INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 10, Issue 3 - V10I3-1236)
Available online at: https://www.ijariit.com

Development of Biophotovoltaic System for Power Generation

Milan Kadari
kadarimilan23@gmail.com
HKBK College of Engineering, Bengaluru, Karnataka

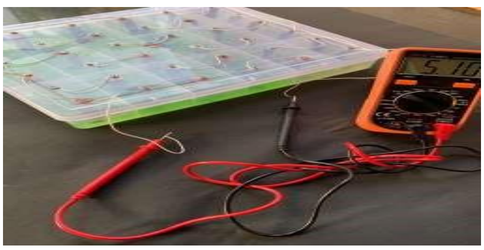
Abstract

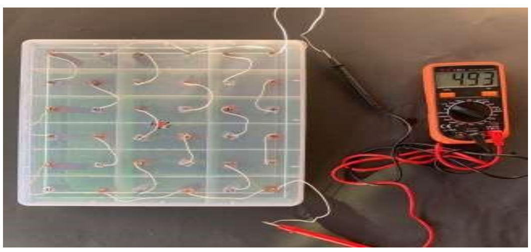
Microbial fuel cells and bio photovoltaic systems (BPVs) are similar in that they use an anode and oxygenic photosynthetic bacteria to produce an extracellular electrical current that is triggered by light. Throughout the past few decades, advancements in wiring schemes and multiple generations of electrode development have contributed to a significant advancement in the study and application of BPVs. There have been reports of power densities as high as 0.5 W m−2, which can power small electrical devices like digital clocks. The bio photoelectrochemical phenomena can now be further utilized to answer biological concerns about the organisms thanks to advancements in standardization. With an emphasis on biological materials, electrode design, and interfacial wiring concerns, we hope to give biologists and electrochemists a comprehensive overview of the evolution of BPVs and suggest future directions for the area.

Key Words: *BPV- Biophotovoltaic, Micro-Organism, Eukaryotic Micro-Algae, Cyanobacteria.*

1. INTRODUCTION

Biophotovoltaic systems (BPVs), also called microbial solar cells or photomicrobial fuel cells, use oxygenic photosynthetic microorganisms, including cyanobacteria or eukaryotic microalgae (often called blue-green algae), to absorb sunlight and produce power. Over 40 years have passed since the initial introduction of the idea of BPVs. Unlike microbial fuel cells (MFCs), which depend on organic substrates to support their living organisms, battery photovoltaics (BPVs) take advantage of the most readily available and widely distributed energy and electron sources on Earth, namely light and water. While anoxygenic photosynthetic bacteria such as Rhodopseudomonas (a purple non-sulfur bacterium) have been used in MFCs, they will not be included in this discussion because they cannot use water as an electron source. Oxygenic photosynthetic bacteria use photosystem II (PSII) to help them take electrons from water by harnessing light energy. These electrons create NADPH and an electrochemical gradient that is necessary for ATP synthesis as they move along the photosynthetic electron transport chain (PETC). Furthermore, in a process known as "exoelectrogenesis," certain electrons from the photosynthetic electron transport move from the thylakoid to the cytoplasmic or plasma membrane before ultimately leaving the cell. A role for respiration and other metabolic processes in exoelectrogenesis is possible. Electrons that are exported by the microorganisms go to an anode via direct or indirectly mediated transfer mechanisms in a basic two-electrode biophotovoltaic device. Following their passage over an external circuit to a cathode, these electrons assist in the reduction of oxygen and protons, which diffuse from the anode and occasionally cross an ion-conductive membrane or salt bridge, in order to create water. The possible distinction between the anodic and cathodic redox reactions is what propels this process.





2. OBJECTIVE

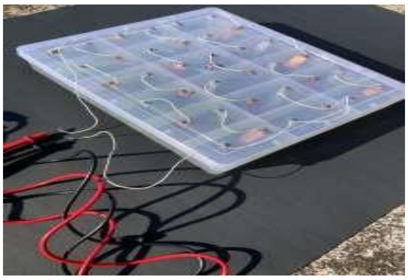
- To create a sustainable model with a cheap cost, adaptable design, minimal maintenance, and non-toxic properties.
- Compare BPV systems to conventional energy sources in order to assess the possible effects and environmental advantages of the former.
- Look into metabolic and genetic engineering methods to increase microorganisms' exoelectrogenic and photosynthetic efficiency.
- Create BPV systems that are affordable and scalable, appropriate for a range of uses, from small-scale gadgets to massive power plants.

