC oxidation of organic materials takes place and to do this there must be no atmosphere of oxygen at the anode otherwise the oxygen becomes the electron acceptor[1].

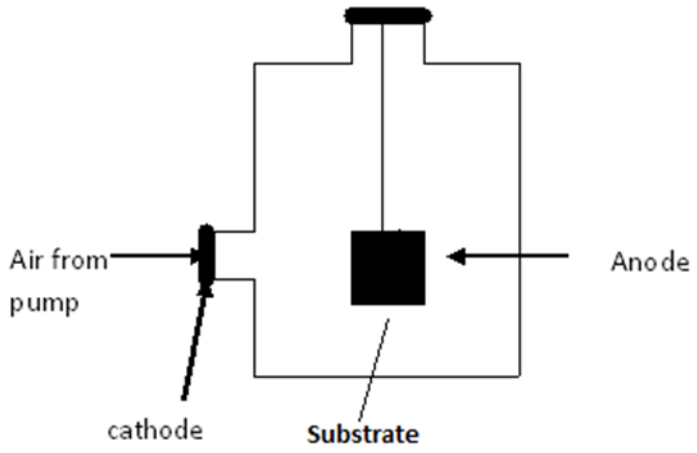
There are some studies dealt with the effect of oxygen on the cell performance, for example Oh et al.[1] studied the effect of supplying the anode chamber with air or pure oxygen at a rate of 50mL/min for a specified time and in general they found that increasing dissolved oxygen in anode chamber reduces the cell potential.

Fornero et al.[2] increased the pressure of air in the cathodic chamber to increase the oxygen solubility and they got that the cell voltage is increased accordingly. Due to the lack of studies or maybe they are not found-according to the author knowledge- about using air flux directly to the cathode side in a similar manner to that used in fuel cell or some electrochemical industries, accordingly this study concerns two aspects, the first is to see what is the effect of oxygen (from air) flux on cathode and the second is to gain some electrochemical parameters and kinetic factors about the anode and cathode and also with respect to this few studies were made[3,4,5], as well as to what mentioned above there will be in this study two lines the first is to detect the cell performance with and without oxygen and the other is to compare the anode and cathodic performance also with and without oxygen.

2. Experimental work

Figure 1 illustrates the cell where it is composed of one compartment which contains waste water from Connecticut University waste water treatment station and was used without other additions and the anode and cathode, the cathode was made of carbon cloth catalyzed with platinum according to Cheng et al.[6] with 1 cm^2 surface area and the anode was a carbon cloth of the same area. Aquarium air pump MK-1504 was used as a source for air to feed the cathode and to keep the temperature at 30C a water bath was used. The Hatch was used to measure the COD in standard method and all the electrochemical plots were obtained by using of Gamry reference 600, the counter electrode is of platinum and with a silver-silver chloride as a reference electrode.

The linear sweep voltammetry LSV and cyclic voltammetry were conducted at the beginning and at the end of process i.e., elapsed of 72 hours of working while the COD values and cell potential ware measured at the end of every day. The current of the cell is detected by measuring the voltage across the load (46 Ω) at the end of each day.



. Figure 1: The used cell

3. Results and Discussion

Figure 2 and figure 3 show the behavior of anode and cathode in waste water respectively. Nothing is seen unusual in anode except that around 600 mv there is a small disturbance in current value which is attributed to passivation of electrode may be due to film formation of growing bacteria but it is covered by small potential range, in figure 4 also the cyclic voltammetry of anode consolidates above besides there is an enhancing in current value around 800 mv and then it is reduced, this is could be another type of organic oxidation since the waste water could have no limited type of nutrients and it could contain more than one.

The open circuit potential was around 500 mV and to find the power curve a polarization was made and figures 5-6 show such behavior.

