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Design, Construction and Evaluation of Algae Photobioreactor (Green Engineering)

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Abstract: The paper presents the design, construction and performance evaluation of an algae photobioreactor. The photobioreactor is constructed with dimensions 1220mm in height and 360mm in diameter, it was made from materials such as glass tubes, plexiglass, uv source, pvc couplers, metal support and metal base. The photobioreactor consist of 12 algae cultures chambers which does the primary aim of enhancing the growth of algaes powered by a uv source which supply light to the algae cultures, with respect to light as the primary need for algae growth. These algae are consequently harvested and used as biofuels; also the fix/removal of C02 from the environment is one of the importance of growing algae as it eradicates global warming creating a cleaner environment. The study's findings demonstrate that photobioreactors serve as the energy source for algae development, and that temperature, pH, salinity, light, and nutrient quality are the key factors controlling algal growth. The spherical surface tubes give the cell a huge exposed area where light can be trapped, accelerating the algae's growth.

Keywords: *Algae, Photobioreactor (PBR), Biofuel, Carbon Sequestration.*

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I. INTRODUCTION

Currently, fossil fuels provide about 80% of the world's energy needs. However, widespread use of fossil fuels has resulted in environmental contamination, health issues, and global climate change [6]. As a result, several nations are focusing on the creation of fresh, sustainable, and clean energy sources. Biofuels are the most intriguing of the many possible renewable energy sources and are anticipated to be vital to the world's energy infrastructure in the future [3].

One of the most widely used biofuels, biodiesel, is acknowledged as a potential primary energy source as well as an ideal recyclable energy carrier [10]. Currently, animal fat, leftover frying oil, and vegetable oil, whose ratio to edible vegetable oil for agricultural land is still debatable, are used to make commercial biodiesel [2]. As a result, microalgae that can grow quickly and use CO2 fixation to transform solar energy into chemical energy are currently being evaluated as a key oil source for biodiesel. Certain microalgal species can accumulate up to 50–70% of oil/lipid per dry weight under the right growing conditions [1]. Microalgal oil's fatty acid composition is appropriate for biodiesel production. The ability of microalgae to generate up to 58,700L of oil per hectare, one or two magnitudes more than any other energy crop is the main reason to employing microalgal oil for biodiesel production [3].

However, a number of technical obstacles make the current development of the algal industry economically unfeasible for large-scale production of microalgae oil [8]. It is also necessary but extremely challenging to develop cost-effective technologies that would enable efficient biomass harvesting and oil extraction [7]. However, since producing algae is thought to be a viable option to reduce global warming [4], it is obvious that making oil from microalgae biomass would be very beneficial. As a result, algae are widely acknowledged as the feedstock for third-generation biofuels [9].

II. MATERIALS AND METHODS

As the world's largest primary suppliers of oxygen, microalgae offer an intriguing but untapped potential for biotechnological exploitation. They also play a significant role in climate modelling and are ecologically significant [4]. The culture conditions have a significant impact on the biomass composition, growth rate, and product spectra [2]. The medium's

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composition, temperature, pH, carbon dioxide, oxygen supply, and above all illumination are significant variables. Algae are photosynthetic organisms that require light from photosynthetically active radiation (PAR) and carbon dioxide as a source of carbon [5].

A 12 chamber algae photobioreactor, it consist of a tube within tube design illuminated system for optimal controlled algae illumination, it maintains 12 separate algal colonies simultaneously, glass algal chambers are scratch free and easily sterilized, it is approximately 122cm tall × 36cm in diameter, it is approximately 12 liters i.e. (1 liter in a chamber) as well as florescent for illumination.

An enclosed, illuminated culture tank intended for the regulated biomass production of phototrophic liquid cell suspension cultures is called a photobioreactor. Light delivery and distribution, gas transfer into and out of the reactor, maintaining the equilibrium of medium components, and preventing the build-up of potentially harmful secondary metabolites are the primary elements that need to be taken into account while designing a high density PBR.

The growth of the algae in the photobioreactor depends on the following conditions.

- Light supply and delivery
- Nutrient supply and algae strain selection
- C02 supply/gas transfer in and out

The source of light consists of the following; the solar radiation, the electrical source of light, as well as the dry cell rechargeable source of light. The first option considered was solar radiation which strikes the photobioreactor tube at an irradiance of 15mj, the fluorescent tube powered by electricity and the rechargeable dry cell. The LED light was powered by 220v rechargeable drycell. This LED light was considered due to its light focusing hardware and low power demand. The culture medium was characterized of poultry dung, which served as source of nutrient for the algae growth, which generally enhanced the growth of algae for the number of days it was monitored.

