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Proposed Bio-Battery for Energy Generation

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Abstract : The traditional battery charging technique uses grid energy to serve the connected load, which ultimately increases the burden on grid as well as it increases the cost of electricity at consumer side. Hence, the new modified battery is presented in this work. The proposed battery charges from organic materials that are renewable, sustainable, and environmentally friendly instead of grid. Such types of batteries are very useful in remote locations where there is negligible or no access to electricity. The main aim of this research work is to provide energy to people who are financially poor/deprived and of rural areas where load shedding is a major problem. The proposed battery i.e., Bio-Battery is using soil as an organic material to charge. Soil has a unique composition, it contains different varieties of minerals, microorganisms, and basic organic material and hence, the electrical conductivity of soil is completely dependent on these factors. Soil battery works on the principle of generating electricity from the potential difference between two electrodes. So, in this work the combination of soil and water is used for charging battery. Also, other waste material like urine, compost and salt water is used in combination with soil for experimental purpose. It is observed that the combination of soil with water gives the highest voltage as compared to others.

***IndexTerms* - Sustainable energy, renewable sources, electricity, Microbial Fuel Cell (MFC).**

I. INTRODUCTION

A biobattery, also known as a biological fuel cell, is a type of energy storage device that converts the chemical energy stored in organic compounds into electrical energy through the use of enzymes or microorganisms. It harnesses the natural processes of metabolism found in living organisms to generate electricity. Biobatteries have gained attention as a potential sustainable and eco-friendly alternative to conventional batteries. The operation of a biobattery typically involves the following steps [1]-[4]:

a) Substrate oxidation: The organic substrate (such as glucose, ethanol, or other biodegradable compounds) is oxidized by enzymes or microorganisms, releasing electrons and protons.
b) Electron transfer: The released electrons are transferred to an electrode surface within the biobattery, typically made of carbon-based materials like graphite or carbon nanotubes. This electrode acts as a catalyst for the electron transfer process.
c) Ion migration: The released protons move through an electrolyte, usually an aqueous solution, to a separate electrode known as the cathode.
d) Reduction reaction: At the cathode, the protons combine with oxygen from the air, creating water as a by-product. This reduction reaction helps maintain a balanced charge within the biobattery.

The overall process of substrate oxidation and reduction of protons and electrons generates an electric current that can be utilized for various applications. Biobatteries have several advantages over conventional batteries, including [1]-[4]:

- Renewable and sustainable: They use organic compounds as fuel, which can be derived from renewable sources like biomass or waste materials.
- Eco-friendly: Biobatteries produce minimal to no harmful emissions or waste products, reducing their environmental impact.
- Scalability: They can be designed and implemented in various sizes, making them suitable for a wide range of applications, from small-scale devices to large-scale power generation.
- Self-sustaining: Some biobattery designs incorporate self-sustaining features by utilizing microorganisms that can produce their own fuel through photosynthesis or other metabolic processes.

While biobatteries show promise, they also face challenges such as low power density, short lifespan, and the need for optimization of electrode materials and microbial strains. Ongoing research aims to improve these aspects and explore new technologies to enhance the performance and commercial viability of biobatteries.

A soil urine battery, also known as a microbial fuel cell (MFC), works by harnessing the natural metabolic processes of microorganisms in soil to generate electricity. Microorganisms such as bacteria and fungi are present in soil and break down organic matter through a process known as anaerobic respiration. During this process, electrons are released as a by-product, which can be harnessed to generate electricity. When human or animal urine is added to soil, it acts as a catalyst for the microorganisms to break down organic matter more efficiently. The urine provides a source of nitrogen, phosphorus, and other nutrients that the microorganisms need to carry out their metabolic processes. As the microorganisms break down the organic matter, they release electrons that are collected by an electrode placed in the soil.

