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Wonderful Agricultural powring using Plant Microbial Fuel cell

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ABSTRACT— Egypt is in the throes of an energy crisis. Both rising demand and falling gas (and oil) output have in recent years transformed the country from exporter to importer of both, a shift that poses a substantial threat to its economy [26]. Although all energy forms have been subjected to high growth, electricity consumption has increased substantially causing serious concerns over the power sector's fuel mix, heavier reliance on fuel oil, and an unaffordable burden on the government budget. As a result, the government is determined to diversify the energy mix and to improve the efficiency of electricity consumption. It has also recognized that energy diversification and efficiency can impart other benefits such as cleaner environment, transfer of advanced technologies, and possible new areas of manufacturing and services. So the solution for this problem must be efficient, economic, sustainable and eco-friendly to overcome most of the troubles facing Egypt in this field. "Plant microbial fuel cell" is believed to be the ideal solution for the energy issue that can fit the previously mentioned requirements so we develop the anode and the cathode in the MFC and we found new material for making the proton exchange membrane which is "Nylon" so we made prototype for this idea and to make test plan on it to know its efficiency and its cost. And we get better results than we expected.

KEY WORDS: Microbial Fuel Cell (MFC) – Electrogensis – Plant Microbial Fuel Cell (P-MFC) – Electrogenic Bacteria

1 INTRODUCTION

Since the last 50 years till this moment, we are suffering from the energy crisis, electricity blackouts and pollution that results from the burning fossil fuel; Egypt relies on the non-renewable source of energy, the fossil fuel, that is neither clean nor cheap. Egypt consumes a huge amount of energy in different fields and these consumptions are not coherent with the production. The continuous increment of consuming fossil fuel is not strange because we ignore renewable sources of energy such as solar cells, wind turbines, geothermal, biomass, Etc…. As a result, we had to find a source of energy instead of the fossil fuel in order to get rid of the energy crisis, pollution and greenhouse gases emissions, which are the main reason for global warming phenomenon. In order to find a solution for this problem, we investigated the prior solutions in this field. From these solutions project, namely microbial fuel cell (MFC) [4,5] that gave us the opportunity of thinking about the idea of P-MFC (plant-microbial fuel cell) that mainly depends on the plants its photosynthesis process, with the equation,

$$6CO_2 + 6H_2O \text{ –sunlight----> } C_6H_{12}O_6 + 6O_2$$

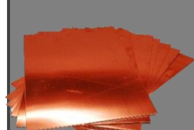
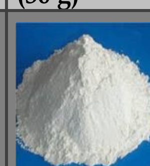
producing glucose ($C_6H_{12}O_6$). The plant consumes 30% of glucose and stores the 70% in the soil of the plant [8] to be eaten by microorganisms naturally living in the soil of the plant like Shewanella and Geobacter [9,24,15]. These microorganisms produce protons H^+ and electrons e^- [6]. In our P-MFC it is separated into two parts one for the soil and it contains the anode, made of Aluminum, to attract electrons produced from the microorganisms and the other half contains the cathode, made of copper, there is PEM (proton exchange membrane) [11,17] between them to let the protons H^+ pass to the cathode while the electrons don't pass. As the plant we already use in the project is a watery plant, needs more water to grow (clay soil), so it prevents the electrons e- from reacting with the oxygen O_2 in the atmosphere. Otherwise, it goes in the circuit from anode to cathode. [26,23]

2 LITERATURE REVIEW

Like Microbial Fuel Cell (MFC), Plant Microbial Fuel Cell (P-MFC) was made in tubular system (Logan.2006), (Helder, 2012). And this system reduces the efficiency of (P-MFC) and increase the internal resistance of it according to (Plant-e, 2013). But we will use better system to overcome these problems which is the flat system. the materials which was used as Proton Exchange Membrane (PEM) may be Nafion or Teflon. Nafion has very low efficiency relative to its high cost (e.g. Nafion). On the other hand, Teflon is inexpensive but has very low efficiency. In our working, we discover new material which was Nylon that is considered the best choice.