III. CONSTRUCTIONAL MATERIALS

- (912) glass tube
- (24) pvc couplers
- (2) 36cm plexiglass
- (1) steel brackets and road support
- Aquarium and marine silicone
- Glass screws and washers
- Algae syrain
- (1) fluorescent tube
- Rechargeable dry cell and tubes
- Wire and connectors

After it was built, the photobioreactor's performance and capacity to promote oedogonium growth and lipid production were initiated. The container was sterilized before being thoroughly cleaned. For forty minutes, the sterilizing process was carried out at 900C. Following sterilization, the bioreactor was allowed to cool to ambient temperature before being aseptically inoculated with the microalgae oedogonium. The entire photobioreactor was put together in a room with a controlled temperature. The vessels were illuminated continuously with solar radiation at irradiance at 15mj with fluorescent white tubes, as well as rechargeable dry cell during electrical power failure and were also aerated optimally.

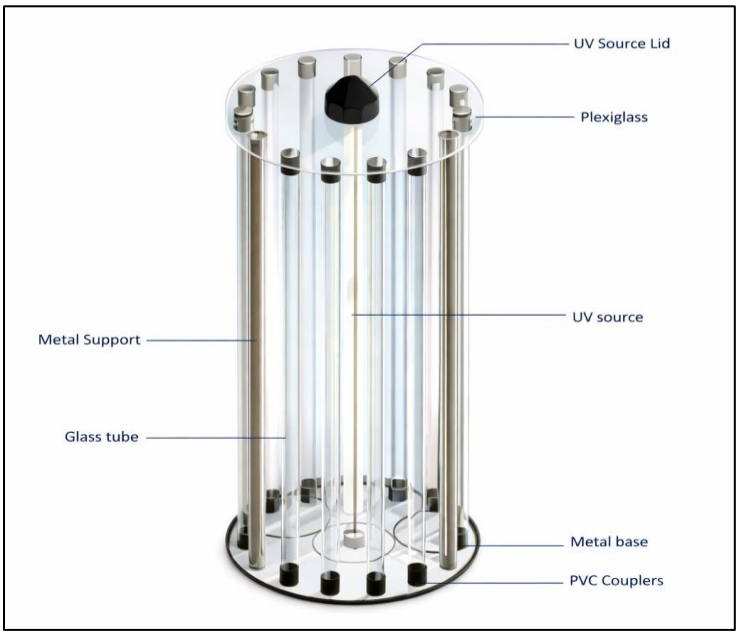

Fig 1: Components of the Photobioreactor

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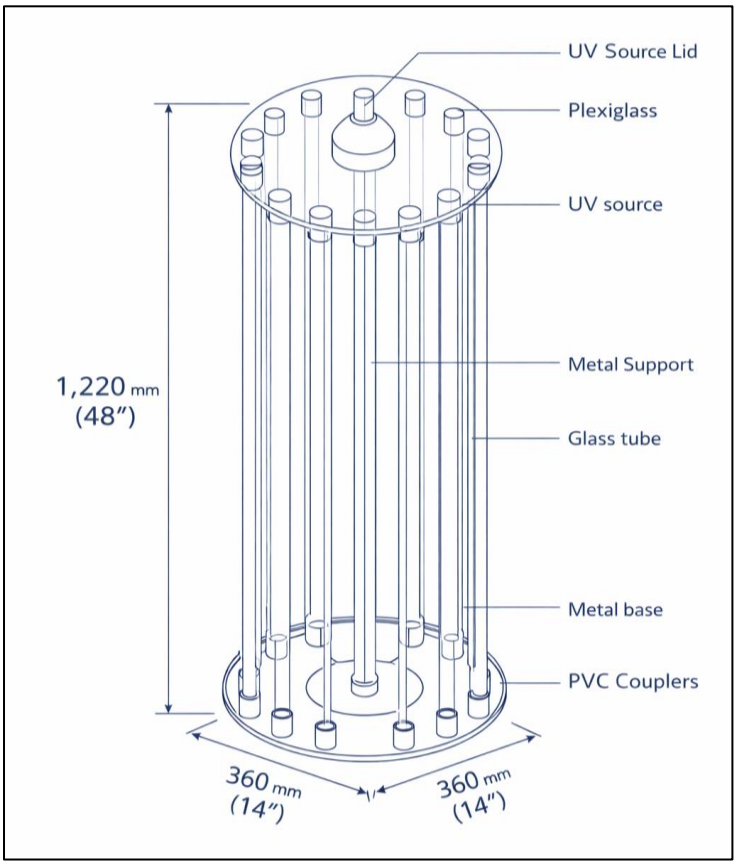

