

ALGAL PHOTOBIOREACTOR

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Technology degree in Biotechnology

by

CHANDINI SENGUPTA (39230009)
MITHRINTHAA.S (39230026)
NISHA.K (39230029)
SRISHTI RAJA (39230045)



DEPARTMENT OF BIOTECHNOLOGY

SCHOOL OF BIO AND CHEMICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of CHANDINI SENGUPTA(39230009), MITHRINTHAA.S(39230026), NISHA.K(39230029), and SRISHTI RAJA(39230045) who have done the Project work as a team who carried out the project entitled "ALGAL PHOTOBIOREACTOR" under my / our supervision from January 2022 to April 2022.

DR. V RAMESH KUMAR
HOD
DEPARTMENT OF BIOTECHNOLOGY
Internal Guide

DR. S SATHISH
HOD
DEPARTMENT OF CHEMICAL ENGINEERING
External Guide

DR. V RAMESH KUMAR
HOD
DEPARTMENT OF BIOTECHNOLOGY
Head of the Department

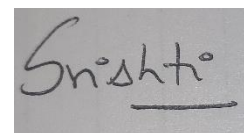
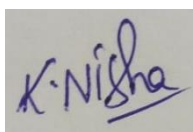
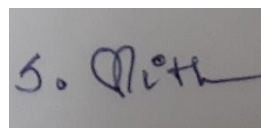
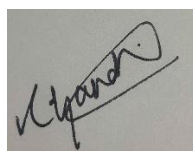
Submitted for Viva-voce Examination held on 29th APRIL 2022

Internal Examiner
(Name in Capital letters
with Signature)

External Examiner
(Name in Capital letters
with signature)

DECLARATION

WE, CHANDINI SENGUPTA(39230009), MITHRINTHAA.S(39230026), NISHA.K(39230029), and SRISHTI RAJA(39230045) hereby declare that the Project Report entitled “ALGAL PHOTOBIOREACTOR” done by us under the guidance of DR. V RAMESH KUMAR, HOD, DEPARTMENT OF BIOTECHNOLOGY (Internal) and DR. S.SATHISH, HOD, DEPARTMENT OF CHEMICAL ENGINEERING (External) at SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY (DEEMED TO BE UNIVERSITY) ACCREDITED WITH A GRADE “A” BY NAAC, JEPPIAAR NAGAR, RAJIV GANDHI SALAI CHENNAI- 600119 is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in BIOTECHNOLOGY.



DATE: April 2022

PLACE: Chennai

SIGNATURE OF THE CANDIDATES

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ABSTRACT

Photobioreactors (PBRs) have a serious role in cultivating phototrophic microorganisms to repair CO₂ and produce target products. Light penetration and distribution because of the energy source and therefore the supply of CO₂ because of the inorganic carbon source are the two key factors for PBR design. Among phototrophic microorganisms grown in PBRs, microalgae are the foremost popular ones with high potential for commercial applications, because they are considered third-generation feedstock for the assembly of biofuels and bio-based chemicals. Conventionally, microalgae are cultured in cost-effective open pond systems, but they have obvious disadvantages like poor mass transfer efficiency and a high possibility of pollutants and impurities. Closed-type PBRs are generally not economical because of high installation and maintenance costs, but they are more efficient in light and gas distribution when appropriately designed and efficiently made to work. Low-cost, energy-efficient PBRs with properly controlled systems to be kept under watch to check the performance of the algal culture as it is the last word goal in large-scale or industrial-scale algal cultivation. Factors affecting microalgal growth and photosynthesis are often useful in designing efficient PBRs. Various types of photobioreactors are introduced with stress on closed-type systems. Factors to be considered for microalgal cultivation in PBRs with a special configuration include solar panels. Finally, to conclude, commercial microalgae cultivation systems are currently in use, and so are the applications of the obtained microalgal biomass.

