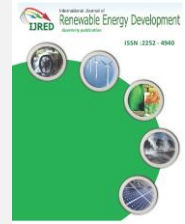




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# Scale Up Sediment Microbial Fuel Cell For Powering Led Lighting

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**ABSTRACT.** Sediment microbial fuel cells (SMFCs) are expected to be utilized as a sustainable power source for remote environmental observing 30 day's investigations of experiment to understand the long-term performance of SMFCs. The point of this investigation is to increase power generation, 8 individual sediment microbial fuel cells is stacked together either in series or in hybrid connection. Two combinations, of the hybrid connection, are proving to be the more effective one, step-up both the voltage and current of the framework, mutually. Polarization curve tests are done for series and hybrid connected sediment microbial fuel cell. The maximum study state voltage and current are obtained 8.150V and 435.25 $\mu$ A from series and 4.078V and 870.75 $\mu$ A hybrid connected SMFC. This study suggests that power of SMFC scale-up by connecting series and hybrid for practical use of the device.

**Keywords:** sediment microbial fuel cell , series, hybrid connection, open circuit voltage, Power source

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## 1. Introduction

Presently, expanding world population and expanding welfare, energy request worldwide is growing. Right now, jumble-sale of fossil fuels is unevenly appropriated over the world is being depleted, and is unsustainable. Sustainable renewable energy sources are accessible these days all have their disadvantages. They are climate subordinate (wind, solar power), contend with food/feed generation (some biofuels) or include high speculation costs. The present environmental change by CO<sub>2</sub> production from burning of fossil fuels raises the resolution for renewable energy invention. Presently many researchers are working on various sustainable power sources such as solar energy, wind and geothermal (Panwar et al., 2011). But every one of these sources cannot be utilized in areas that don't have particular geological elements. Therefore, new innovations should be created to block this gap. Fuel cell innovation is a standout amongst the most encouraging lines since it proposes a one of a kind combination of advantages that make it a crucial innovation. Fuel cell is in a perfect world suited for extensive market fragments of our vitality framework

without any pollution, have the high efficiency conversion of biochemical energy to electricity (Kreuer 2013). Over the previous decade, the progress of the microbial fuel cell (MFC) in biotechnological study offers a brand new innovation that turns biochemical energy of biological matter into electricity using micro-organisms as the substance (Aelterman et al., 2006, Lemuel et al., 1982, Reimers et al., 2001, Kim et al., 2002, Gil et al., 2003).

Sediment microbial fuel cells (SMFCs) are expected to be utilized as a sustainable power source to activate remote sensors and electrical equipment for environmental observing (Dewan et al., 2014). Soil of lakes, rivers, and oceans used as electrolyte and generate power where needed without maintenance (Donovan et al., 2008, Tender et al., 2008, Reimer et al., 2001). The main advantages of SMFCs are that they do not generate toxic wastes, tiny maintenance necessity, long-term energy generation as well as in situ waste water treatment, while the batteries generally utilized for this reason are not relevant for a long time (Donovan et al., 2013, Zho et al., 2014, Ewing et al., 2014).

The organic compounds in the sediment serve promising renewable fuel of electro-organic microbes

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to inoculate the anode surface. Electro-genic microbes involve *Geobacter sulfurreducens* (Wang et al., 2014, Bond et al., 2003), *Rhodospirillum rubrum* (Jiang et al., 2010), *Shewanella putrefaciens* (Chaudhuri et al., 2003), *Clostridium spp.* (Kim et al., 1999), and *Bradyrhizobium spp.*, which oxidize organic matter and generate electrons and protons (Rismani-Yazdi et al., 2007, Zhang et al., 2012, Aller 1994). Open circuit

red-ox potential Between the sediment and overlaying water is 0.7 V to 0.8 V (Reimers et al., 2006). These electrons are moved from anode to cathode via an external circuit and accepted by an electron acceptor in the cathode, where they condense oxygen (Ateya et al., 2002). Single-chamber SMFC has just an anode while the cathode is presented to the air, with electron acceptor O<sub>2</sub>.