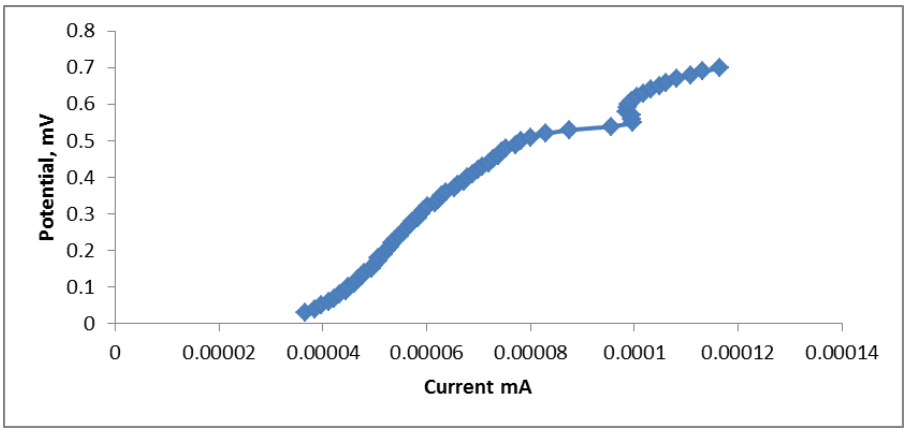


Figure 2: Anode Polarization in waste water at the beginning of the process

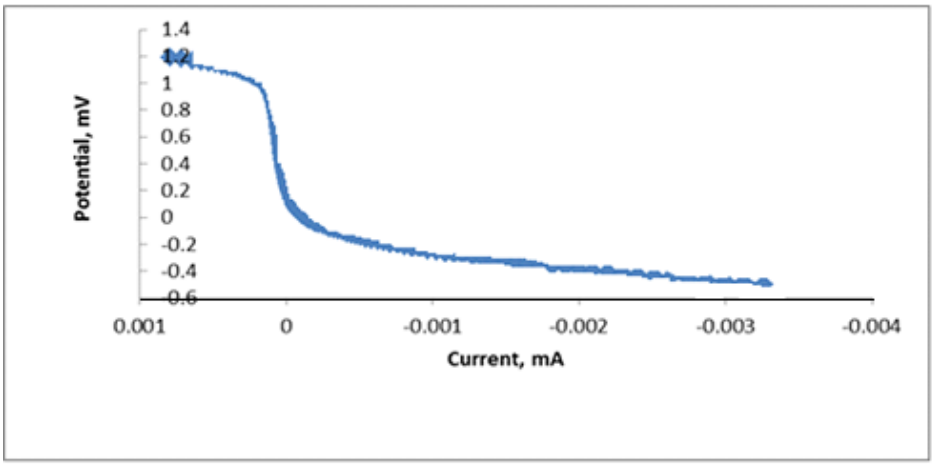


Figure 3: Cathode polarization in waste water at the beginning of the process

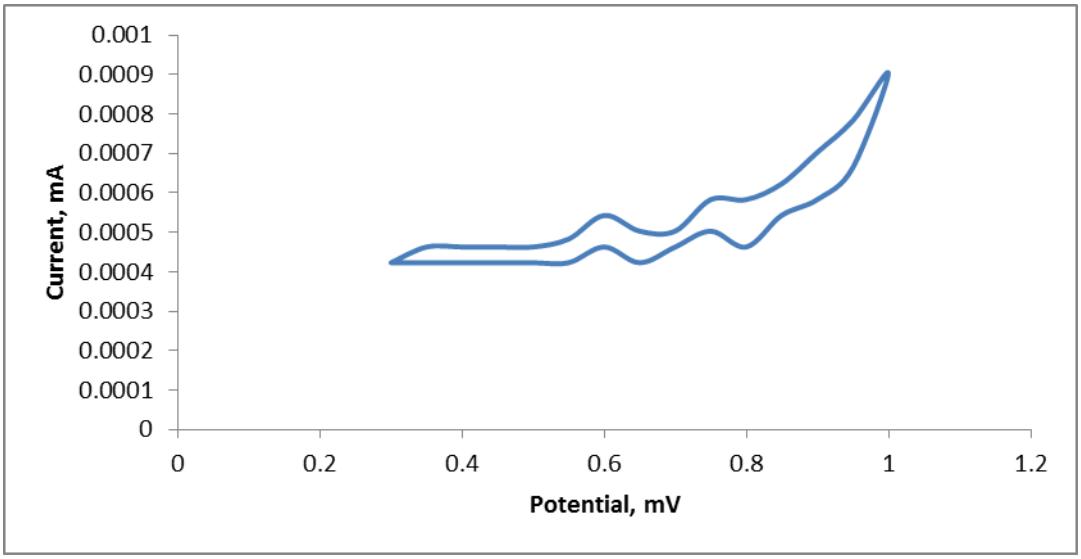


Figure 4: Cyclic voltammetry of the anode at the beginning of the process

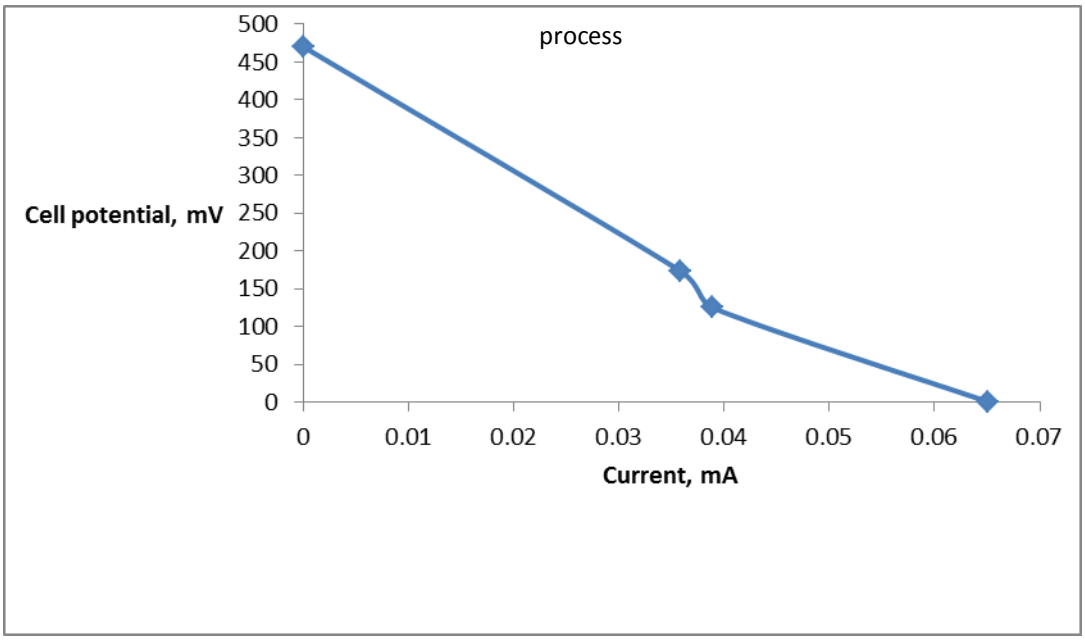


Figure 5: Cell voltage-current relationship at the beginning of the process

The maximum current is about 0.066 mA that can be brought from this cell at the beginning of the process but this current of course will fall to a low value due to consumption of feeds.