CHAPTER 1

INTRODUCTION

Algae have been estimated to include over 50,000 to 1 million species in the world. Algae serve as an important group of organisms for the biotechnological field's exploitation. They grow primarily in freshwater and marine environments, but despite it, they tend to grow in diverse habitats withstanding harsh climatic and environmental conditions as in soil, glaciers and rocks. Microalgae can remove metal ions from contaminated water bodies and can achieve greater production at lower expenses than commercial wastewater treatment technologies. For the past decade, several photobioreactors have been designed to maximize the growth of algae to obtain high-intensity photosynthetic systems. Some studies have proved the significance of algae in carbon dioxide fixation. Closed system PBRs have been proved to be advantageous over open ponds by the number of closed type PBRs being operated in pharmaceutical laboratory and biotechnological firms as the closed system give out better cultivations under controlled conditions such as pH, temperature, amount of nutrients, illumination intensity etc., Photobioreactors such as airlift, stirred tank and bubble-column have high scalability because they have low-illumination surfaces.

1.1 MICROALGAL CULTIVATION SYSTEMS

The Japanese experimented with out-of-door culture in an 'open rotation system', by using shallow open ponds in which the algal biomass suspense was cultivated by circulating via a series of moving pipes equipped with spurts for the injection of fresh culture fluid. As time

went on, algal biomass products came veritably important in the field of marine and hydroponics, as well as the product of chemicals and health supplements thus developing sophisticated ways for growing algal biomass. Presently, there are two extensively rehearsed microalgae civilization systems with open ponds and closed systems which are compactly described then

1.1.1 OPEN PONDS

Open ponds are classified into various types, the most commonly used systems include shallow big ponds, tanks, circular ponds and raceway ponds. The most common type of open pond system is a raceway pond which is often a rectangular canal with algal cultures flowing from the supply to an exit. The length to width ratio should be taken into consideration when constructing a raceway pond. Easier to construct, and operate than most closed systems is one of few advantages of an open pond system. However major limitations include evaporation losses, high contamination risks, diffusion of CO₂, and the requirement of the large-scale canal area. Due to an insufficient stirring mechanism, the transfer rates are very less resulting in low production of microalgae.

1.1.2 CLOSED SYSTEM

The main purpose of designing a closed system is to outsmart the open ponds and overcome the disadvantages. A PBR is defined to be a closed system when energy is supplied by electric lights; illumination should be uniform and sufficient. A typical PBR has a four-phase system; solid (algal cells), liquid (media that provides growth), gas (carbon dioxide and oxygen) and

a superimposed light radiation field. So, to develop a sustainable and reliable algae photobioreactor it is necessary to understand the interaction between biomass production and environmental factors (e.g., transfer of light and fluid resonance). Moreover, PBR design should be suitable for the cultivation of various microalgal species universally and to prevent fouling of the reactor.

To increase the production of microalgae, bioreactors are fitted with fluorescent lamps and other light distributors like Light Emitting Diode to increase efficiency. The use of LEDs based solar concentrating systems for microalgal photobioreactors has the potential to meet two significant criteria with illuminating systems for algal photobioreactors.

1. Electrical energy efficiency
2. Lighting distribution efficiency

CHAPTER 2

AIM

To construct a sustainable algae photobioreactor to increase the growth efficiency of microalgae during the day as well as the night time using Light Emitting Diode connected with solar panels in a closed type photobioreactor.

2.1 SCOPE

Photobioreactors have been designed to achieve an economical, rapid multiplication and increase algal biomass density. The study mainly focuses on the

construction of an algal photobioreactor under aseptic conditions with the help of suitable materials which are readily available. Generally, algae grow under sunlight which leads to a decline in its growth during night time. The construction of PBR is done in such a way that it can extend the algal growth by an artificial method of producing light from solar energy to improve its photon conversion efficiency, increasing the growth time by 6-7 hours. The container in which algae will be cultivated is made of glass which has the property of more absorbance of light, therefore initiating more algal cultivation. The constructed PBR has a major advantage in low energy consumption, good mixing with low shear stress, and is easy to sterilize. The study is limited due to some disadvantages such as scalability problems, requires temperature, pressure, pH maintenance, subject to daily and seasonal changes to temperature and humidity. To design adequate photobioreactors, it is necessary to understand the major phenomena which are limiting the performance of microalgae cells such as light availability, nutrients supply including CO₂, N, environmental conditions such as temperature and solar energy radiation, and mixing. To fulfil the requirements of microalgae cells, different technologies have been proposed such as raceway and thin-layer open reactors, in addition to tubular and flat-plate closed reactors. These technologies or methodologies are still being upgraded and improved to maximize the biomass production capacity and reduce production and labour costs. Additionally, the control and modelling of these reactors is a hot topic for the industrial development of microalgae-based processes. Further scope of this study can apply to growing

cyanobacteria for biofuels, bioplastics, pharmaceuticals, nutraceuticals, food additives, carbon capture, and wastewater remediation.