The electrode, typically made of graphite or carbon fiber, is connected to a circuit that allows the flow of electrons, creating a current that can be used to power small electronic devices or to charge batteries. The amount of electricity generated depends on several factors, including the amount of urine added, the type of soil used, and the size and configuration of the electrode. Soil urine batteries have several advantages over traditional batteries. They are environmentally friendly, as they use natural processes to generate electricity and do not require toxic chemicals or heavy metals. They also have the potential to provide a sustainable source of electricity in areas without access to traditional power sources, such as rural or remote areas. However, soil urine batteries are still in the experimental stage and are not yet widely used. Researchers are working to optimize the design and performance of these batteries to make them more practical for real-world applications.

The power output of a soil urine battery depends on several factors, including the amount of urine added, the type of soil used, and the size and configuration of the electrodes. In general, soil urine batteries have low power output, typically in the range of a few mill watts to a few watts. However, they have the potential to provide a sustainable source of electricity in areas without access to traditional power sources. Soil urine batteries have several potential applications, including powering small electronic devices such as sensors, LED lights, and low-power radios. They could also be used to charge batteries for portable devices such as cell phones and tablets.

II. Literature Survey

Microbial fuel cells (MFCs) are bio electrochemical devices that convert the chemical energy present in organic matter, typically provided by microorganisms, directly into electrical energy. MFCs offer a sustainable approach to generate electricity while also treating organic waste. MFCs consist of an anode and a cathode, separated by a proton exchange membrane or another type of selective barrier. The anode is colonized by electrochemically active microorganisms, known as exoelectrogens, which oxidize the organic matter and release electrons. These electrons flow through an external circuit to the cathode, where they combine with protons and an electron acceptor (usually oxygen) to form water [5]-[8].

There are various types of MFCs based on design and operational modes, including single-chamber MFCs, double-chamber MFCs, air-cathode MFCs, and microbial electrolysis cells (MECs). Each configuration has its own advantages and limitations, depending on the specific application and desired outcomes. MFCs have a wide range of potential applications, including wastewater treatment, power generation from organic waste, biosensors, and remote power sources. They have been studied for their ability to generate electricity from various organic substrates, such as wastewater, agricultural residues, and lignocellulosic biomass. MFCs offer several advantages, such as their ability to simultaneously generate electricity and treat organic waste, as well as their potential for scalability. However, there are challenges to address, including low power output, slow reaction rates, membrane fouling, and the need for improved electrode materials and system optimization. Ongoing research aims to enhance MFC performance and address these limitations [5]-[8].

Microbial fuel cells (MFCs) have been studied since the early 20th century, but it wasn't until the late 20th century that significant research was conducted on their potential for electricity generation. Here are a few notable research studies on microbial fuel cells before the year 2000.

In 1911, M.C. Potter reported the first known experiment of using bacteria to generate electricity and used bacteria to power a small light bulb [9]. Barnet Cohen make additional advancements in this area in 1931 and discovered that adding glucose to a liquid medium containing a yeast and bacterial culture created a voltage of 0.3 to 0.5 V when a platinum electrode was submerged. Managing to generate 35 V by series-connecting several microbial half fuel cells. [10]. In 2011, researchers at the University of the West of England, Bristol developed a soil microbial fuel cell that was able to generate electricity from human urine. They found that the system was capable of generating a maximum power output of 0.037 mW/m2, which was sufficient to power a small LED light [11].

Using a carbon cathode and a zinc anode, Lin et al. [12] of 2015 describe a fuel cell that can generate 60 W. Powering an on-site irrigation control system with a comparable metallic MFC has been proposed [13]. These studies evaluate overall cellular efficiency but make no distinction between galvanic and microbial energy production. Long-term deployments benefit from distinguishing between the two, as microbial energy is renewable whereas galvanic contributions degrade over time. In 2017, A research was done on the Himalayan mud in which they received a 0.99 mwatts energy at 24 degrees Celsius [14]. Table 1 [15] displays a catalogue of MFC electrodes together with their respective maximum power, voltage, and current outputs.