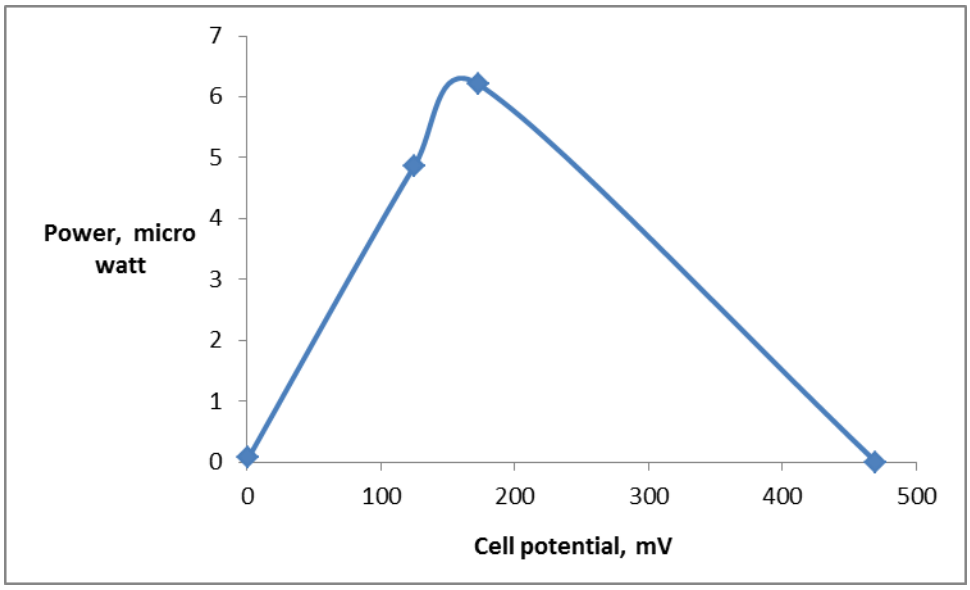


Figure 6: Cell power - voltage curve at the beginning of the process

Figure 7 below shows the COD reduction throughout the process (for 72 hours), it can be seen that as the time of the process increases the COD reduction efficiency increases but beyond the second day the efficiency is decreased and this is attributed to the reduction of the cell performance due to decreased in nutritious with time since the process is a batch one.

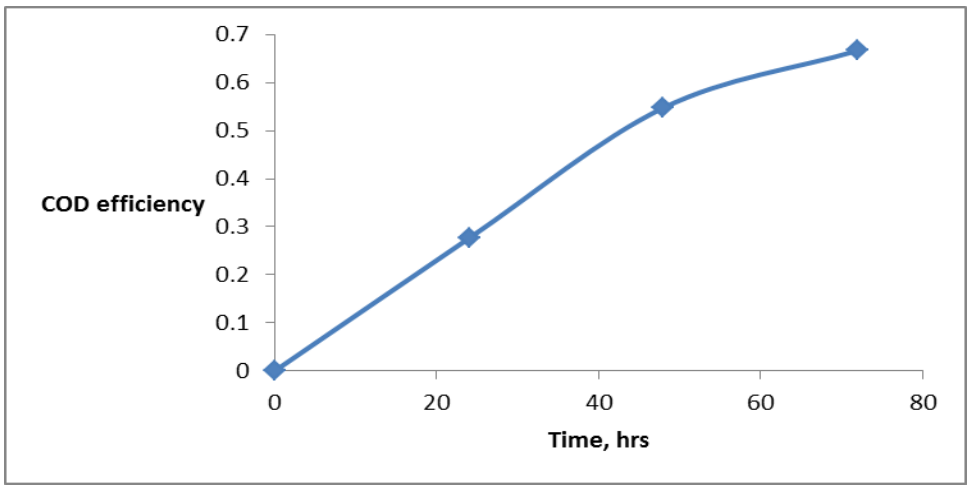


Figure 7: the COD efficiency-time relationship

Figures 8-10 show the behavior of anode, CV of anode and cathode polarization curves at the end of treating period (72 hours). It can be seen from figure 8 that there is still a case of distruption around 600 mV and it means that there still an organic cultures that sustain current and this also enhanced by seeing figure 9 for the CV of anode after exposure where there is also a case of filming occurs but till now this film is not detected in detail as seen in figure 4.