3. Materials

Glass container (25cm*25cm*20cm)	Nylon (25cm*20cm)	Sugar-cane	Plate of Aluminum (anode)
			

Copper plate (cathode)	pH meter	calcium carbonate (30 g)	4.Crocodile wires &Multimeter
			

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4.Methodes

1- Putting the wet plant (Sugarcane) with its soil inside the glass container
2- Making space between the soil and the wall of the glass container around 2cm to 2.5cm and Watering the plant with water
3- Putting the membrane (Nylon) in the end of the soil
4- Immersing the Anode (Aluminum) in the soil and touching it with the root of the plant
5- Putting the cathode in the container behind the proton exchange membrane.
6- Connecting the anode and the cathode plates with crocodile wires.
7- Using Calcium Carbonate and pH meter to make the pH reading from the membrane to 10cm in the direction of the soil between 7 to 7.3 and the pH reading in the rest of the soil from 6.7 to 7. (Fig.1) shows the final prototype model

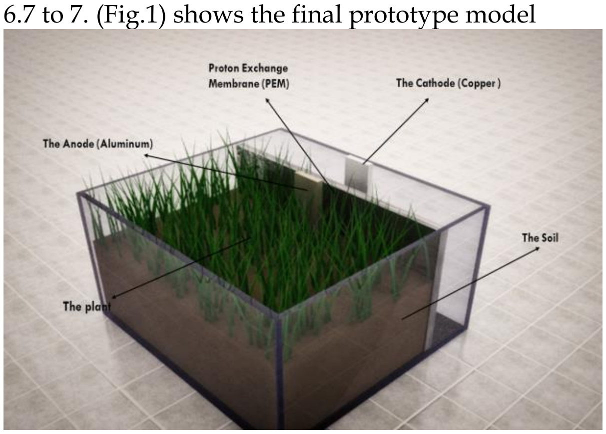

Figure 1.
The final 3D design for prototype

5.Test Plan

The readings of the multimeter are recorded to determine the potential difference in our project to compare btween it and the other projects such as Microbial Fuel Cell (MFC). (Table.1)
the readings of the multimeter are also recorded to our project using Nylon Membrane and Gelatin membrane to know which one is better. (Table.2)
We calculate the cost of each component in (P-MFC) and compared btween the price of (P-MFC) and the cost of (MFC). (Table.3)
Afterall we compared between the price of 1000 watt that is produced with (P-MFC) and Solar cell. (Figure.2)

6. Results

Time	MFC	P-MFC
9 AM	725 MV	1300 MV
1 PM	713 MV	1420 MV
5 PM	702 MV	1340 MV
9 PM	698 MV	1280 MV

Table1.
The multimeter readings of MFC and P-MFC

Time	Gelatin	Naylon
9 AM	720 MV	1300 MV
1 PM	760 MV	1420 MV
5 PM	705 MV	1340 MV
9 PM	685 MV	1280 MV

Table 2. The multimeter readings of P-MFC Using Nylon and Gelatin

Material	in MFC (average cost)	In P-MFC (average cost)
Proton exchange membrane	Nafion (150 $)	Naylon (0.165$)
Anode	Graphite (2$)	Aluminum (0.5$)
Cathode	Graphite (2$)	Copper (0.5 $)
Total	154 $	1.165 $

Table 3. The price of component of MFC and P-MFC

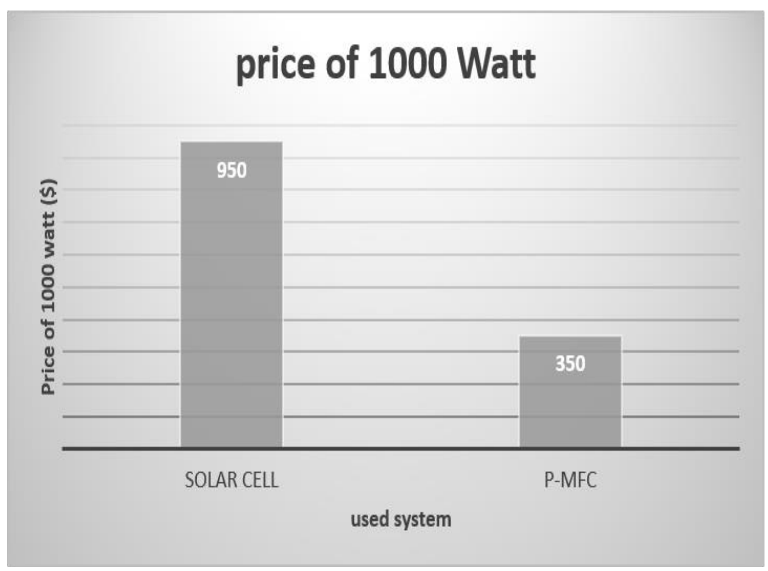

Figure.2
Comparison between solar cell and (P-MFC)

