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Fabrication and Characterization of a Novel Eco-Friendly Plant Microbial Soil Cell

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Abstract— In present study our attempt is to generate electric power from plant and soil. We fabricated microbiological soil cell by using different plantand soil samples (Laterite, Red Alluvial and saline soil). Certain amount of soil sample diluted with water which act as electrolyte and Copper and Zinc plate use as positive and negative electrode respectively. Maximum value of 0.9 Volt has been obtain from cell having saline soil. Water hyacinth and gametophyte plant grown in the soilto construct plant microbiological soil cell.The plant soil cell so constructed are found to providestable voltage of about 1.5 volt per cellfor time of about one month. The cell so constructed is pollution free, eco-friendly and found to be rechargeable by adding specific quantity of water. The working model based on this research is also selected for National Level Science exhibition.

Keywords-Soil cell, OCV, Microbiological fuel cell

I. INTRODUCTION

The importance of preserving our green environment has seriously been felt in the recent years, mainly because of the very high rate of industrialization, modernization and due to population explosion. Wind, solar, geothermal, and hydro-electric power undoubtedly decrease CO_2 footprints; however, they have some disadvantages, such as landscape transformation, energy-intensive processes, and geographic limitations [1].Hence a significant part of energy research effort is directed toward the development of economically feasible alternative energy storage system that can provide energy where the energy source is intermittent. This has favoured the search for advanced and high energy electrochemical system that would be capable of replacing the conventional batteries to have a more efficient and less polluted atmosphere. A plant microbial fuel cell is a new technology that converts the solar energy into the bioelectricity with an aid of the microbes at the rhizosphere region of plant, seems to be an emergent source of sustainable energy[2].It can generate continuous energy without competition for food and can be operated at any location. Mild operating conditions make PMFC more attractive than these traditionally viewed alternative sources of energy. However, there are some challenges that need to be met before its real application. Depending on plant species, age, and environmental conditions,upto 60% of the net fixed carbon can be transferred from its leaves to the roots. The plant root system produces and releases different types of organic compounds into the soil, which includes exudates of sugars, organic acids, polymeric carbohydrates, enzymes, lysates of dead cell materials, and gases like ethylene and CO_2 etc. Summation of these released products by plants is termed as plant rhizodeposits while the process is called as rhizodeposition. The produced rhizodeposits accounts approximately 40% or even more of the plant's photosynthetic productivity. Utilization of these abundantly produced rhizodeposits, as energy rich substrates for production of electricity is the underlying concept of PMSC. This energy source seems to be an alternative for harnessing the energy [3, 4]. The biochemical reactions taking place in PMSC are as mentioned below in equation 1 and 2 and the schematic representation of cell comprising of plants is as depicted in Figure 1.

At Anode: $C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$ … (01)

At Cathode : $6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$ … (02)

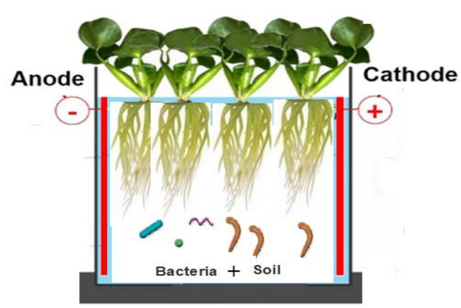

Figure 1.Schematic representation of fuel cell comprising of plants and soil

II. EXPERIMENTAL DETAIL

I. SELECTION OF PLANT AND SOIL

Different soil i.e. Saline, Red, Alluvial and laterite were collected from various places of Raipur district. The soil sample were washed with distilled water to remove the surface impurities and dried in oven at 110^0 C for 2 days to remove traces of moisture. The constituent of the soil samples have been tested in the Laboratory. The pH of the subjected soil samples has been measured by pH meter. The EMF of cells were measured by use of potentiometer.Marshy grasses(i.ewater hyacinth (Eichhorniacrassipes) and bryophyliumpinnatum)plant were grown in the beaker containing Saline soil. The reson about selection of these plant due to their adaption to the system, high biomass production, and salinity tolerance, aquatic and evergreen and capable to generate electricity in all season [5].

The power output in a PMSC depend on amount of root exudates [6], root morphology [7], photosynthetic efficiency [8] and plant-microbe relationship [9]. It can be improve with better rhizodeposition(like organic acids and carbohydrates) at optimum conditions and choice of suitable plants. Molecular compounds like cellulose, dead cells, and slough of root takes prolonged time for voltage generation.