**Table 1**  
 Performance studies of different anode cathode used in Sediment MFC

Anode	Cathode	Open circuit voltage (V)	Reference
Graphite anode	Carbon fibre	0.400	(Wotawa et al., 2010)
Graphite fibre	Graphite fibre	0.664	(Xu et al., 2017)
Carbon felt	Carbon felt	0.158	(Abazarian et al., 2016)
Graphite felt	Iron	0.431	(Zhang et al., 2015)
Iron	Graphite felt	0.645	(Zhang et al., 2015)
Carbon cloth	Carbon cloth	0.250	(Majumder et al., 2014)
copper	zinc	1.160	[This work]

Microbial fuel cell can be a stacked configuration either in the form of series connection or in parallel connection (IoannisIeropoulos et al., 2008). The voltage of the MFC in series connection is the sum of the Single MFC voltages and the current of the MFC stack in parallel configuration is the sum of the single MFC currents and the voltage is the average voltage of all the MFCs in the stack (Peter Aelterman et al., 2006, IoannisIeropoulos et al., 2010).

In an effort to increase power from MFCs, eight MFCs stacked in series electrically connected by copper wires. The stacked configuration enabled an increase in the total voltage to 2.02 V (Peter Aelterman et al., 2006). In another MFC study, a double-cell air-cathode MFC stack verified and found that the stacked MFC developed an operational voltage of 0.9 V (external load 500Ω) and in good condition, the MFC had an open circuit voltage (OCV) of 1.3 V (Oh et al.,2007). Performance studies of different anode and cathode used in Sediment MFC Type have been summarized in Table1. They developed the different voltage using different anode and cathode material. In this research work, development of a Sediment MFC is using copper anode and zinc cathode has been done. It has been observed that this generates higher voltage in comparison to the previous reported researcher. In this study, the power output from sediment substrates was examined 8.15 V by series connected SMFCs using zinc as an anode and copper as a cathode. The spacing between the anode and the cathode was kept as minimum as possible. In order to increase power generation, SMFCs were stacked together in series

and in parallel. Additionally, the stack MFC was operated in batch mode for 30 days in series.

## 2. Materials and Methods

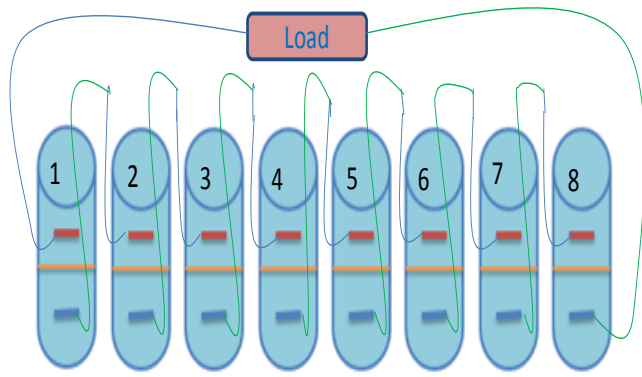
### 2.1 Raw Materials

Electrolyte material consisting of sediment collected from flower field of Motilal Nehru National Institute of Technology (MNNIT), Allahabad, U.P, India was used as electrolyte. The sediment was kept at room temperature (25°C) prior to experiment. This experiment tested in electrical laboratory of MNNIT, Allahabad, U.P,India.

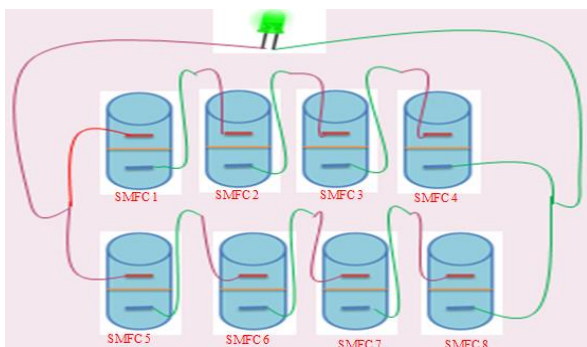
### 2.2 Sediment Microbial Fuel Cell assembly

We designed Single chamber SMFC systems of volume 8L. The stacked SMFC 1 module was prepared by 8 individual SMFC units (Figure 1). Each individual SMFC unit had cylindrical poly-acrylic plastic shape of volume ~1000 mL (8.89 cm width x 16.51 cm height). Half of the bottles were filled with sediment and other half were filled with water. An anode of Copper electrode (7.5 cm height, 2.5 cm width and 2mm thickness) was inserted into the cylindrical anode compartment. A cathode of Zinc electrode (7.5 cm height, 2.5 cm width and 2mm thickness) was inserted into the cylindrical cathode compartment. The Copper anode is set into sediment and zinc cathode is suspended in the water section. The distance between electrodes kept 2 cm. The electrode was connected by copper wire (1.5mm<sup>2</sup>) through the external load. The inoculated cultures were incubated

at room temperature 25°C. The microscopic organisms were completely developed for the term of 24 h in sediment with no unsettling. For the series connection of 8 SMFC units, the cathodes of SMFCs1 were connected to the anode from SMFCs2 up to final SMFC units (Figure1a). For the hybrid connection, 2 units connected in parallel; each unit contains 4 SMFC which was connected in series (Figure1b).