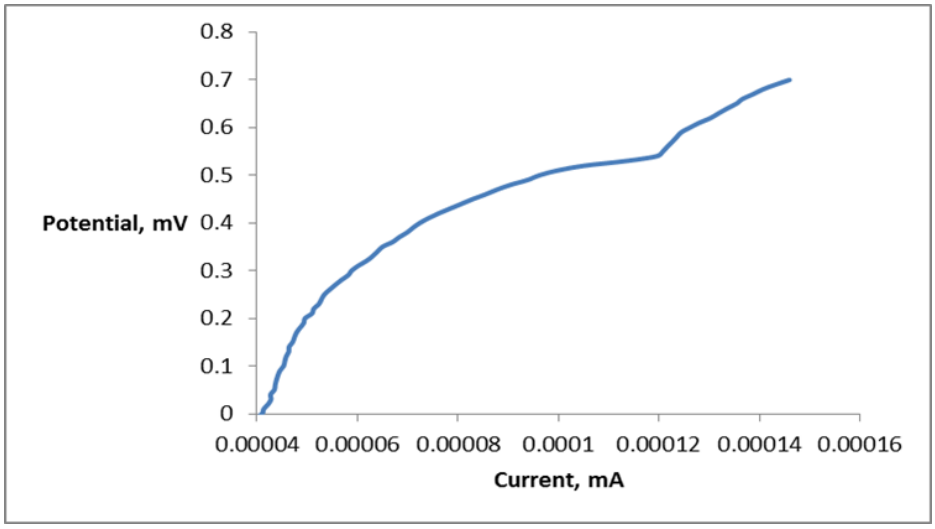


Figure 8: Anode polarization at the end of the process

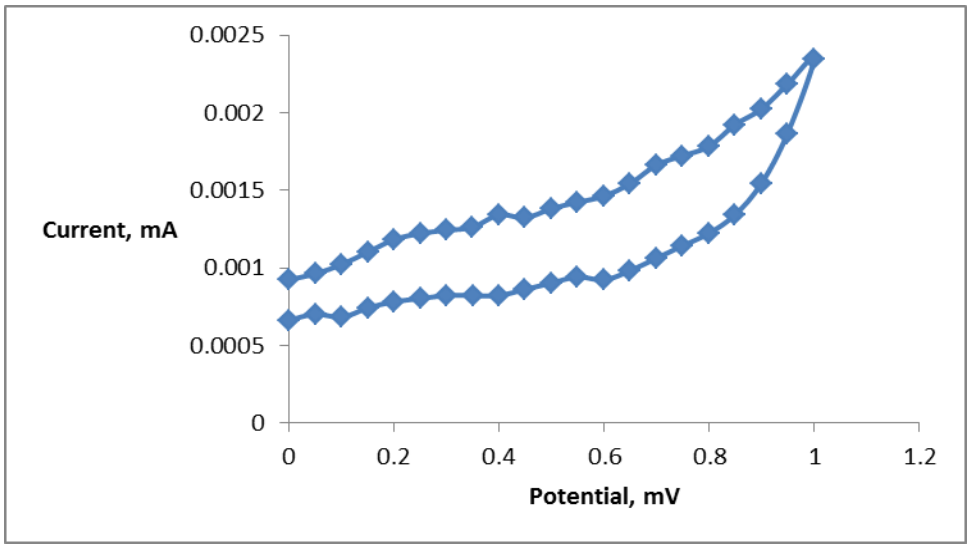


Figure 9: Anodic CV at the end of the process

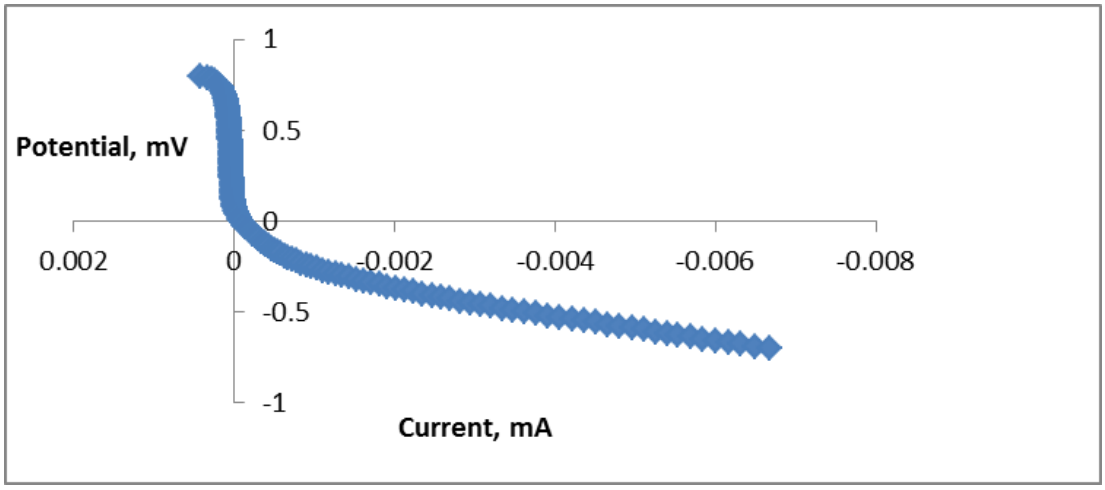


Figure 10: Cathodic polarization curve at the end of process

From figures 2, 3, 8 and 10, table 1 is abstracted which reflects the kinetics or characteristic parameters obtained from polarization curves of the anode and cathode.

Table 1: Kinetic parameters for anode and cathode

Waste water		Exchange current, mA/cm^2		Beta slope	
		at the start	at the end	at the start	at the end
anode	Without air	$2.3*10^{-5}$	$28*10^{-5}$	0.75	1
	With air	$1.7*10^{-5}$	$29*10^{-5}$	1.75	1.2
cathode	Without air	$7*10^{-5}$	$11*10^{-5}$	0.8	0.66
	With air	$2.56*10^{-5}$	$56*10^{-5}$	1	0.98

From table 1 it is obvious that at the end of the process the kinetic factors tell us that the performance of the

cell is somewhat complicated in such a manner that by taking the anodic exchange currents in above it is anticipated that the anode will affect the cell performance positively but it is reversed when one compares the two Tafel slopes values and this could be related to the new activation energy which it is attributed to the film formation so this film has a catalytic nature and not passsivator which enhance the cell performance although the COD value is reduced. While that for cathode there is much less improvement of exchange current meaning that cathode will not affect the cell performance as anode did.