CHAPTER 3

TYPES AND PROPERTIES OF PHOTOBIOREACTORS

3.1 DIFFERENT TYPES OF PHOTOBIOREACTORS

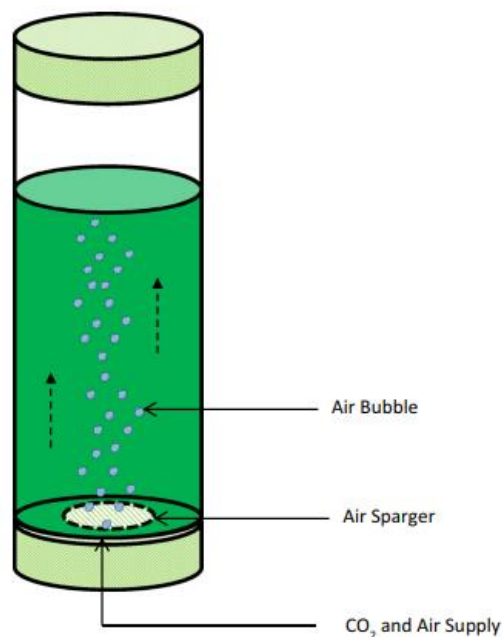
3.1.1 VERTICAL TUBULAR PHOTOBIOREACTOR

A vertical tubular photobioreactor is the most widely used bioreactor for outdoor mass cultivation, owing to its large surface to volume ratio. They are generally made up of transparent vertical tubes that allow the penetration of light through the surface. The microalgal cultures are circulated into the system either by pump or airlift system. Bubble column and airlift photobioreactors are examples of vertical tubular photobioreactors based on their mode of liquid flow.

3.1.2 AIRLIFT AND BUBBLE COLUMN PHOTOBIOREACTORS

Airlift and bubble column systems were initially designed to increase the biological oxygen demand of the microbial algae suspension. Airlift is a commonly used type of bioreactor for plant cell culture, technically Airlift PBRs differ from Bubble column PBRs due to the fluid flow turbulence and pattern caused by the presence of an internal and external draft tube which results in axial flow circulation. ALBs provide lower

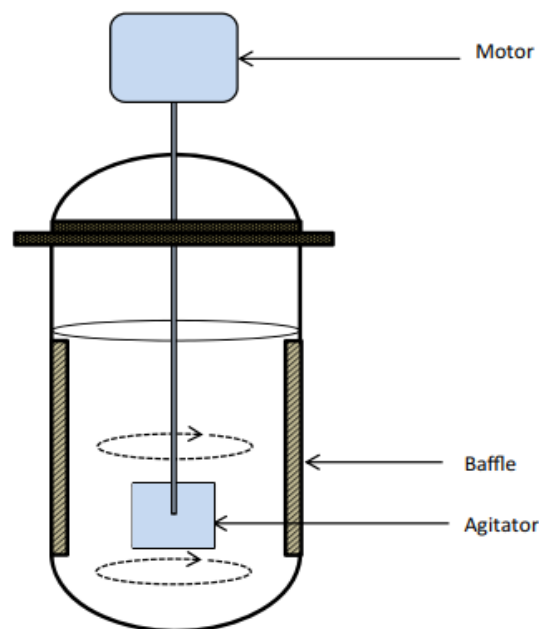
oxygen transfer rates than bubble column photobioreactors but with similar airflow. Indeed, they both have similar simple structures, since no mechanical force or propeller stirring or shaking is involved. Airlift PBRs have stable and stationary parts which can reduce maintenance time and cost, they provide low shear. However, foam formation and aggregation of bubbles can be a major problem. In a recent study, the application of airlift PBRs could accelerate genetic transformation in *Castanea dentata*. Since then, Airlift PBRs have been employed to grow embryogenic cultures of various plant species, such as alfalfa carrot (*Daucus carota*), grape (*Vitis vinifera*) and cork oak (*Quercus suber*).