(a)



(b)

Fig. 1 SMFC Array connections. (a) Series (b) Hybrid

Table 2

The maximum study state voltage and current generated from different configuration

Type of configuration	Open circuit voltage(V)	Maximum generated current (µA)
Series Connection	8.150 ± 1.031	435.25 ± 20
Hybrid Connection	4.078 ± 0.980	870.75 ± 50

2.3 Experimental method and analysis

About 600 gram of sediments was poured into the cylindrical plastic bottles for making all SMFC. This was then fixed with a plastic cap to recreate anaerobic condition anaerobic condition. The voltage and current were measured for the charged MFC using two digital multimeters (Agilent U1232A) at a specific time. The power output was checked by measuring voltage and

current the outer resistor associated with the anode. Keeping in mind the end goal to acquire the polarization bend, the outer resistance was shifted from 47 Ω to 147 Ω, to 214 Ω, to 327 Ω, to 475 Ω, to 687Ω, to 735 Ω, to 835 Ω and 987 Ω. The meter was associated with the framework through cathode terminals of the particular cathode and anode.

The voltage (V<sub>o</sub>) and current (I<sub>o</sub>) through different resistance (R<sub>o</sub>) of the MFC measured every 60 second interval by two digital multi-meters. Where, the voltage V<sub>o</sub> (in V), the current I<sub>o</sub> (in µA) and outside resistance R<sub>o</sub> (Ω). Power (P<sub>o</sub>) was computed by P<sub>o</sub> = I<sub>o</sub>.V<sub>o</sub>, Where P<sub>o</sub> is in µW. The projected anode area was 0.339 m<sup>2</sup>.

The Coulombic efficiency (CE) is determined as the coulombs recovered by way of current (CE<sub>e</sub>) versus the theoretical amount available in organic matter (CE<sub>t</sub>), was calculated by integrating the current over time for an each interval of time as

$$CE = \frac{CE_e}{CE_t} \times 100 \tag{1}$$

$$\text{Where } CE_e = \sum_{x=0}^t \frac{V_x \cdot I_x}{R} \tag{2}$$

The theoretical value of coulombs that is available from COD (i=c) or propionate (i=p) oxidation was determined as

$$CE_t = \frac{b_x S_x F v}{M_x} \tag{3}$$

Where F is faraday’s constant (96,485 C/mol.e-), b=4 mole e-/mol.o<sub>2</sub>, v=1L is total SMFC volume and M=32g/mol is molecular weight of oxygen.

3. Experimental results and discussion

3.1 SMFC Start- up and Operation

Microorganism in the Sediment microbial fuel cells requires an adaptation process and need a period of time for creation of the biofilm on the surface of the anode. Therefore, anaerobic fluidized bed microbial fuel cells startup require some time. Copper has standard potential (E<sub>o</sub>) value higher than Zinc with +0.337 V and -0.763 V respectively. It means that Copper and zinc Electrode material generated maximum electrical energy and potential. At the beginning of startup, OCV of single SMFC was 1.160, 0.931, 1.009, 0.982, 0.945, 1.029, 1.090 and 1.010 V, respectively. After 18 days, the maximum open circuit voltage of SMFCs was 1.140, 0.920, 1.009, 0.981, 0.941, 1.029, 1.090 and 1.010V appeared, and OCV of SMFCs was same for 30 days (Figure 2). Different voltages were obtained in each Individual SMFC units indicating that into to the two systems were generated different oxidation-reduction reaction rates and difference in potential on the electrode due to the

decreased the COD concentrations in each SMFC. Voltage of SMFC configuration is stable after 18 days.