II. FORMATION OF SALT BRIDGE

2% agar was taken in the 0.1 N solutions of NaCl / KCl. Then the solution was heated up to 100^0 C and stirred simultaneously till agar completely dissolves. These solutions were added into the plastic or glass tube covered from one end and the solution was left undisturbed until solidification of agar [10].

III. CONSTRUCTION OF PMSC SET UP

Plants were grown in different chambers having copper plates as anode and zinc plate as cathode which are connected by salt bridge. In the anode compartment, the plants having fibrous roots (*Asparagus fern)* and soil and some drainage water was added. Cathode compartment was containing only demineralized water. The anode compartment was covered with help of plastic so that the less oxygen condition was maintained in the compartment. The voltage readings were taken with the help of multimeter. After few days for the proper growth and development of plants, plant growth hormones were added [11].

III. RESULT AND DISCUSSION

The saline, red, alluvial and laterite soil samples and distilled water have been used as starting material. The various constituent of different types of soil collected and their pH value is shown in table 1, the electrical conductivity and open circuit voltage (OCV) was measured which has been shown in Table 2. It is found that Saline soil has maximum metal content, pH value, electrical donductivity and open circuit voltage therefore this soil was taken as base for the construction of microbiological soil cell.

Table 1: Types of soil and its constituents

S. N	Types of Soil	Electrical conductivity in S/m	OCV in Volt
1.	Alluvial	0.5	1.38
2.	Red	0.4	1.36
3.	Saline	4.0	1.39
4.	Laterite	0.1	1.33

Table 2: Electrical conductivity and Open circuit voltage

S.N	Soil	Cu	Mn	Fe	Zn	K	pH
1.	Alluvial	0.48	4.36	5.32	0.70	20	8.1
2.	Red	0.94	12.04	5.98	1.16	28	7.7
3.	Saline	0.30	4.70	8.06	1.58	25	8.3
4.	Laterite	2.42			1.25	17	8.0

We use two plant named water hyacinth (Eichhorniacrassipes) and bryophyliumpinnatum for the construction of microbiological soil cell. These plate were placed in beaker containing saline soil and water. Copper and zinc electrode were used as anode and cathode respectively. The voltage generated was recorded using a mustimeter for a period of 30 days, the result is depicted in figure 2.

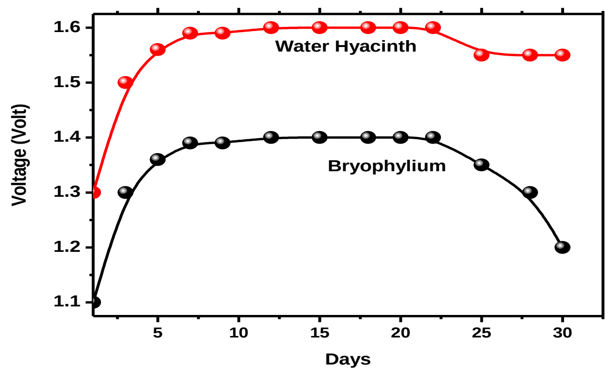

Figure 2: Voltage generation by (a) water Hyacinth and (b) Bryophyliumplant

It is seen from the figure that the voltage generation by water hyacinth is about 1.5 volt and remain constant throughout the month. It is because this plant is evergreen and required water in whole life time. But in case of bryophylium in average voltage is about 1.35 for 20 days, after 20 days the voltage output decreases it is because of decreases in water content which stop the process of electrolysis. When some water is added to it, the cell start providing constant amount of voltage.

Electricity generated using is considered to be a function of composition of nutrients present in water, constituents of salt bridge and material of construction of metal used as electrodes in soil cell [12, 13].When plants gets older, rhizodeposition decreases hence power output decreases at the end of the life cycle.

IV. CONCLUSION AND FUTURE SCOPE

Soil, plant and Bacteria are able to produce electricity by using plant rhizodeposits as a substrate and metallic ions present in soil under limited oxygen condition. We were able to attain the maximum voltage of 1.4 V on 3rd day using water Hyacinth and andBryophyliumplantbased PMSC. Futheroptimization in terms of area, electrode composition, salt bridge composition, etc can increase the amount of energy generated.

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Authors Profile

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