Fig 2: Isometric Drawing of Photobioreactor


Fig 3: Algae Culture in the Photobioreactor

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IV. RESULTS AND DISCUSSION

The photobioreactor's culture produced the results shown in the table below. The quality and amount of nutrients, light, PH, turbulence, salinity, and temperature are the most crucial factors controlling algal development. The distribution and delivery of light naturally determine the pace of algae growth. Important aspects of PBR design are light distribution and delivery. It is important to provide light in a way that minimizes photon loss, eliminates heat creation from the light source, and filters out potentially dangerous wavelengths. All of these issues are avoided by employing PBR. Internal lighting is the greatest approach to reduce photon loss, and photobioreactors enable this. Below is the table of results of the growth rate of algae culture in the photobioreactor.

Table 1: Summary of Results

Day	Date	Sampling Time at (hrs)	Cell Growth Concentration (pbb)	Cell Density	Cell Productivity Rate (μ)	PH	Temp (^{0}C)
1	9/8/15	24	20.2	0.9	0.021	7.1	14.1
2	10/8/15	48	25.0	1.2	0.041	6.8	17.4
3	11/8/15	72	35.2	1.4	0.032	6.3	10.6
4	12/8/15	96	56.7	2.3	0.09	7.7	23.4
5	13/8/15	120	62.8	3.3	0.04	7.1	28.9
6	14/8/15	144	62.1	3.2	0.03	6.5	29.4
7	15/8/15	168	49.2	3.0	0.02	7.8	29.0
8	16/8/15	192	81.2	3.7	0.008	6.3	29.1
9	17/8/15	216	82.0	3.9	0.0082	7.1	29.7
10	18/8/15	240	78.3	3.6	0.009	7.4	29.4

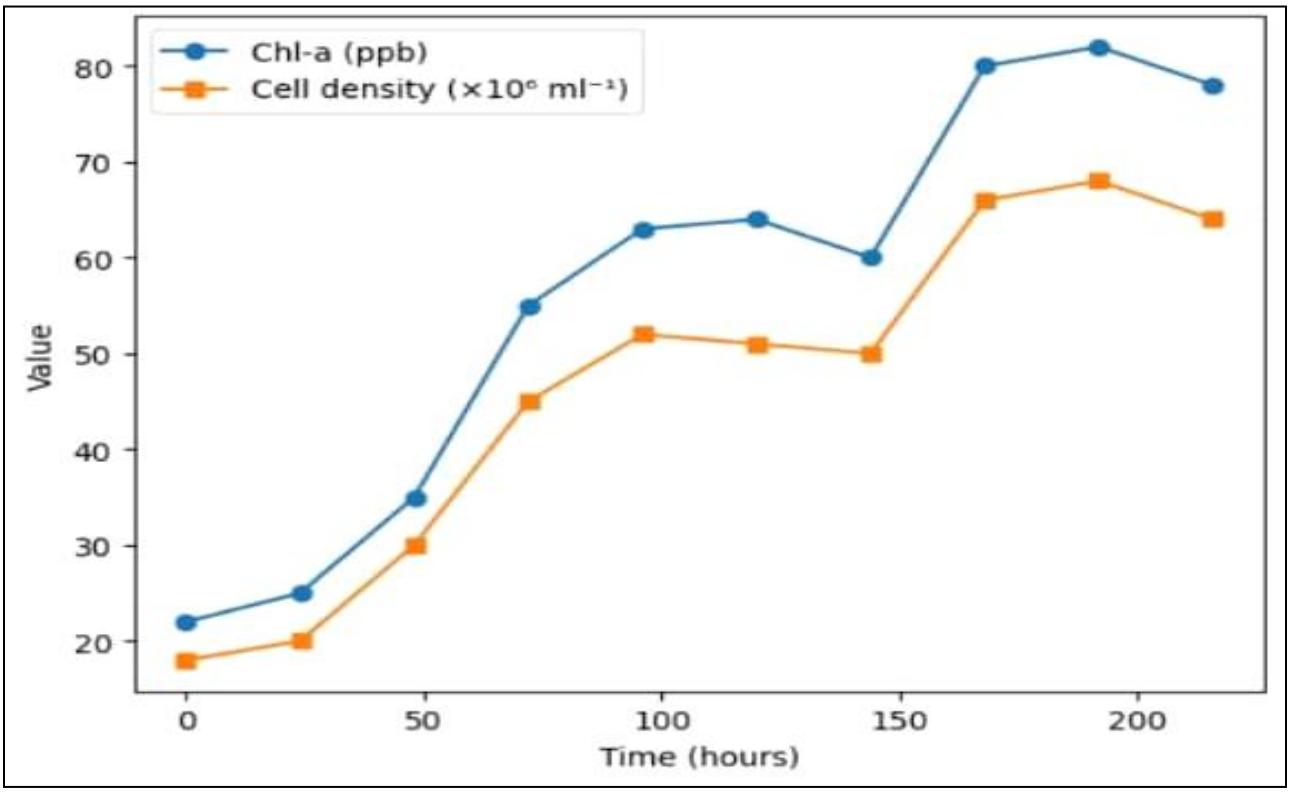

Fig 3: The Graph of the Growth of Oedogonium in the Photobioreactor with Respect to Time in Days.