3.1.3 STIRRED TANK PHOTOBIOREACTOR

Stirred tank photobioreactor is a simple yet prominent reactor that's extensively used as a fermenter design that consists of a spherical vessel with a stirrer. Stirred tank reactors (STRs) are now the most functional

bioreactors in the Power and Telecommunication Coordination Committee. STRs are extensible devices with effective fluid mixing systems and high Oxygen Transfer Rates that can be integrated with different types of impellers. Also, STRs comply with the current Good Manufacture Practices. The lesser microturbulence and advanced shear rates are the vital problems of STRs. Shear stresses are generated by the impeller and bursting gas bubbles in STRs. Still, these forces sometimes lead to beneficial elicitor effects, and so, there's a boost in the factory's secondary metabolism. For the case, cysteine protease produced by cell suspension of the species of papaya as well as its proteolytic exertion in STRs were planted to be more compared with the ALBs and BCBs due to the lesser microturbulence force in STRs.



3.1.4 TUBULAR MEMBRANE PHOTOBIOREACTOR

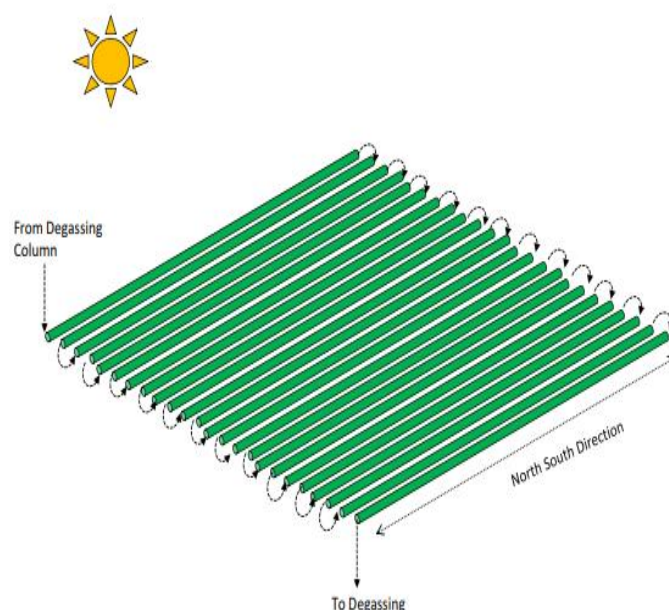
Tubular MRBs (TMBRs) with different membrane systems, similar to sunken- fibres or ceramic capillaries

have been designed with advanced surface-to-volume rates for high thick factory cell cultures under veritably lower shear stress. Poor OTR, complex operation, and scalability are the limitations of these bioreactors. The TMBR conception is analogous to tissue-suchlike conditions analogous to the network of highways in the human body. TMBRs can be impeccably integrated with cell immobilization systems, as the membrane performs like an immobilizer, to retain the cell culture in the reactor cube. It also serves as an attachment face for glutinous cell types. TMBR has been successfully used to enhance the origin of betanin from beetroot.

3.1.5 FLATPANEL PHOTOBIOREACTOR

Flat-panel PBRs use simple systems that greatly reduce the light penetration depth through the culture face. Flat-panel PBRs correspond to a frame covered by a transparent plate on two sides, A circulating pump is used to circulate the algal cell suspense. The main traits of the flat panel PBRs are high face to volume rate, the perpendicular or tilted inclination from the vertical of the channels, and the absence of mechanical bias for cell suspense. Still, these systems generally give a lower yield compared to tubular PBRs. The lower performance given out by societies in flat-panel PBRs has been characterized by the fact that these systems, unlike tubular PBRs, have veritably short light penetration depths and don't offer light dilution, therefore, leading to inhibition of microalgal growth. Due to their demand for numerous sections and support inputs, the difficulty in controlling the

aeration is also existent.



3.1.6 DISPOSABLE BIOREACTORS

Disposable bioreactors (DBRs), also known as single-use bioreactors are made of plastic bags, suitable for a microalgae and factory cell suspension culture. DBRs are time-and cost-effective, able to bar cross-contamination and reduce development time between each run. Considering the tremendous impact of genoproteomic-supported strategies in the field of medicinal factory parentage and molecular husbandry. DBRs can give new features to produce biopharmaceuticals and recombinant proteins. DBRs can be incorporated with various bioreactor systems; still, scalability poses a major challenge to their development.