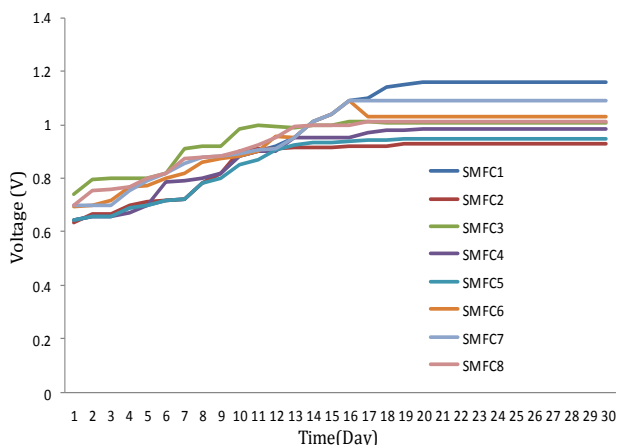


Fig. 2 Voltage generated by eight individual SMFCs

In order to increase power generation, all individual SMFCs were connected together either in series or in hybrid. The anode of the SMFC 1 is connected to the Cathode of SMFC 2 in order to complete the stackable series circuit. The stack circuit was performed when the SMFCs were in good working condition. When all SMFCs were stacked mutually in series, the OCV of the stacked series SMFCs equaled the mathematical addition of the separate SMFCs, which verified the fruitful series assembly. The stackable MFC configuration resulted in an OCV of 5.39 V of first day and OCV of 8.15V after 20 days for the series connection. Steady state maximum short circuit current 435.25  $\mu\text{A}$  was obtained in series configuration.

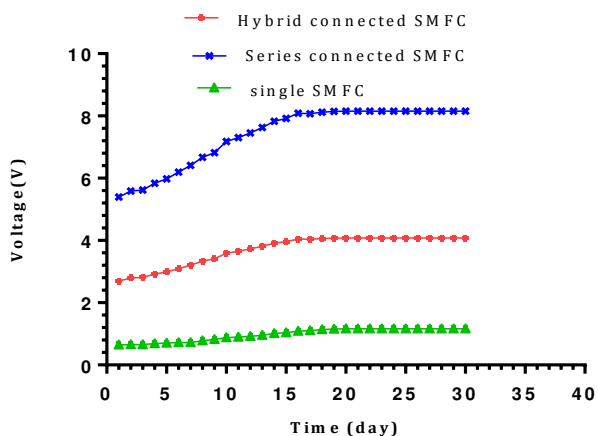


Fig. 3 Voltage generated by series connected and hybrid Connected SMFCs

Figure 3 shows the output voltages obtained during the stacked SMFC systems operation in series and hybrid connection respectively. This is a decent result in terms of potential for SMFC technology to power electronic devices. The individual SMFCs voltage is too low to be able to turn on a device so such

configuration provides a level of voltage to turn on device. LED was glowing lighter in series configuration and brighter in hybrid configuration. This is due to the increase of the current level in hybrid-connection.

In hybrid connection, first day maximum open circuit voltage 2.69V was obtained and voltage was continuous increasing. After 18 day voltage reach steady state voltage of 4.078V and maximum short circuit current 870.75  $\mu\text{A}$  was obtained. Experiments showed that the hybrid SMFC configuration resulted in an increase the voltage as well as current.

### 3.2 Polarization curves for series connection and hybrid connection

The performance of SMFCs configuration was further inspected by polarization curves sweeping through changed resistances (47 $\Omega$  to 987 $\Omega$ ). Voltage and current was observed by varying different resistance. Figure 4 shows the polarization curves of Series connected SMFCs. Voltage showed decreasing trend with increasing in current and power first increases then decreases, which indicated a typical fuel cell behavior. The hybrid Configuration shows this trend, but at a lower power. The SMFCs were then stacked in series and the polarization curve was measured. The maximum power produced from Series connected SMFCs was 780.24 $\mu\text{W}$  corresponding to current of 199.80  $\mu\text{A}$ . For the series configuration, the voltage is higher, starting at approximately 8 times the individual MFC at 7.57 V at 21.72  $\mu\text{A}$  and decreased to 1.03 mV at 66.51  $\mu\text{A}$  by increasing load.

