Generation of Green Energy and Oxygen from Cyanobacteria

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Abstract – *The demand for essential needs has increased with the constant growth of population. With the advancement of science and globalization our demand for electrical energy has increased to fuel the growth of various industries. There are many critical constrains in unleashing the full potential of power sector. Added to this, coal and petroleum are the most relied upon resources for electricity generation. These are non-renewable resources which also increase carbon emission in the atmosphere leading to climate change and global warming. Thus, the use of alternative energy is a need of the hour. Cyanobacteria, also called as blue green algae, are single celled microscopic organisms mostly found growing on water. They are found in any self-sustaining environment and are photosynthetic in nature. They consists of Chlorophyll A (excitation maximum at 440 and 680 nm) and phycobilisomes that include two major pigments: phycocyanin (excitation maximum between 595–640 nm) and allophycocyanin (excitation maximum between 650–655 nm). As a result of the composite light harvesting systems, the photosynthetic reactions in cyanobacteria are primarily driven by orange and red light. During photosynthesis they produce water dissolved oxygen and while illumination, they transfer electrons to their surroundings. This electron originates during photosynthesis and passes through photosynthetic electron transfer chain (P-ETC). The yield of electrons harvested by extracellular electron acceptor to photons depends on terminal electron acceptor (the anode). Through this process both oxygen and electricity can be derived.*

Key Words: Cyanobacteria, microbial fuel cell, photosynthetic electronic transfer chain, redox reaction, oxygen harvest, green energy, sustainable energy, climate change

1.INTRODUCTION

Cyanobacteria, most commonly referred to as 'blue-green algae' are prokaryotic organisms abundantly present on various landforms of earth, ranging from moist rocks and trees, coral reefs, fresh waters and oceans to extreme temperate zones such as deserts and glacial regions. They are capable of performing photosynthesis. Oxygenic photosynthesis carried out by cyanobacteria billions of years ago led to oxygenation of the atmosphere and oceans, allowing aerobic respiration and leading to the evolution of complex, intelligent and large organisms and also contributing to the formation of ozone layer. For aeons, the cyanobacteria have continued to thrive and support higher life, being beneficial to the ecosystem by converting solar energy into organic matter, releasing oxygen and hydrogen, helping in nitrogen fixation and supressing growth of pathogenic organism in soil and water. Solar energy is known to reach earth at 178,000 TW, out of which 0.2% to 0.3 % is harnessed by cyanobacteria [1].

The idea is to essentially use the characteristics of cyanobacteria as a component of microbial fuel cell, maximise electricity production and also store the oxygen generated in this process. The photosynthetic reaction helps in converting water and CO2 to Oxygen and sugar. The electrons formed by redox reaction during the process of photosynthesis and respiration can be used to generate electricity. This light driven electron transfer is achieved through a setup containing endogenous mediator and graphite electrodes, without adding any sacrificial electron acceptors or donors [2]. Photolysis of water caused by photosystem 2 (PSII) is the main source for the discharge of electron by the illuminated cyanobacteria, where Plastoquinone is an important P-ETC energy shuttle [3].

1.1 Problem Statement

With the growing need of electricity to power all industry and for development, the use of nonrenewable resources such as coal and petroleum are still highly prevalent. In the process of generating electricity such way, we also degrade the environment and human health. They are responsible for pollution and green house effect. Thus, the demand for clean, renewable resources is high. Most of the process of renewable energy generation like wind, solar, thermal, etc. are expensive and don't generate electricity to the same level as coal. Thus, cyanobacteria being vastly available is a good alternative for green energy. The process of electricity generation can be naturally achieved through the daily activity of a living organism and oxygen can also be harnessed in parallel. In order to maximize benefits, genetic modification to increase phycobilliosomes can be done and production can be augmented by culturing cyanobacteria or the wavelength of light can be studies and specifically altered to yield the required output.