2-With air

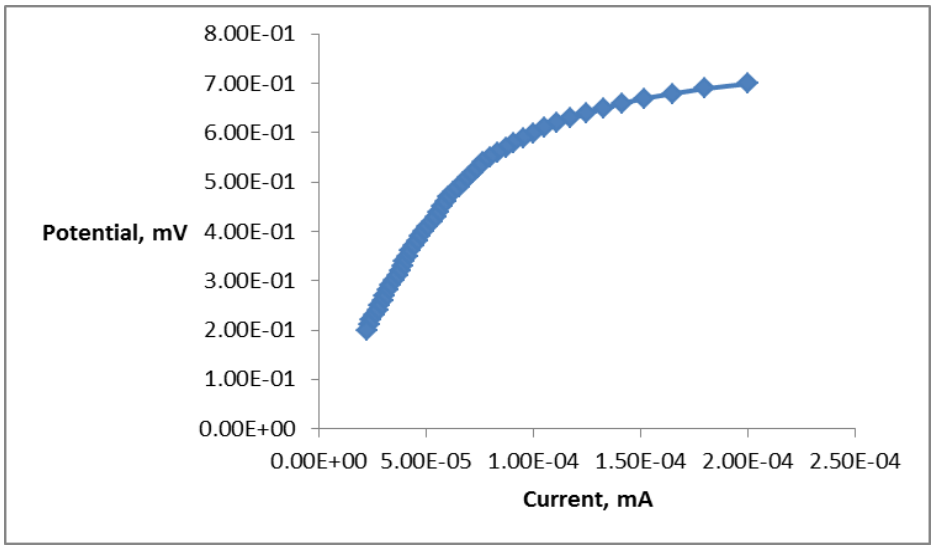


Figure 11: Anodic polarization in waste water with air purging at the beginning of the process

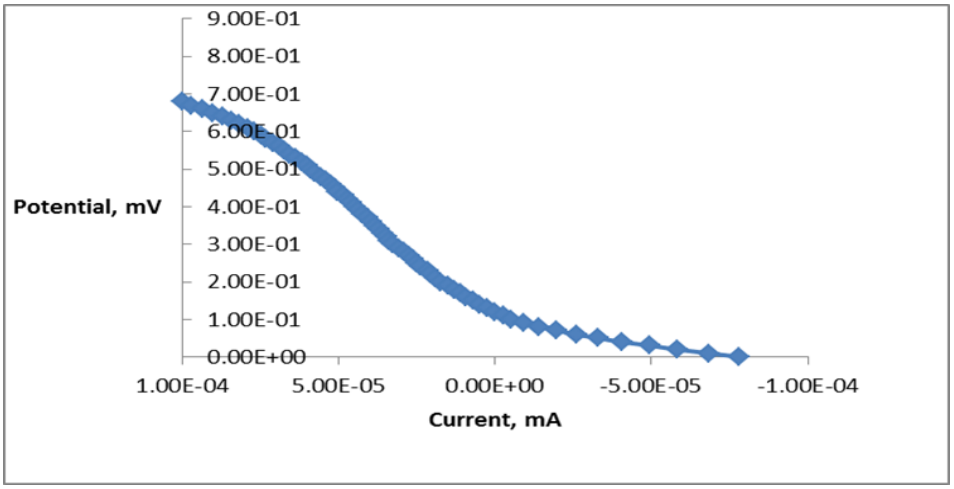


Figure 12: Cathodic polarization at the beginning of the process with air purging

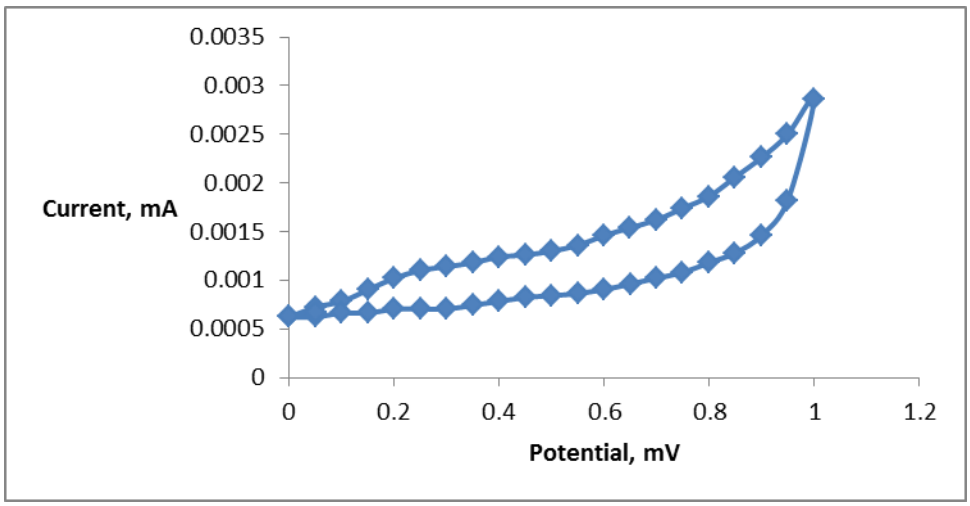


Figure 13 : Cyclic voltammetry for anode in presence of air

From figures 11-13 it can be seen that no valuable differences in the behavior of anode with respect to that one in case of without air as in figure 2 while for that for cathode figure 12 there is no limitation for oxygen mass transfer or in another words there is no case for limiting current or diffusion current compared to figure 3 and this is to be expected since there is a forced draft of oxygen supplied to the gas diffusion layer and hence to the catalyst layer or platinum load. It can be seen that from cyclic voltammetry figure 13 that the current for oxidation reduction is not clear and the effect is focused on the alteration of electrical double layer and its effect and contribution to the cultures strategy of growing, indeed this can be further elucidated by checking the COD values which is shown by figure 14 below