Table.1 Different Types of Electrodes

Cathode	Maximum PD	Maximum CD	Maximum voltage (mV)
Activated carbon fiber felt	315 mW/m^2 (0.7 W/m^3)	$1.67 * 10^{-3}$ mA/m^2	679
Air-cathode with graphite	283 mW/m^2	1210 mA/m^2	440
Carbon felt	77 mW/m^2 (0.2 W/m^3)	$6 * 10^{-3}$ mA/m^2	575
Plain carbon	67 mW/m^2 (0.1 W/m^3)	1.5 mA/m^2	598
Pt-coated carbon paper	0.3 W/m^3	4.69 mA/m^2	644
Tubular ACFF	784 mW/m^2	3.17 A/m^2	716
ACFF granules (1 cm)	667 W/m^3	3.34 A/m^2	658
Biocathode	19.53 W/m^3	41.78 A/m^3	432
Graphite felt	539 mW/m^2	3145 mA/m^2	742.3

Overall, the research on soil urine batteries has shown that they have the potential to generate electricity from human and animal urine and may be a useful technology for sustainable energy production in the future. However, more research is needed to improve the efficiency and scalability.

III. METHODOLOGY

The proposed methodology for the bio battery depends on the three main components: -

1. Electrodes – Having a better combination of electrodes is must for working of a good battery. The combination used here was aluminum and Graphite (carbon). They have an higher electron affinity pair between each other. They play the role of energy carrier.
2. Microbes – The microbes play an important role in this procedure as this is part of the energy generation of the battery. The do the reaction for their food and produce a potential difference in the soil.
3. Soil mixture – The soil mixture has res soil and water mixed in it and work as a medium for energy generation and to reach till the electrodes. They work as an energy medium.

And then due to the reaction of the microbes in the soil they produce a potential difference which is taken by electrodes that work as a positive and negative terminal. In this way the bio battery works. Fig. 1 shows the block diagram of proposed bio-battery.

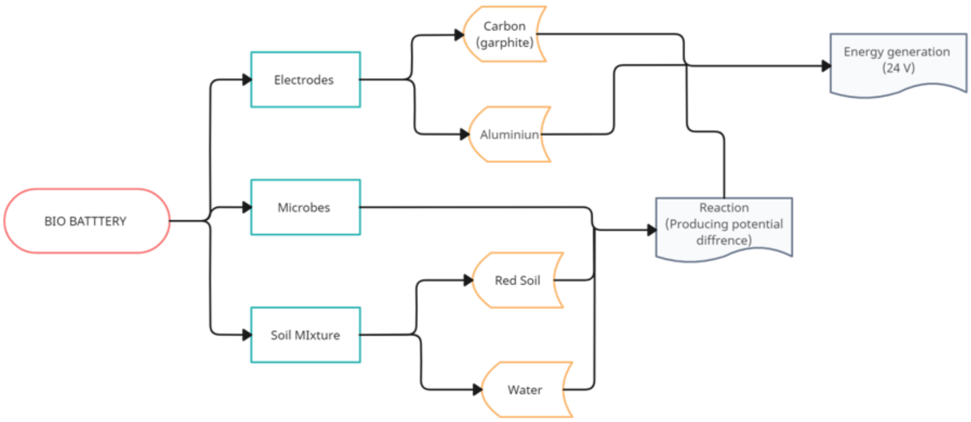

Fig.1 Block Diagram for Proposed Bio-Battery

As behind every invention there is an experiment. The author has experimented in every type of combination. The combinations contained of varying sizes of the electrode, different weight of soil and different mixtures used. When the soil alone was taken it contained a very few microbes and no good medium for charge to flow so little to no output was obtained. The electrode combination was the largest one but as very less output was received no further experimentation was done. When soil was made moist there was a medium for charge to flow and the microbes became active so there was 0.7 V of output was obtained with the largest electrode combination. But as this small amount of voltage was passing from such a large electrode, resistance was the problem. So, to tackle this problem, the size of the electrodes was reduced that provide a positive outcome. The electrodes size was made into half, so the conduction also became fast with minimum resistance. Then next problem was weight of cell, it was reduced by reducing the amount of soil and tried to obtain the same result. Fig.2 shows the practical setup for the proposed work.