1.2 Impact of Various Wavelengths of Light on Cyanobacteria

Several years ago, Engelmann studied the effects of various wavelengths of light on photosynthesis. While studying the effect on cyanobacteria, from the genus Oscillatoria, the initial observation drawn was that red, blue and orange light resulted in high O2 production [4]. Also, since Chlorophyll A has excitation maxima at 440 nm and 680 nm, electrogenic activity of cyanobacteria is majorly driven by red and blue light [1]. In addition, some researches specify the amount of photovoltage achieved in different wavelengths of light. For instance, taking the example of Arthrospira Plantesis and testing it using LED light of various wavelengths for 25 hours, it has been found that blue light (λ=460 nm) generated 0.047673 V, yellow light (λ=590 nm) generated 0.048619 V and red light (λ=660 nm) generated 0.029320 V [5]. Emerson and Lewis confirmed that phycobiliproteins of cyanobacteria play a key role in light gathering [6]. The phycobiliproteins consist of light harvesting antennae called phycobilisomes (PBS). As the light is absorbed by PBS is transferred to Chlorophyll A, cyanobacteria is able to rebalance its excitation energy by moving PBS between Photosystem I (PSI) and Photosystem II (PSII) during the process of photosynthesis. This process is called state transition [7]. It could be possible that Chlorophyll A is concentrated in PSI. Blue light induces high PSI and low PSII. Since blue light is poorly absorbed by PBS and not distributed equally over the two photosystems, it results in less O2 yield [8]. However, with varied outputs and observations, there seems to be more scope of study left to understand the impact of wavelength on cyanobacteria and the resultant effects due to the same.

2. METHADOLOGY

2.1 Working Mechanism

BG-11 broth is a media commonly used for the growth of cyanobacteria. Cyanobacteria grows optimally better in neutral or alkaline medium. However, the mechanism of electron transfer is also achievable by identifying NADPH, as an endogenous mediator present in cyanobacterial species. Surge in the concentration of NADPH secreted into the external cell medium is obtained due to illumination. NADPH is a key metabolite of redox reaction as a result of anabolic processes. In photosynthetic organisms under light conditions, it is produced from NADP+. Elimination of NADPH in the external cell medium revokes the photocurrent while addition of exogenous NADP+ significantly increases and protracts the photocurrent production. Addition of exogenous NADP + can further increase photocurrent productivity [9]. Graphite being an excellent conductor of electricity is chosen as the electrode material at anode and cathode.

The following diagram shows of media and electrolyte is taken at the inlet and a graphite electrode is placed as the anode in the setup. Electricity generated at the cathode can be measured and stored for future use. Oxygen can also be obtained as an end product after purification. The oxygen as byproduct of photosynthesis of cyanobacteria is first let to dissolve in water. Dissolved oxygen can reach up to a saturation of 100% in water. Oxygen can be obtained by various process such as electrolysis, boiling under reduced pressure or nitrogen purging. Nitrogen purging is the most recommended method, as research by Butler, Schoonen and Rickard suggests that the process of Nitrogen purging for around 20-40 minutes at the rate of flow of 25 mL/s obtained 0.2-0.4 ppm, the highest oxygen yield out of various other methods tested [10].