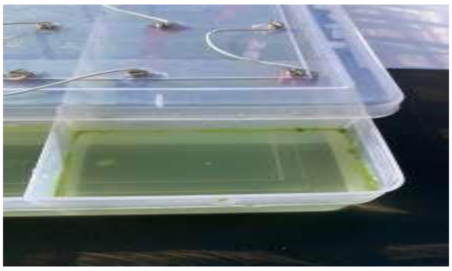
3. MATERIALS REQUIRED

- Photosynthetic Microorganisms: Eukaryotic microalgae, Cyanobacteria (blue-green algae)
- Electrodes: Anode(Typically made from conductive materials like carbon (graphite, carbon cloth, carbon paper)).
- Cathode: Common materials include carbon-based materials or metals with catalytic properties (platinum, stainless steel).
- Light Source: Sunlight (natural), Artificial light sources (LEDs or fluorescent lamps) for controlled experimental conditions
- Electrolyte Solution: Aqueous medium that supports the growth and metabolic activities of microorganisms (e.g., nutrient-enriched water, specific growth media)

4. METHODOLOGY:

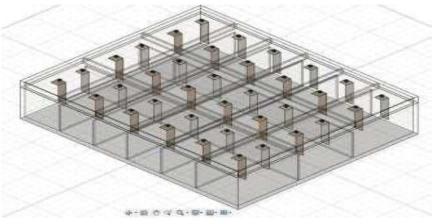
- Microorganisms that are capable of photosynthesis, such as algae or cyanobacteria, are chosen for their ability to produce energy.
- The microorganisms are cultivated in a controlled environment that optimizes the parameters of light, temperature, and nutrition for photosynthetic activity and growth.
- Following the immobilization of the microorganisms on a solid substrate, such as an electrode or conductive material, an electrical current is produced by the electrons moving from the microbe to the electrode.
- The design of the BPV cell is optimized by modifying the variables that impact the system's efficiency, such as the kind of electrode employed at various wave intensities.

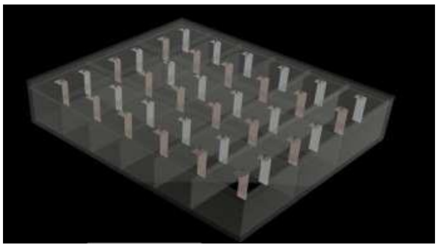




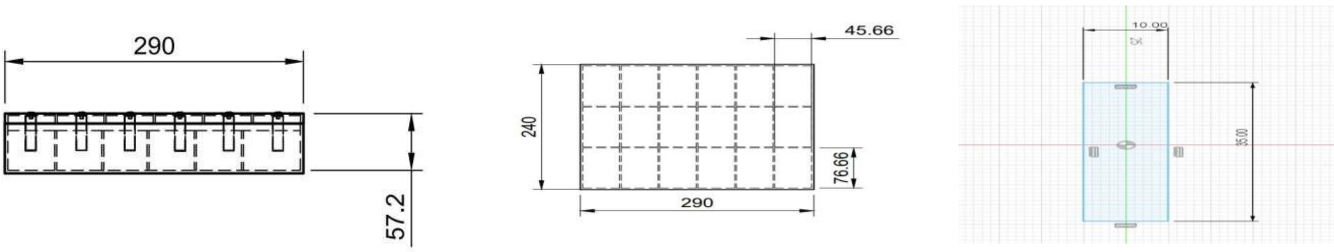
5. PRODUCT DESIGN

- Fig Shows the revised design of our BVP cell which consists of 18 Galvanised Iron and Copper electrodes. This setup gives a higher value of voltage than the previous setup that is it yields about 5v voltage on average.
- Electrodes used are Galvanised Iron and Copper





- **<u>Dimension of The Unit</u>**

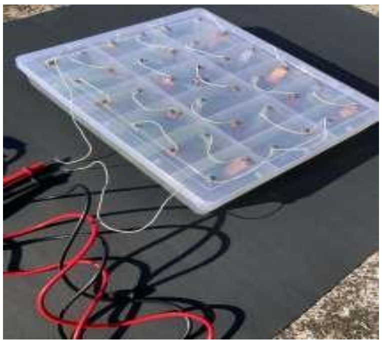


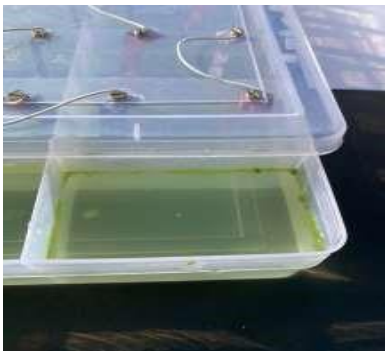
6. WORK DONE:

- Experiment Under White Light Or Sunlight
- Experiment Under Red Blue & Green Light
- Experiment Under different pH levels