3.2 ALGAL PHOTOBIOREACTOR

3.2.1 GENERAL CHARACTERISTICS OF ALGAE

Green algae and blue-green algae together comprise a large group of photosynthetic organisms. Algae are

some of the most robust organisms on earth, suitable to grow in a wide range of conditions. Algae are generally planted in wetish swamps and damp places and therefore are common in terrestrial as well as marine surroundings. It's distributed throughout the biosphere and grows in the widest possible range of conditions from a submarine (brackish to extreme saltiness) to terrestrial places. Algae warrant the internal structures that characterize land plants, similar to leaves and rhizoids in nonvascular plants, or roots, and other organs that are present in vascular plants. Its unique trait that separates them from other microorganisms is due to the presence of chlorophyll and having the photosynthetic capability in a single algal cell, thus allowing easy operation for biomass generation and effective inheritance and metabolic exploration in an important shorter period than conventional plants. Bad rainfall can frequently trick algal growth. Still, major limitations in open ponds include uneven light intensity, evaporative losses, proximity of CO₂ to the atmosphere, and demand for large areas of land. Likewise, impurity by bloodsuckers and other fast-growing heterotrophs.

3.2.2 PHOTOBIOREACTORS

A photobioreactor can be defined as an enclosed, illuminated culture vessel carefully designed for controlled biomass production. Photobioreactor refers to closed systems that are closed to the environment having no direct exchange of gases and contaminants with the environment. Photobioreactors, despite their costs, have several major advantages over open systems:

- Photobioreactors minimize contamination and allow axenic algal cultivation of monocultures.
- Photobioreactors offer much better control over conditions such as pH, temperature, light, CO₂ concentration etc.
- Photobioreactors lead to less CO₂ loss.
- Photobioreactors prevent evaporation of nutrients added.
- Photobioreactors allow higher cell concentrations.
- Photobioreactors help in the production of biopharmaceuticals.

3.2.2.1 POINTS TO BE TAKEN INTO CONSIDERATION WHILE CONSTRUCTING A PHOTOBIOREACTOR

The reactor should permit the cultivation of many universally present microalgal species.

- The reactor design must provide for the uniform illumination of the culture surface for the fast mass transfer of carbon-di-oxide and oxygen.
- Cells of microalgae are highly adhesive which results in rapid fouling of the light-transmitting surfaces of reactors. This leads to frequent shutdown of the reactors for mechanical cleaning and sterilization. The reactor design must prevent or minimize the fouling of the reactor, particularly of its light-transmitting surfaces.
- High mass transfer must be achieved by means that will neither cause any damage to the cultured cells nor suppress their growth.

3.2.3 ALGAL PHOTOBIOREACTORS

In algal photobioreactors, depending upon the nutrients needed by algal species, several sources of wastewater can be used for algal culture. For some marine-type microalgae, seawater can be used. While this is indeed the simplest of all the growing ways, it has some downsides because the terrain in and around the bioreactor isn't fully under control but Closed Pond systems like growing algae in algal photobioreactors bring further than the open ponds, and vastly lower than photobioreactors for analogous areas of operation. As a variation of the open pond system, the idea behind the unrestricted pond is to close it off with a transparent or translucent hedge which turns it into a greenhouse system type. These closed systems are designed and constructed using plexiglass. It allows further species to be grown; it allows the species that are being grown to stay dominant, and it extends the growing season – and if heated the pond can produce time-round. It's also possible to increase the quantity of carbon-di-oxide in this quasi-closed system, therefore adding to the rate of growth of algae by hours. The actual design of algal photobioreactors is to give algae all the sufficient nutrients like nitrogen, phosphorus, carbon, potassium, sulphur, iron, calcium etc., and also controlled pH and temperature that can optimize the growth of algae in photobioreactor accommodated with LEDs to maximize and produce continued growth