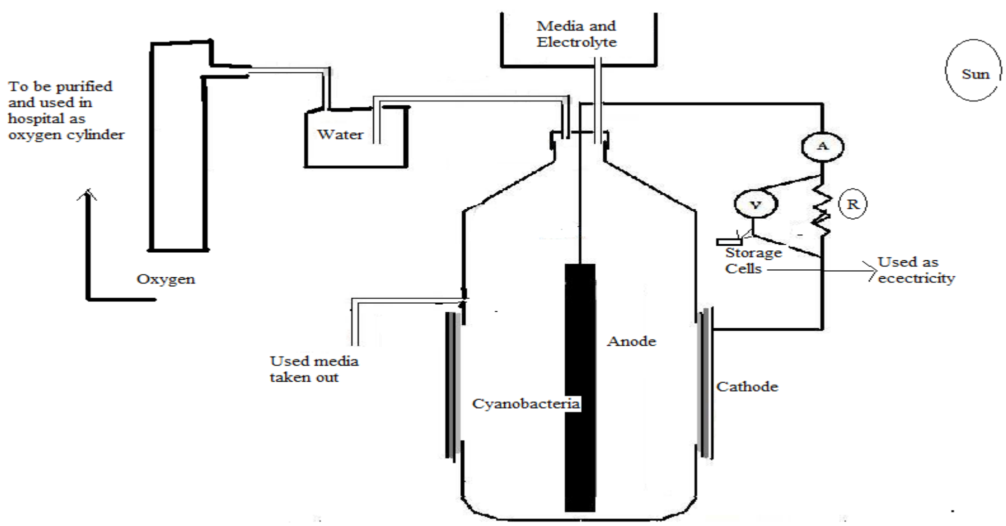

Fig -1: Schematic Diagram

2.2 Summary of Production

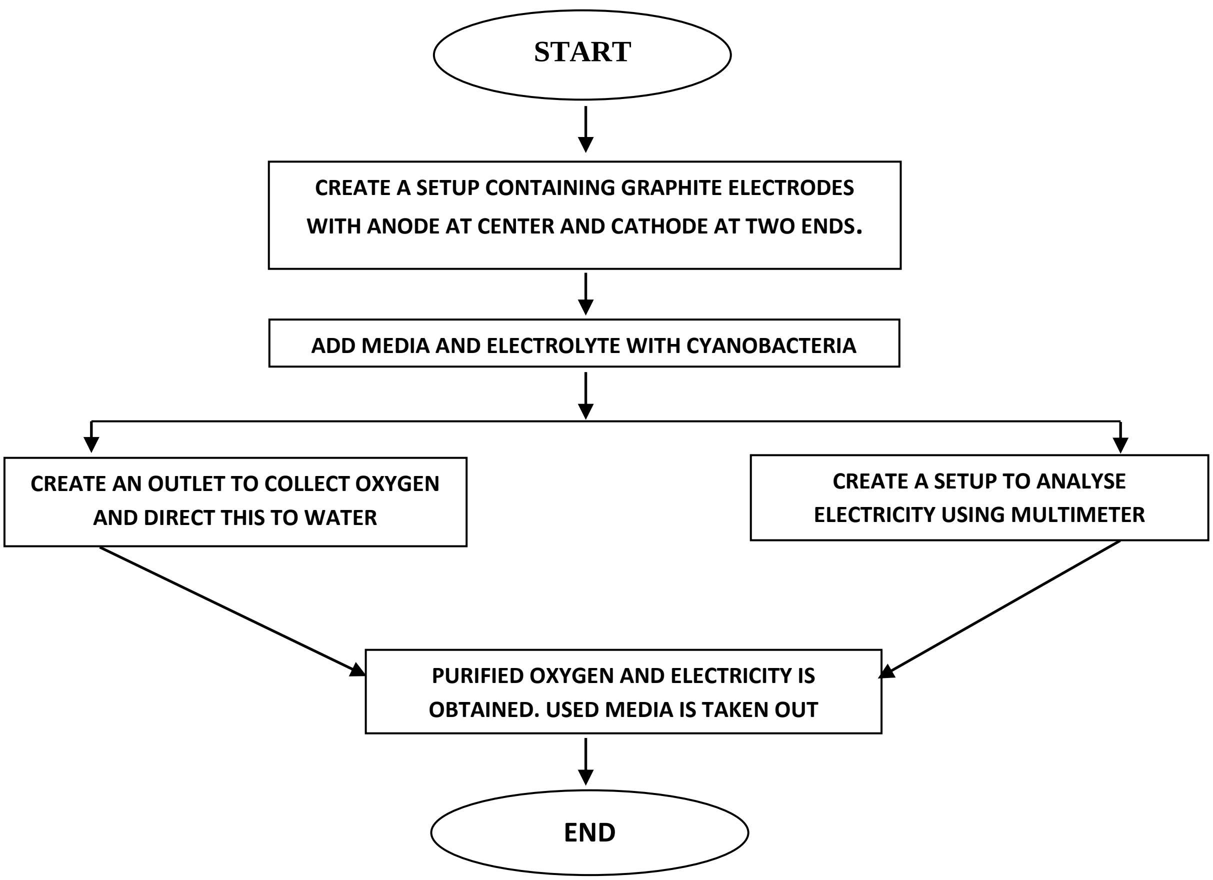

Chart -1: Flowchart

3. CONCLUSIONS

The following prototype can be used to harness both oxygen and electricity. There is scope for further research on how to maximize the yield of electricity and oxygen obtained. So far, we know that oxygen produced can be obtained the best way through Nitrogen purging. For electricity to be generated to its maximum potential, genetic modification of cyanobacteria can be done by cloning phycobilisomes. Also, utilization of the correct wavelength of the visible spectrum can maximize yield. So far, we have learnt that blue light results in the least production of oxygen. Yellow light produces good amount of electricity in comparison to red and blue light. Thus, taking both factors into consideration, yellow light may be the right choice for optimum harvest. Given the current scenario where green electricity generation is the need of the hour, this model would serve the purpose well. In addition, we have noticed that there is a lot of oxygen scarcity in hospitals for Covid 19 (SARS-CoV-2) patients. This method can help in deriving oxygen to fulfill the demand and circulating to hospitals.

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