Fig.2 Practical setup for the proposed work

The main principle of this battery revolves around the bacteria present in the soil. That produces energy which creates a potential difference in the soil and between the electrodes. To increase the efficiency of the soil different mixtures were used so that the reactivity of the microbes could be checked in different environment. The results are mentioned below in the conclusion section. The below fig 3 and 4 shows the preparation of solution. Different tests were done on different solutions.

Fig.3 Preparation of different solutions

Fig.4 Prepared solution of Microbial Fuel Cell (MFC)

IV. RESULT

As mentioned, the principle of this battery works on the type of microbes, so a different combination of solutions was tried to get the better result. The below Fig 5 shows the circuit and the output testing of the prepared solution and Soil battery.

Fig.5 Testing of the prepared soil battery.

The results were positive and received almost the same output with reduced cell weight and electrode size. Same processes were done using -

1. Soil in combination with Urine mixture
2. Soil in combination with compost
3. Soil in combination with milk
4. Soil in combination with water

The solution of alcohol was good with it but the main problem was it sublimated very fast due to which the voltage not last long. The soil with water was giving good results and it lasted for a longer period of time. The result for every combination is shown in Table 2. Not only the solution a different dimension of cathode and anode was also taken so as to get a better result.

Table.2 Results with different solutions.

Material	ANODE (Graphite) L*D			CATHODE (Aluminium) L*D			SOIL (grams)			VOLTAGE (mV)
	10*10	6*10	3*0.45	12*10	6*10	3*10	250	150	50	
Soil	A			C			S			0
	A			C			S			0.96
		A			C			S		0.88
Soil+Water			A			C			S	0.84
Soil+Urine			A			C			S	0.75
Soil+Milk	A			C			S			0.64
	A			C			S			0.70
Soil+Compost			A			C			S	0.73
Soil+Coconut water	A			C			S			0.57
Soil+Salt water			A			C			S	0.76
	A			C			S			1.02
Soil+Alcohol			A			C			S	0.9

In the above Table 2, A represents anode, C represents cathode, S represents soil, L represents length and D represents Diameter.

V. Challenges faced in Soil Batteries

Soil batteries or soil microbial fuel cells (SMFCs), face several challenges that can affect their performance and practical implementation. Some of the key challenges in soil batteries include [16]-[20]:

1. Low Power Density: Soil batteries typically have relatively low power densities compared to other energy storage technologies. The power output of MFCs is limited by the slow microbial metabolic processes and the low conductivity of the soil environment.
2. Variability in Performance: Soil conditions can vary significantly, leading to variations in the performance of soil batteries. Factors such as moisture content, temperature, nutrient availability, and microbial activity can impact the power output and stability of MFCs.
3. Microbial Community Dynamics: The performance of soil batteries depends on the presence and activity of electrochemically active microorganisms. However, the composition and dynamics of the microbial community in the soil can be complex and influenced by various factors, making it challenging to control and optimize the system.
4. Scaling-Up Challenges: While laboratory-scale soil batteries have demonstrated promising results, scaling up to larger systems poses challenges. Maintaining uniform conditions, efficient substrate distribution, and effective mass transfer in larger-scale MFCs can be difficult.
5. Electrode Fouling: Over time, soil batteries can experience electrode fouling due to the accumulation of organic and inorganic materials on the electrode surfaces. This fouling can lead to reduced power output and increased system resistance, requiring periodic maintenance and cleaning.
6. Long-Term Stability and Durability: Ensuring the long-term stability and durability of soil batteries is a challenge. Factors such as electrode degradation, biofilm growth, and microbial community shifts can impact the performance and lifespan of the system.