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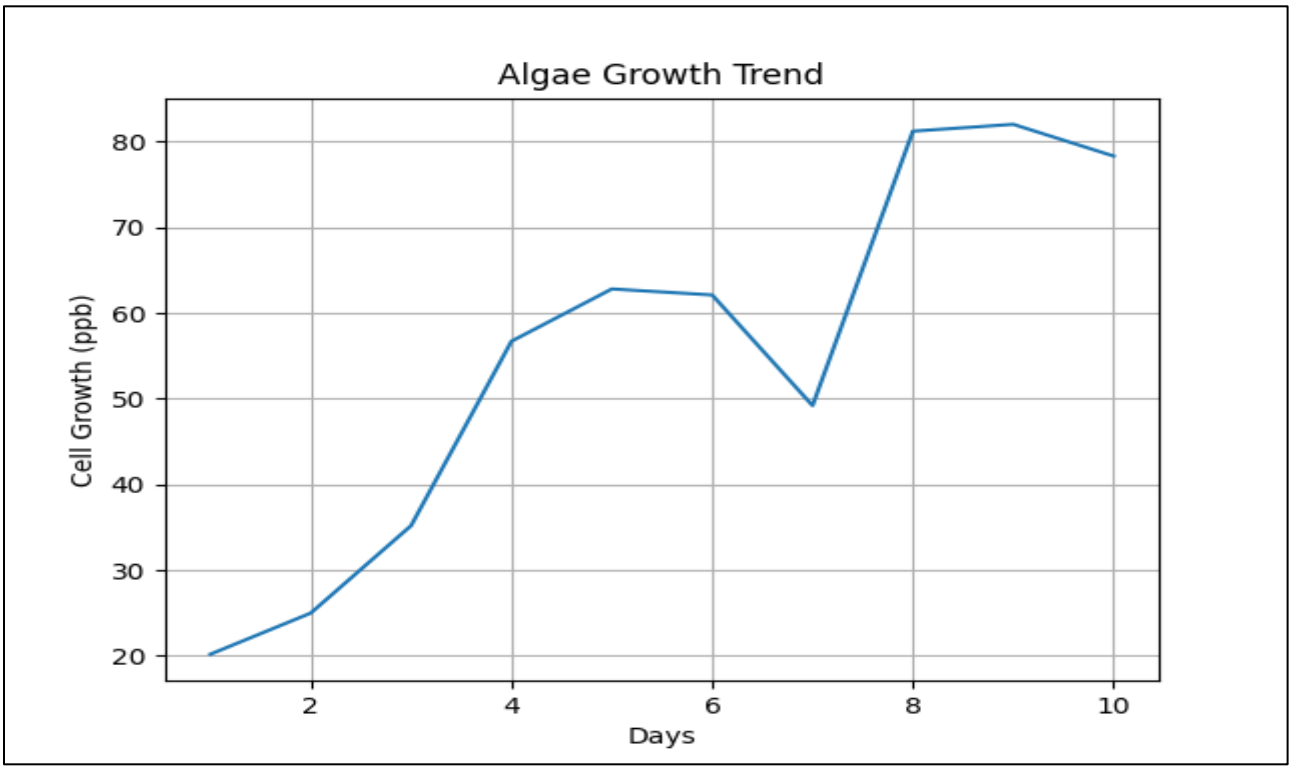

Fig 4: The Graph of the Growth the Oedogonium in the Photobioreactor with Respect to Time in Days.

➢ *Biomass Growth Equation*

$$\frac{dX}{dt} = \mu X$$

Where: X = Biomass concentration, **μ** = Growth rate

V. CONCLUSION

This study demonstrates that enhancing algae photobioreactors through design optimization, advanced materials, and IoT-based monitoring significantly improves their efficiency and cost-effectiveness. These advancements address existing limitations, positioning PBRs as viable solutions for sustainable industrial applications. Future research should explore scaling these innovations and their application across diverse environmental and industrial contexts.

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