7 DISCUSSIONS

➢ THE PLANT & SOIL

The plant is the main part in our project because it is the source of organic matter. So, we chose rice (in the summer) and alfalfa (in the winter) to make the integration between the agricultural seasons. We think that the rice and the alfalfa are the suitable to plant to use in our project because they have high photosynthetic efficiency [19] and the properties of their soil which are:

- o Having Good water retention capacity.
- o Having the Good amount of clay and organic matter.

first property (Having Good water retention capacity) was needed as Existence of water in anodic half helps to prevent the electron from combining with the molecules of Oxygen (O2) from the air. We also need the second property (Having the Good amount of clay and organic matter) because the organ-ic matter is the nutrient of bacteria.

Additional to these properties, the soil of these plants has a suitable environment for the living of micro organisms like Shewanella and Geobacter.

As we research for a similar plant which is planted in the same environment and has the same properties of rice and alfalfa, we found the sugarcane.

Sugar cane is the source of sugar in all tropical and subtropical countries of the world. We can use sugarcane in all seasons because it is planted all over the year. Sugarcane also has the highest photosynthetic efficiency (from 7% to 8%). So, it would be the best choice to use in our prototype. [19]

➢ THE ELECTRODES

Plant Plant microbial fuel cell (P-MFC) consists of two parts that have been separated by the proton exchange membrane (made from Nylon). Each part of P-MFC contains one electrode in the soil there is the anode electrode (made of Aluminum) and the other half contains the cathode electrode (made of copper). Test was done on Traditional (MFC) to be able to choose the electrode [9]. The test was done over 14 days on 20 different pair of electrodes (Figure 2). As shown in (Figure 2) , two combinations of electrodes Cu/Al and Cu/Zn gave the higher voltage compared to other combination of electrodes which have been studied. But if we compared between them according to other factors like life span and the cost, we will find that the Aluminum (Al) has low corrosion rate that mean that it has life span that is approximately 150 days. On the other hand, zinc (Zn) has relative high corrosion rate that is 100. So, the using of Aluminum as electrode will make the electrode last for longer time. For the cost, the Aluminum cheaper than the Zinc with ratio .9 : 1.So, the using of Cu/Al pair will be efficient with low cost.

Importance of the electrodes in (P-MFC):

O The anode (Aluminum):

As the bacteria breath metal (Aluminum), it condenses over its surface (Figure 3) And start to produce electrons [6]. The electrons produced from bacteria are attracted to be transferred to the cathode through the circuit. The anode is buried deep enough, where there is no oxygen, so this reaction (between electron and oxygen) could not take place right next to the anode. And the following equation represent the oxidation reaction in anodic half.

$$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 4e^-$$

O The cathode (Copper):

It completes the circuit with anode to let the passage of the electrons flow through the wire. Electrons from the anode travel up a wire to the cathode with out any mediators [15] and, once there, they react with oxygen (from the air) and hydrogen (produced by the bacteria as it digests the nutrients in the soil) to create water.

We chose copper because it is good conductor of electricity, It is cheaper than other electrodes (like graphite), has higher surface area. And the following equation represent the reduction reaction that happens In cathodic half.

$$6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$$

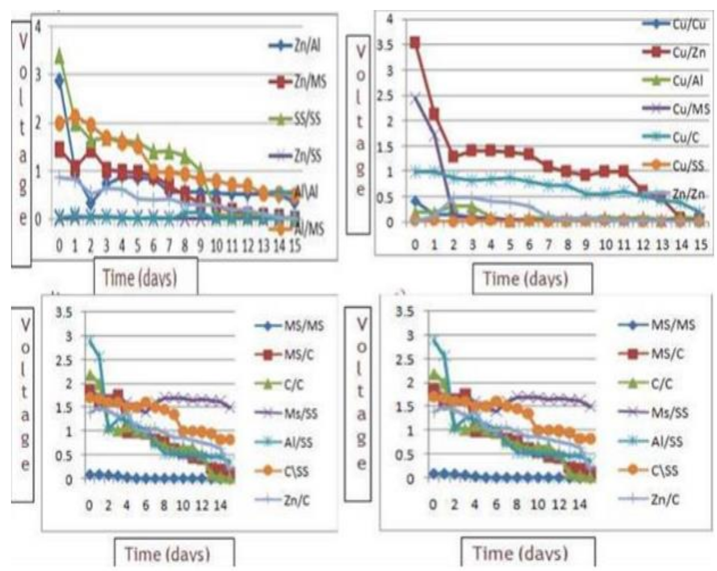

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Figure 2.
Results of electrode Test