VI. Applications

Soil batteries have potential applications in various fields, including agriculture, environmental monitoring, and renewable energy storage. Here are some of the possible applications of soil batteries [7]:

1. Agriculture: Soil batteries can be used to power sensors that monitor soil moisture, temperature, and nutrient levels. This information can be used to optimize irrigation and fertilization, leading to improved crop yields and reduced water and fertilizer use.
2. Environmental monitoring: Soil batteries can be used to power sensors that monitor environmental conditions such as air and water quality, climate change, and biodiversity. This information can be used to inform environmental policy and management decisions.
3. Remote power generation: Soil batteries can be used to generate electricity in remote areas where traditional power sources are not available. This can be useful for powering communication equipment, monitoring stations, and other remote devices.
4. Renewable energy storage: Soil batteries can be used to store renewable energy from sources such as solar and wind power. This can provide a reliable source of energy even when the weather is not favorable for renewable energy generation.

5. Disaster relief: Soil batteries can be used to provide emergency power in disaster-stricken areas. They can be used to power communication equipment, lighting, and other critical infrastructure.

Overall, the applications of soil batteries are diverse and promising. With further research and development, soil batteries have the potential to become a reliable and sustainable source of energy and a valuable tool for environmental monitoring and agriculture.

VII. ADVANTAGES

Biobatteries, also known as biological fuel cells, offer several advantages compared to conventional batteries. Here are some key advantages of biobatteries [21]-[25].

a) Renewable and Sustainable: Biobatteries use organic compounds, such as glucose or other biodegradable substrates, as fuel sources. These compounds can be derived from renewable sources like biomass or waste materials, making biobatteries a more sustainable alternative to conventional batteries.
b) Environmental Friendliness: Biobatteries produce minimal to no harmful emissions or waste products during their operation. They rely on natural processes of metabolism found in living organisms, reducing their environmental impact compared to conventional batteries that often require hazardous materials for their operation and disposal.
c) Scalability and Flexibility: Biobatteries can be designed and implemented in various sizes, ranging from small-scale devices to large-scale power generation systems. This scalability and flexibility make them suitable for a wide range of applications, from portable electronics to remote sensing devices and even grid-scale energy storage.
d) Self-Sustaining Systems: Some biobattery designs incorporate self-sustaining features by utilizing microorganisms that can produce their own fuel through processes like photosynthesis or other metabolic pathways. This capability allows for long-term and autonomous operation without the need for external fuel supply.
e) Biochemical Diversity: Biobatteries can utilize a wide range of organic substrates, including waste materials, making them adaptable to different feedstocks and potentially aiding in waste treatment by converting organic matter into electricity.

It's important to note that while biobatteries offer promising advantages, they also face challenges such as low power density, short lifespan, and the need for optimization of electrode materials and microbial strains. Ongoing research and development aim to address these limitations and enhance the performance and commercial viability of biobatteries.

- Because enzymes work so quickly, biobatteries can charge gadgets considerably more quickly than conventional ones.
- Because glucose or sugar is always present, bio-batteries don't need a separate power source.
- High-energy-density bio-batteries are readily available and can be utilized conveniently at room temperature.
- Biobatteries don't produce any harmful byproducts and can be recharged indefinitely.
- Because they don't cause leaks or explosions like chemical batteries can, biobatteries can be used with confidence.

VIII. FUTURE SCOPE

Integration with renewable energy systems. Soil batteries can be integrated with other renewable energy systems, such as solar panels and wind turbines, to provide a complete energy storage solution. Engineers can work on optimizing the integration of soil batteries with other technologies to improve overall system efficiency. Secondly, biobattery technology can also be extended beyond electricity generation to enable bio electrochemical synthesis. This involves using the biocatalytic activity of microorganisms in biobatteries to drive chemical reactions and produce valuable compounds, such as biofuels, platform chemicals, and pharmaceuticals.

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