Experiment Under White Light or Sunlight

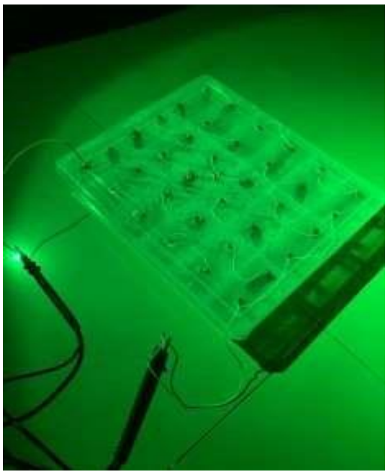
Fig shows the cell being exposed to normal sunlight. The reading was noted down manually in Excel using a Multimeter. For every 10-minute time interval, the reading from Multimeter was noted down in Excel.





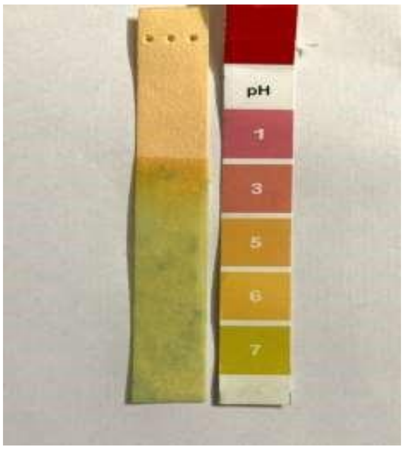
Under Red Blue & Green Light

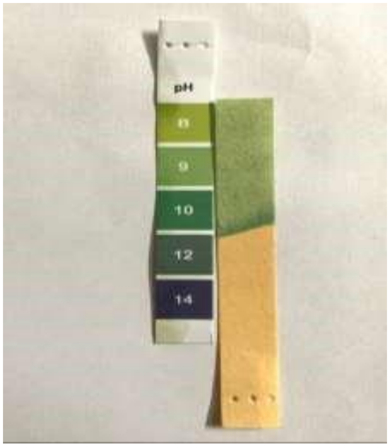
Fig Shows the cell being exposed to Red Green & Blue light respectively. The reading was noted manually in Excel using a Multimeter for every 10 minutes of time interval. This was done in a dark room and using colored Film Sheet and a table light as a light source

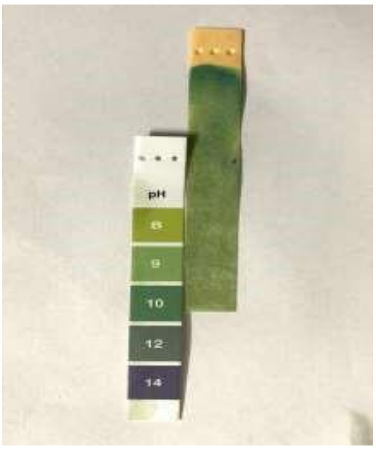


Experiment Under different pH levels

Fig shows the pH level of different algae solutions at pH level 7, pH level 8 & pH level 9 respectively. pH affects the Algae in many ways and is also a factor affecting the voltage. Generally, the pH of algae water is 7-8 pH.