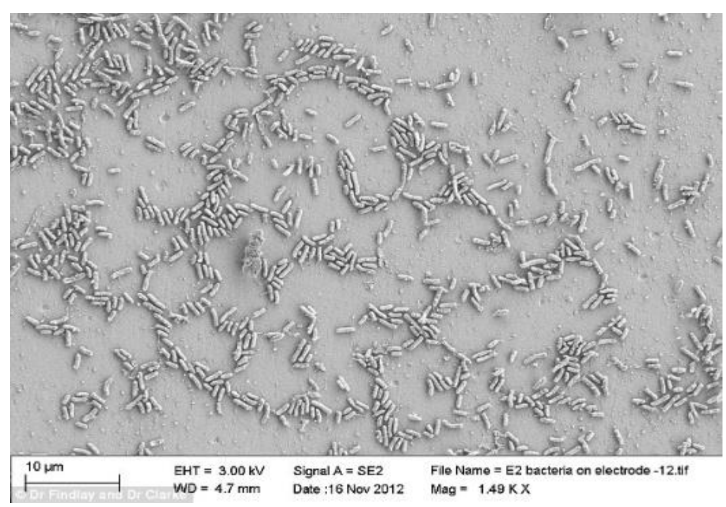

Figure. 3
Condensation of bacteria over an electrode

➢ PROTON EXCHANGE MEMBRANE (PEM)

A semipermeable membrane that is designed to allow pro-ton penetration from anodic half to the cathode due to the protentional difference between the two sides of the plant microbial fuel cell also, prevent the water and the electrons penetration. [11] As the existence of the water in anodic half is preferable to prevent the electron from combining with the molecules of Oxygen (O2) from the air. In traditional Micro-bial Fuel Cell (MFC), fluoropolymer Perfluoro sulfonic acid -with trade name Nafion which is used as (PEM) but, it is low-efficient in a relation with its price which is around 150$ and it isn't available in Egypt. [25] An alternative membrane must have high efficiency and low in cost, gela-tin powders which are used in the food can be used as a pro-ton exchange membrane if it is feezed at the lower temperature. [17] A test is made on the plant microbial fuel cell with gela-tin membrane but, low results were observed. Also, gelatin has low thermal stability as it melts at the room temperature (25 °C) after 4 hours to form jelly material. After that, the pro-totype were built with the nylon membrane that led the pro-ject to have high efficiency as it raised the output voltage more than what the gelatin did. Nylon (C12H22N2O2). Nylon is waterproof material formed from a polymer of adipic acid and hexamethylene diammine. It is widespread material as it used in several fields. The efficiency of the plant microbial fuel cell depends on the effect of proton exchange membrane (PEM) is still lacking. [25] PEM is important for any MFCs as it acts to transfer the produced protons from the anode to the cathode compartment. The efficiency and economic viability of MFCs depend strongly on the performance of PEM as shown in the (Figure.4) the passage of the protons (H+) de-pends on the protentional difference on the both sides of the membrane. [10]