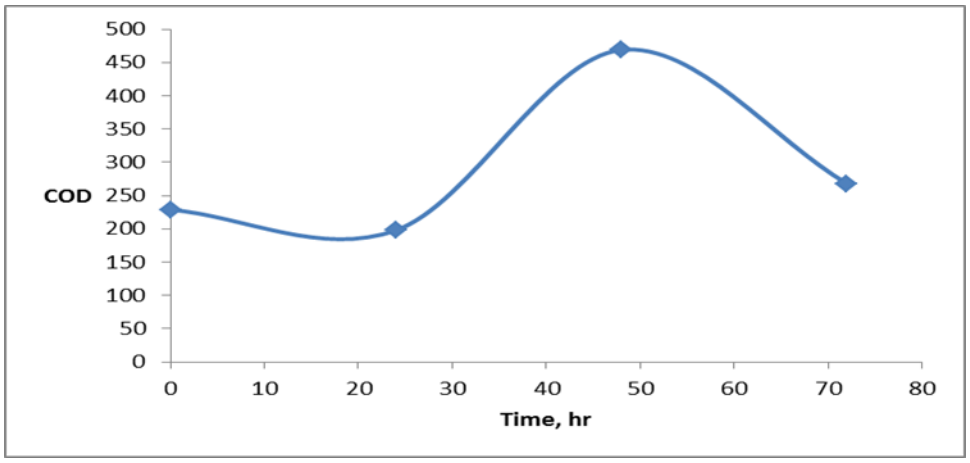


Figure 14: COD-time relationship

From figure 14 it can be seen that the COD is increased to its maximum within about two days of working which it means that the organics are building themselves and this to be happened there must be either a reduction of current or less degradation of these cultures compared to their growing and this to be occurred

there must be anaerobic bacteria which by existence of oxygen they must be died and hence the current is reduced and the COD in increased accordingly. This explanation is in confliction by considering figure 15 below due to increasing in current.

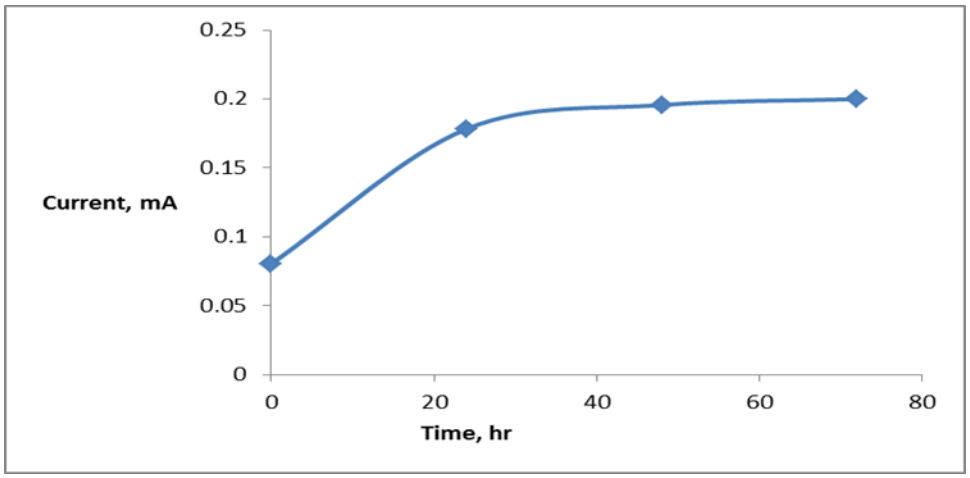


Figure 15: Current-time relationship during the treatment process with pressing of air

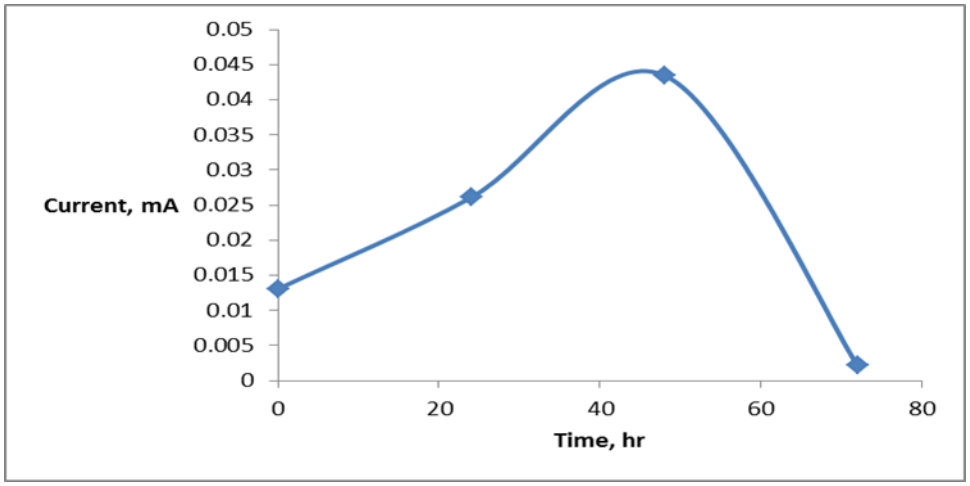


Figure 16: Current-time relationship during the treatment process without pressing of air

But one can also consider that the pressed air is composed of nitrogen about 78% and this could displace oxygen in the solution especially near the anode which enhance the growing of anaerobic bacteria that degrade the organics.