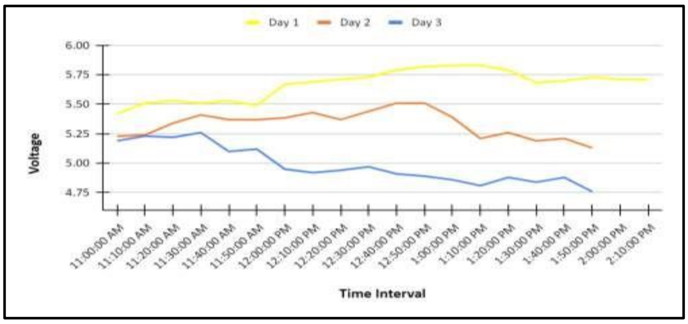




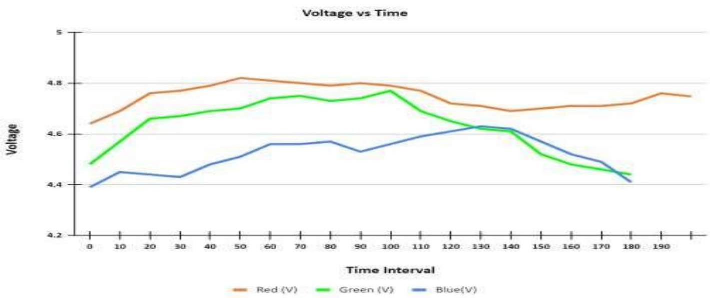


7. GRAPHICAL REPRESENTATION OF VOLTAGE VS TIME:

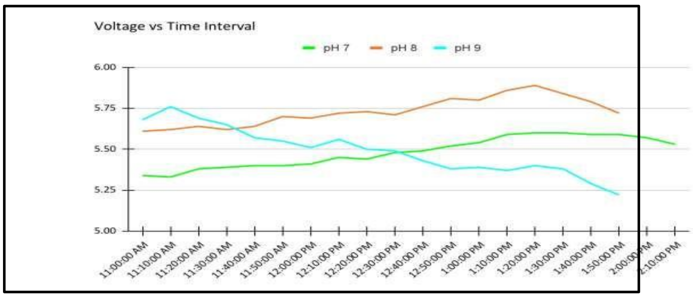
- It was observed that the Voltage efficiency of bio photovoltaic (Algae) decreases with time. Moreover, it can also be observed that the bio photovoltaic organism (Algae) has its highest efficiency during peak sunshine This is because the photosynthesis activity of the bio photovoltaic organism increases as the intensity of sunlight (white light) increases.



- For Red light having the highest wavelength of 700 nm the BPV gave the maximum efficiency of 4.75V average. For Green Light having the Wavelength of 550nm the BPV gave the maximum efficiency of 4.6V average. For Blue Light having the Wavelength of 495 nm the BPV gave the maximum efficiency of 4.51V average.



- It is observed that as the pH increases the voltage increases with time; However there is an optimal range of pH, it is seen for pH 9 the voltage kept decreasing with time This is because due to the high alkalinity of water, the cells of the organism started dying resulting in lower voltage output.



8. RESULT AND DISCUSSION:

- **Voltage Output**: The system is expected to generate voltage in the range of millivolts to hundreds of millivolts, indicating successful conversion of light to electrical energy.
- **Current Output**: Current production is anticipated to be between microamperes to milliamperes, reflecting the activity of the microorganisms.
- **Power Output**: Power output should be in the micro to milliwatt range, showing the system's potential for small-scale energy applications.
- **Photosynthetic Efficiency**: High photosynthetic efficiency will demonstrate effective light energy conversion by the microorganisms.
- **Overall System Efficiency**: Evaluating overall system efficiency will highlight the effectiveness of the entire BPV setup.
- **Growth Rate**: Monitoring microbial growth rates ensures that the microorganisms remain healthy and active for sustained energy production.
- **Electron Transfer Rates**: High electron transfer rates from microorganisms to electrodes will indicate efficient exoelectrogenesis.

- **Long-term Performance**: Stability in long-term performance will demonstrate the durability of the BPV system.
- **Environmental Stability**: Maintaining optimal temperature and pH will be crucial for consistent microbial activity.
- **Cost Analysis**: Understanding material and operational costs will help assess the economic feasibility of the BPV system.

9. CONCLUSION:

- As time passes, the BPV organism's life cycle shortens, which lowers voltage efficiency.
- Because photosynthetic activity is strongly correlated with sunlight intensity, the BPV operates most efficiently between 12:30 and 1:00 pm.
- High electrical conductivity and catalytic activity are prerequisites for the electrode material's efficiency.
- The BPV's voltage output varies with the wavelength of light; red light produces a voltage of 4.82V, blue light produces a voltage of 4.63V, and green light produces a value of 4.5V.
- The photosynthetic activity of algae rises with increasing water pH, which results in an increase in voltage output; Nevertheless, it was found that at a pH of 9, the voltage first rises and then sharply decreases. This is because the algae's cells are destroyed by increasing alkalinity, which reduces output. Therefore, it was found that a pH of 8 to 8.5 was optimal for best effectiveness.
- The photosynthetic activity of algae rises with increasing water pH, which results in an increase in voltage output.

REFERENCE

[1]. Maira Anam, Helena I. Gomes, Geoffrey Rivers, Rachel L. Gome. "Evaluation of photoanode materials used in bio photovoltaic systems for renewable energy generation." Sustainable Energy Fuels, 2021, 5, 4209.
[2]. Alex Driver and Paolo Bombelli. "Biophotovoltaics." In Paolo Bombelli, "Photosynthesis photovoltaics energy efficiency engineering design Energy from algae." 2019.
[3]. Jenny Tschörtner, Bin Lai, Jens O. Krömer. "Green Power Generation From Sunlight and Water." Sustainable Energy Fuels, 2021, 5, 4209.
[4]. Schneider K, Thorne RJ, Cameron PJ. "An investigation of anode and cathode materials in photo microbial fuel cells." 2019.
[5]. Laura T. Wey, Paolo Bombelli, Xiaolong Chen. "The Development of Biophotovoltaic Systems for Power Generation and Biological Analysis." *ChemElectroChem* 2019, 6, 5375–5386.