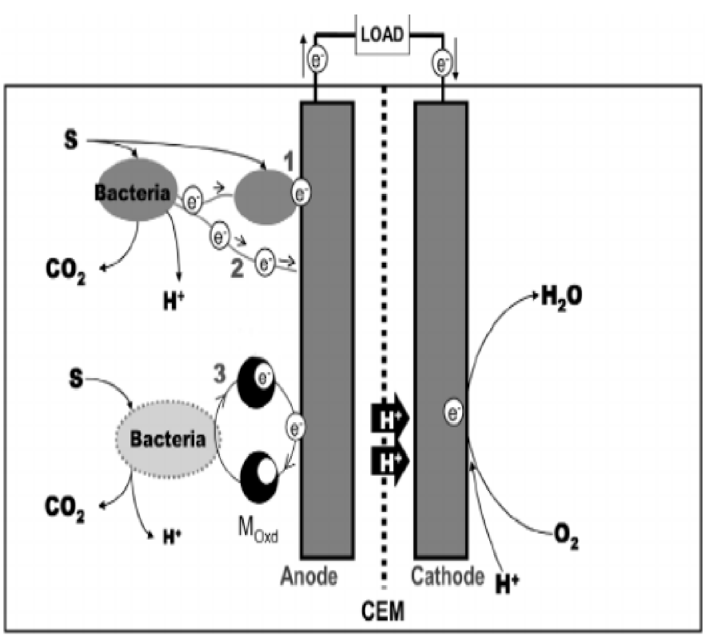

Figure. 4
Mechanism of plant microbial fuel cell

➢ PH IN THE SOIL

Firstly, pH is a numeric scale used to specify the acidity or basicity of a soil. More Existence of proton (H+) for example more acidity means low pH and vice versa for calculating the PH (PH formula):
pH = -log[H+]
Or with pH meter.
The neutral pH rate in the soil is from 6.6 to 7.3. As we know, we need the proton (H+) to diffuse from anodic half to cathodic half so we need to make the pH rate of cathodic half higher than the pH rate in anodic half to make the proton (H+) diffuse from an area of high proton concentration (low pH rate) to an area of lower proton concentration (high pH rate) [18]. So we used Calcium Carbonate ($CaCO^3$) to make the pH rate in cathodic half from 7 to 7.3 and the pH rate in anodic half from 6.6 to 6.9.[20]

➢ PROTOTYPE SYSTEM

In order to achieve the highest efficiency for our plant-microbial fuel cell, we have to choose the best system design to build our plant microbial fuel cell according to it. There are two different systems (tubular system & flat plate system) (Fig.5) [7] each one plays an important role for increasing and reducing the internal resistance (diffusion of the ions in the plant microbial fuel cell from the anode to the cathode) inside the plant-microbial fuel cell.

O Tubular system:
The internal resistance in this system is very high. There is a long distance between the anode and the cathode (A long distance from anode to cathode leads to transport losses in the anode) of the plant microbial fuel cell. [3,4]

O Flat-plate system:
Since the membrane in the flat-plate design is placed vertically, membrane surface area per geometric planting area is increased, which allows for lower internal resistances. From the advantages of the flat- plate system is that the distance between the anode and the cathode is shorter than the one in the tubular system.

thus, in order to increase the output of the P-MFC, the internal resistances need to be reduced and this will be found in the flat- plate system so we chose this system to build our prototype according to it

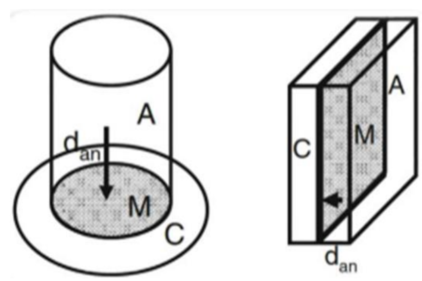

Figure. 5
The Tubular system and the Flat system

➢ Mediator-less P-MFC

One of the features in the plant microbial fuel cell that makes it different from the traditional microbial fuel cell is that the P-MFC is mediator-less unlike the traditional MFC that depends on specific mediators or electrolytes to facilitate the pass of electrons to the anode like the potassium hydroxide, potassium chloride, sodium hydroxide, sodium nitrate.[20]

Reason for being the P-MFC mediator-less:

1. It does not depend on electrolytes (such as potassium hyd roxide) because they are toxic substance that may harm the plant and have bad influence on the plant
2. Electrolytes have bad influence on the electrogenic microorganisms which are the bacteria that produce the electrons(e-) and protons (H+) like shewanella and geobacter.[1,3]

The alternative of the mediators and electrolytes in the plant microbial fuel cell (P-MFC).

There are electrogenic bacteria naturally found in the soil of the plant [1]. These electrogenic microorganisms have the ability to breathe metals and produce sticky substance that facilitate the electron pass to the anode. These sticky substances collected around the anode making layer called "biofilm".[24]

➢ Microorganism (Bacteria)

They are electrogenic microorganisms that are naturally being found in the soil, also they are found in anaerobic environments such as sediments of rivers, lakes or seas. These creatures have the ability of producing electrons and protons when they breathe the metals. [1, 23]

Since we will put Aluminum as anode (bacteria will create a biofilm on it) in the soil the bacteria will have the ability of producing protons (H+) and electrons (e-). [24]

Types of electro-genic bacteria:

1. Shewanella
2. Geobacter

➢ Electrogenesis

Most microorganisms use respiration to convert biochemical energy into ATP [1]. This process involves a cascade of reactions through a system of electron-carrier proteins in which electrons are ultimately transferred to the terminal electron acceptor [19]. In WAP project electrogenic bacteria like shewanella and Geobacter contains extracellular electron acceptor, which helps it to release the electrons in their last stage of their chemiosmosis [13]. Extracellular electron transfer in microorganisms has been applied for bio electrochemical synthesis utilizing microbes to catalyze anodic and/or cathodic biochemical reactions. Anodic reactions (electron transfer from microbe to anode) are used for current production and cathodic reactions (electron transfer from cathode to microbe) have recently been applied for current consumption for valuable biochemical production. [15,17]

The extensively studied of electrogenic bacteria Shewanella and Geobacter showed that both directions for electron transfer would be possible. This mechanism proposes direct electron transfer between electron carriers in the bacteria and the solid electron acceptor. This mechanism is supported by the presence of outer-membrane cytochromes which can interact directly with the solid surface to carry out respiration. [13]

7. Conclosion

Modifying the plant microbial fuel cell with effective changes on it that increases its efficiency and noticeably reduce its cost instead of being expensive. Using very cheap and high efficient materials and this led the plant microbial fuel cell to meet its design requirements. Plant microbial fuel cell is an easy project to be applied in the agricultural field and it will be good resource of electricity to the developing country.

The following calculations for the output from plant microbial fuel cell (P-MFC) and what this project will provide Egypt with if it is applied.

Voltage = 1.4 V (±3%)

Current intensity = 1.6 A (±3%)

Power intensity (per 25 Cm *25 Cm) = voltage *Ampere
= 1.4 * 1.6 =2.24 W per 25Cm*25Cm

Power intensity per M2 = 2.24 * 16 = 35.9 W / M2

We have 4200.83 M2 in one acre

Power intensity in one acre = 35.9 * 4200.8 = 150808.7 W/acre

- For water that is produces in cathodic half

Since the produced current intensity from the applied project (25 * 25 *25) cm^3 is equal 1.6 ampere in one second.

I = Q / T

Current intensity = quantity of charge / time

Q = 1.6 / 1 = 1.6 coulomb/ sec

N = Q / e

Since (N) number of electrons, (Q) quantity of charge and (e) charge of one electron.

No. electron = 1.6 / 1.6021762*10-19
= 9.9875*1018

No. moles = No. electron / Avogadro's number

No. moles = 9.9875*1018 / 6.02214*1023
= 1.6585 * 10-5 Mole

Ratio between the moles of e- and the moles of H2O is
2 : 1

No. moles of water (H2O) = 1.658466*10-5 * 12 / 24
= 8.293*10-6 Mole

Mass of the water (H2O) =
No. of moles of water (H2O) * molar mass
= 8.293x10-6 *18.1 = 1.593x10-4 g/s = 1.593x10-4 ml/s

Produce water in one day = 1.593x10-4 *86400 = 12.8973 ml / day

The produced water in (25 * 25) prototype = 12.8973 ml / day

The produced water in m2 = 12.8973 * 16 = 206.4 ml / day Since on acre contains 4200 m2