In figure 15 one can see that the current is increased and reached its maximum at the end of the process (elapsed of 72 hrs) and by doing so, it is anticipated that the COD has to be decreased while the experimentation has a reversed portrait. To answer this it is assumed that there should be the familiar two types of bacteria, viz, aerobic and anaerobic and here it is assumed both of them have their independent

action of each and according to this one can conclude that some type of bacteria is still working in presence of oxygen existence and this could be agreed with others[7]. By comparing figure 15 with that of 16 (performance in absence of air) the evolved current from cell with pressing air is better and more stable than the cell that lacks air and this assured the former discussion that the cultures responsible for evolution of current is stable in their numbers and they don't suffer reduction or in another meaning the COD is not diminished due to the existence of more than one type.

Figures 17-18 show that the maximum current is about 0.08 mA and the generated power is about 9µw which is better in value compared to the power gained in case of no air is forced.

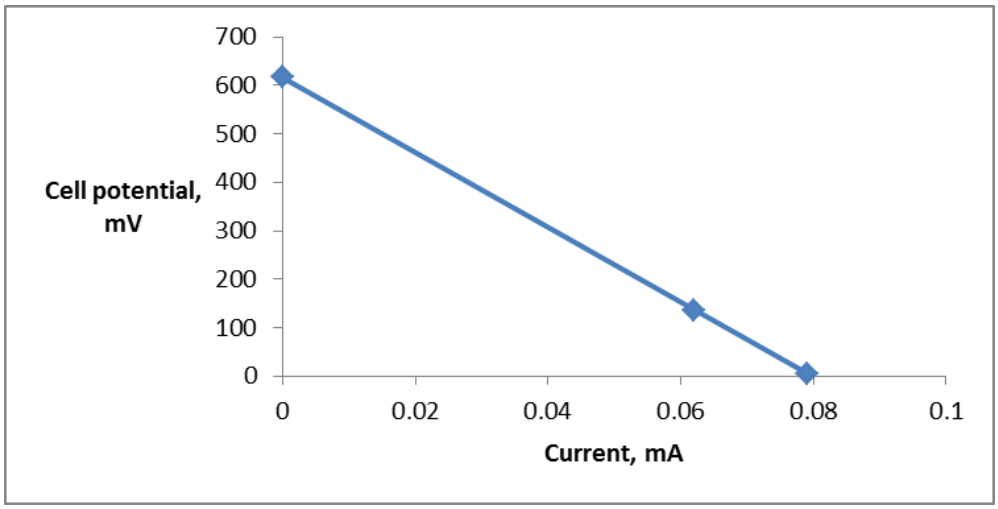


Figure 17: Cell voltage-current relationship at the beginning of the process with air purging