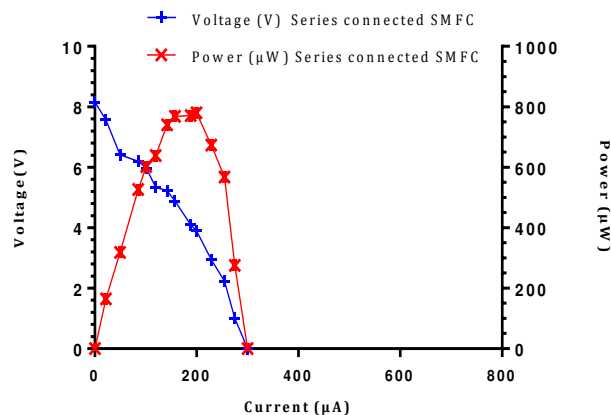


Fig. 4 Polarization Curve for series connected SMFCs

Figure 5 shows the polarization curve for the hybrid connection. The hybrid connection show lesser voltage and power developed by SMFC as compare to series configuration. But current profile is increased. By default, when the SMFCs were connected in hybrid, the voltage and current was increase. The maximum power of 486.84  $\mu\text{W}$  was obtained, corresponding to the maximum current of 350.50  $\mu\text{A}$ . In the hybrid connection, the voltage starts at 3.40 V at 21.98  $\mu\text{A}$  and decreased to 0.60 V at 567.3  $\mu\text{A}$  which is

approximately 2 times the current output of an individual SMFC. The stack performances were performed successfully without any voltage reversals. Power achieved in this experiment was comparable more with the previous MFC studies with acetate as substrate (Liu et al., 2004).

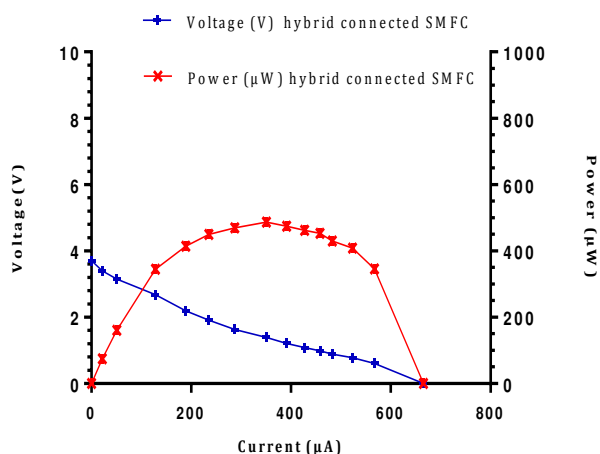


Fig.5 Polarization Curve for hybrid connected SMFCs

Our result indicates the potential to power implanted sediment microbial fuel cell using bacteria. In each of configuration, the power is sufficient to operate devices. Based on this connection of sediment microbial fuel cell, we altogether enhanced the power generation of the SMFCs unit and potentially established a general design platform for a scalable biological fuel cell. In future work power can improve by using dc to dc boost converter.

### 3.3 Columbic efficiency

Coulombic efficiency (CE) determined how proficiently an MFC harvests electrons. The SMFC was filled with the wastewater COD concentration of 192 mg/L and sediment anode compartment had pH value of 7.4. CE calculated of 8 SMFC by equation (1) were 28.20%, 26.01%, 27.62%, 26.90%, 26.50%, 27.91%, 27.69% and 27.70% for SMFC1, SMFC2, SMFC3, SMFC4, SMFC5, SMFC6, SMFC7 and SMFC8 respectively. The average CE of all 8 SMFC was 27.31%. CE is not a kinetic constraint due to this fact these results were relatively low. CE is not directly linked to power density.

There are many possible reasons for a low range CE for MFCs (0.03–31%) such as; high Oxygen leakage into the anode chamber (Hao Ren et al., 2014), wastewater consists of heterogeneous complex composition (which including variance electron donors), electron move from substrate to non-electrode electron acceptors presence of sulfate in the solution which decreases electron recovery. MFC internal resistance also affects a decrease in the Coulombic efficiency (Ismail et al., 2017).

## 4. Conclusion

The use of minimum conventional energy sources forces the scholars to think such kind of renewable energy source. We tested the execution of Sediment Microbial Fuel Cell for expanding power by series and hybrid connection. Under present investigation, bioelectricity was successfully generated from sediment via microbial fuel cell innovation. SMFC generate maximum voltage and stable for a long time. With a majority of little units, series configuration can be used to boost up voltage over the level (1.80V) required to power the real world electrical or electronic applications; an LED and a dc-motor. This sediment MFC was cost effective and eco-friendly due to utilization of sediment as substrate. Microbial Fuel Cell innovation is still in a beginning period of advancement but shows great promise as new methods for renewable electricity generation. Sediment microbial fuel cells can be utilized as a sustainable power source for remote environmental observing.

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