The produced water in one acre = 206.4 ml * 4200
= 866698.569 ml / day

Produced water in one day = 866698.569 / 1000
= 866.6985 L / day

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8.REFERENCES

[1] Reece, J., & Urry, L. (n.d.). Campbell biology (Tenth ed.).
[2] Kelter, P., & Zumdahl, S. (2007). Chemistry, seventh edition, Zumdahl. Boston: Houghton Mifflin.
[3] Helder et al. Biotechnology for Biofuels 2012, 5:70 www.biotechnologyforbiofuels.com/content/5/1/70
[4] Bruce Logan Research - Microbial Fuel Cells. (n.d.). Retrieved April 21, 2016, from http://www.engr.psu.edu/ce/enve/logan/bioenergy/research_mfc.htm
[5] Gude, V. (2016). Microbial fuel cells for wastewater treatment and energy generation. Microbial Electrochemical and Fuel Cells, 247-285. doi:10.1016/b978-1-78242-375-1.00008-3
[6] O. (2016, January 19). Extracellular electron transfer from cathode to microbes: application for biofuel production. Retrieved February 19, 2017, from https://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-016-0426-0
[7] P., & Quick, D. (n.d.). Plant-Microbial Fuel Cell generates electricity from living plants. Retrieved April 21, 2016, from http://www.gizmag.com/plant-microbial-fuel-cell/25163/
[8] A. H. (2015). Http://vixra.org/pdf/1509.0145v1.pdf. Egypt : ViXra.
[9] H. L. (n.d.). Production of Electricity during Wastewater Treatment Using a Single Chamber Microbial Fuel Cell (1st ed.).
[10] Biotechnology for Biofuels. (n.d.). Retrieved April 21, 2016, from https://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/1754-6834-5-70
[11] A review on the role of proton exchange membrane on the performance of microbial fuel cell. (n.d.). Retrieved April 19, 2016, from http://onlinelibrary.wiley.com/doi/10.1002/pat.3383/full
[12] He Z, Huang Y, Manohar A, Mansfeld F. (2008). Effect of electrolyte pH on the rate of the anodic and cathodic reactions in an air-cathode microbial fuel cell. Bioelectrochemistry 74: 78–82
[13] Hernandez M and Newman D. (2001). Review Extracellular electron transfer. CMLS, Cell. Mol. Life Sci. 58: 1562–
[14] Beer, C. D., Barendse, P., & Khan, A. (2012). Emulation of high temperature PEM fuel cell electrical dynamics and operational phenomena. 2012 IEEE Energy Conversion Congress and Exposition (ECCE). doi:10.1109/ecce.2012.6342216
[15] Operational parameters affecting the performannce of a mediator-less microbial fuel cell. (n.d.). Retrieved February 20, 2017, fromhttp://www.sciencedirect.com/science/article/pii/S0956566302001100
[16] Hosseinpour, M., Vossoughi, M., & Alemzadeh, I. (n.d.). An efficient approach to cathode operational parameters optimization for microbial fuel cell using response surface methodology. Retrieved April 17, 2016, from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3937156/
[17] Prepare The Proton Exchange Membrane. (n.d.). Retrieved March 29, 2015, from www.instructables.com/id/Microbial-Fuel-Cell-Of-Science/step2/Prepare-The-Proton-Exchange-Membrane/
[18] Treacy, M. (n.d.). Plant-Microbial Fuel Cell Produces Power from Plants. Retrieved April 21, 2016, from http://www.treehugger.com/clean-technology/plant-microbial-fuel-cell-produces-power-plants.html
[19] A. M. (2015, January 20). Energy Efficiency Of Photosynthesis in plants . Retrieved January 5, 2016, from https://www.britannica.com/science/photosynthesis/Energy-efficiency-of-photosynthesisEnergy.gov. (n.d.). Retrieved March 15, 2015, from http://energy.gov/eere/fuelcells/fuelcells
[20] Aelterman P, Rabaey K, Pham T, Boon N, Verstraete W. (2006). Continuous electricity generation at high voltages and currents using stacked microbial fuel cells. Env. Sci. Technol. 40: 3388-3394.
[21] Aelterman P, Versichele M, Marzorati M, Boon N, Verstraete W. (2008) Loading rate and external resistance control the electricity generation of microbial fuel cells with different three-dimensional anodes. Biores. Tech. 99: 8895–8902.
[22] Ahn Y, Logan B. (2010). Effectiveness of domestic wastewater treatment using microbial fuel cells at ambient and mesophilic temperatures. Bioresour Technol. 101: 469–475.
[23] Beliaev A, Thompson D, Fields M, Wu L, Lies D, Nealson K and Zhou J (2001) Microarray Transcription Profiling of a Shewanella oneidensis etrA Mutant. J Bacteriol. 184: 4612-4616.
[24] Franks A, Nevin K, Jia H, Izallalen M, Woodarda T and Lovley D. (2009). Novel strategy for three-dimensional real-time imaging of microbial fuel cell communities: monitoring the inhibitory effects of proton accumulation within the anode biofilm. Energy Environ. Sci. 2: 113-119.
[25] Gorby Y, Yanina S, McLean J, Rosso K, Moyles D, Dohnalkova A, Beveridge T, Chang I, Kim B, Kim K, Culley D, Reed S, Romine M, Saffarini D, Hill E, Shi L, Elias D, Kennedy D, Pinchuk G, Watanabe K, Ishii S, Logan B,

Nealson K and Fredrickson J. (2006). Electrically conductive bacterial nanowires produced by Shew
[26] Various Disadvantages of Fossil Fuels. (2017, May 21). Retrieved July 15, 2017, from http://www.conserve-energy-future.com/Disadvantages_FossilFuels.php