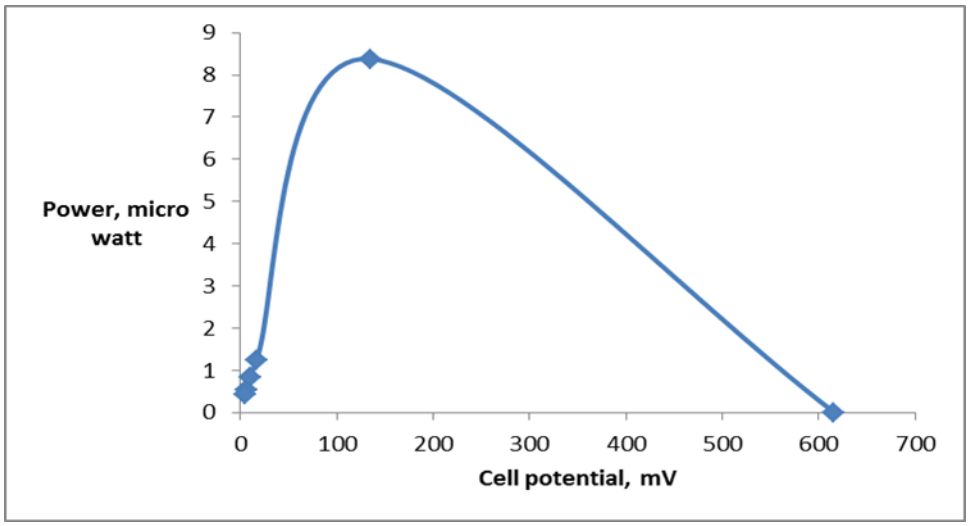


Figure 18: Power-cell voltage curve at the beginning of the process

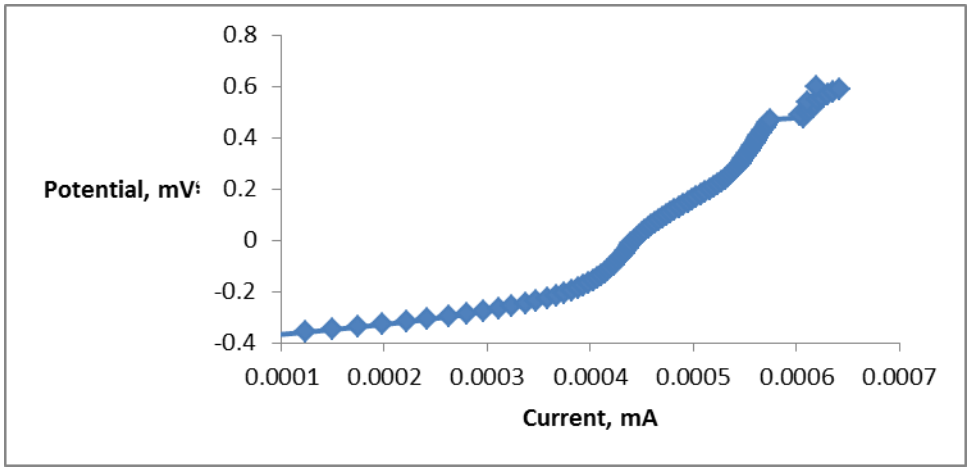


Figure 19: Anodic polarization curve at the end of process

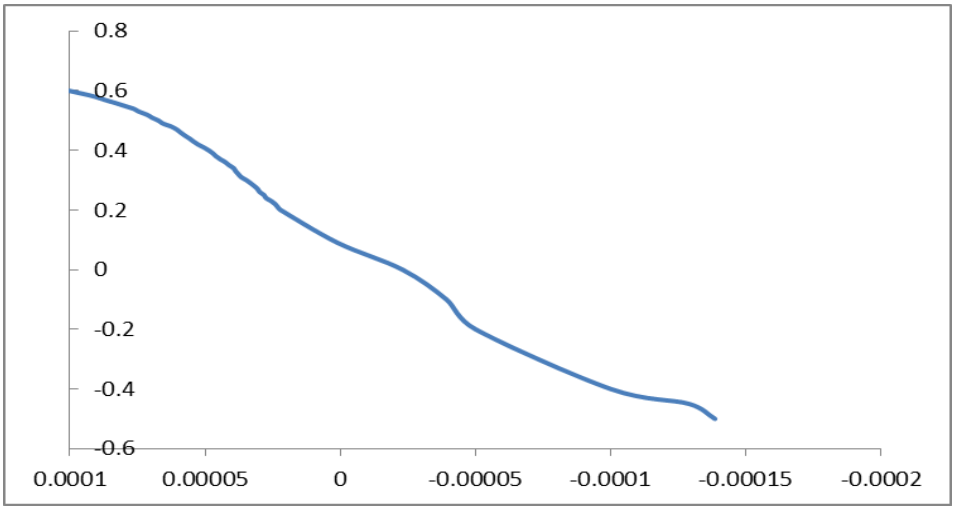


Figure 20: Cathodic polarization curve at the end of the process with air

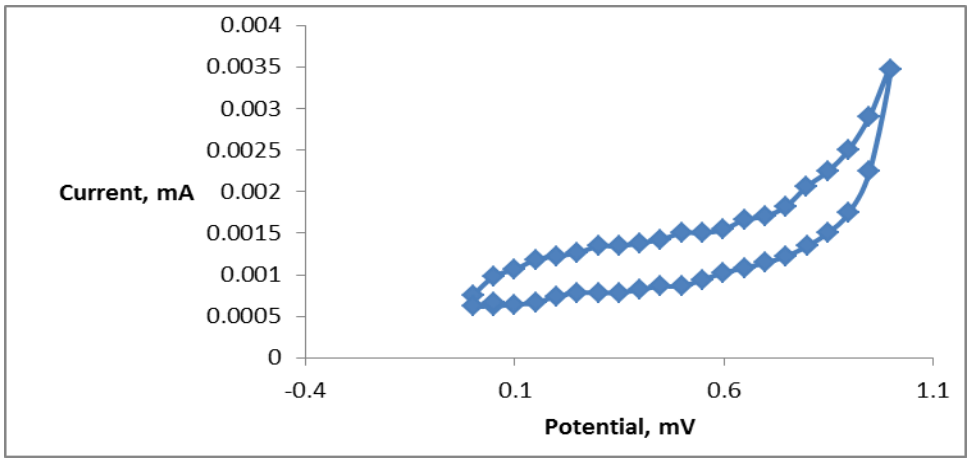


Figure 21: Anodic cyclic voltammetry at the end of the process

Figures 19-21 show the anodic, cathodic and cyclic voltammetry, from these figures no distinguished things with respect of anode compared to that in figure 11. For the case of cyclic voltammetry figure 21 shows the same trend as in the case of the beginning figure 13 which approves the stability of the system while for that of cathode in figure 20 there still an absence of mass transfer limitation which is resembles that in case of figure 12.

Referring to table 1 the abstracted values of kinetic factors for the case of presence of air that the anode is affected clearly to the situation it improves the cell performance and this could results from the alteration of the symmetry factor which is a distinguished trace for the positive effect of bacteria on the anode surface. While for cathode there is improvement in the open circuit potential as well as a reduction or elimination of concentration potential which has a clear improvement during the period of the process.

Conclusions

Pressing oxygen to the cathode side effect positively the cell performance and it was seen that the COD is increased at the end of the process and this could be attributed to the variety of bacteria that working on pollutants also the performance of the cell is improved.

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