3.2.4 SOLAR CONNECTED PHOTOBIOREACTORS

Autotrophic growth of algae depends on photosynthesis, which involves light electromagnetic radiation energy absorption and conversion by

photosystems I and II (PSI and PSII) into electrochemical potential and chemical energy (NADPH and ATP). In an ideal case, a photobioreactor (PBR) must have the capability to capture all light available in the environment and transfer it into the culture to be used for biomass production. Although in normal conditions this does not happen because photosystems are exposed to an amount of light energy below or greater than the amount that can be transformed into chemical energy. Under sunlight energy, the biomass growth rate is insufficient to compensate for the rapid changes in sunlight intensity. Consequently, light attenuation (a reduction in the light beam as it propagates in the matter by dual property involving absorption and scattering of light) conditions that are fixed by biomass concentration are never optimal. This is why determining the maximum photosynthetic efficiency and the upper limits of biomass production through photosynthesis has been an important topic of investigation in the mass culture of microalgae since its beginning. A solar cell or solar panel is a device that traps rays of sunlight and directly converts them to electricity. The device is made of a two-layer of silicon (a semiconductor) sandwich, where the silicon is specially treated to allow electricity indeed to flow through it.

When a layer of the latter is placed on a sheet of the former, a wall forms in between the junction. No electrons can pass this barrier. However, this ceases to be the case when light strikes on this silicon(semiconductor) sandwich. When the sunlight strikes the surface of a solar cell, energy from sunlight is absorbed by PV cells in the panel creating photon

excitation and causing the electricity to flow. As the excited photon, or light particles, enter the silicon sandwich, they "give up" the energy they carry to the silicon atoms. This incoming energy which is formed blasts electrons out of the lower layer of the semiconductor so that they leap across the barrier to the top layer and then flow out and around the electrical circuit. The lighter strikes the surface, the higher the number of electrons that are knocked off, and the larger amount of the current will be derived. Such a phenomenon is referred to as the photoelectric effect.

The solar cell used in this study consists of 20W power connected to a solar battery of 12V. During the daytime, the PBR will work with exposure to sunlight, as time passes the intensity of sunlight decreases resulting in a decline in biomass density. To enhance further growth, a LED is connected to a charged solar panel which will provide continuity in the growth of algae thus, achieving additional 12 hours of microalgae growth in absence of sunlight.

3.2.5 BENEFITS AND APPLICATIONS OF PHOTOBIOREACTOR

Considering the broad diversity development of microalgal and cyanobacterial species, they represent a very unique reservoir of potentially novel commercial compounds. They have been used for the production of biomass for industries relative to human nutrition and health (e.g., nutraceuticals, pharmacological bio-actives), agriculture and aquaculture (e.g., bio-fertilizers, food supplements), and renewable fuels (e.g., fatty acid methyl esters, alcohols, and hydrogen).

Eukaryotic microalgae study has become a central topic due to their cellular storage of compounds (e.g., lipids, starch, and proteins), while cyanobacteria are relevant for the production of unique molecules (e.g., toxins) or molecules that can be secreted (e.g., ethanol, butanol, exopolysaccharides). Unicellular cyanobacteria rarely produce large quantities of commercially attractive bioproducts. Thus, their genetic manipulation of them is normally oriented to increase the production of biofuels and other chemicals. On the other hand, eukaryotic microalgae and filamentous cyanobacteria are more complicated for genetic modification. In the former, the foreign DNA needs high energy to trespass cell walls and membrane compartments; whereas the segregation of mutants is more difficult in multicellular organisms, such as filamentous cyanobacteria. Nonetheless, these organisms are good biotechnology prospects because they naturally accumulate commercially interesting compounds.

3.2.6 FOR THE PRODUCTION OF BIOFUEL

Over the past decades, the energy industry has faced the challenge of providing new energy sources, and as new climate policies demand, it has to fulfil the requirement of finding ecologically friendly alternatives. In this context, biofuel production from microalgae biomass is an alternative that captures and sequesters atmospheric carbon dioxide, the main greenhouse gas responsible for the current global warming. In general, biofuels are classified into four main types: biodiesel, bioethanol, biogas, and biohydrogen.

3.2.7 ADVANTAGES OF CULTURING MICROALGAE

Microalgae exhibit great biotechnological applications for the production of a wide variety of compounds such as polysaccharides, lipids, proteins, and other pigments, vitamins, steroids, among others. Dozens of algal species are used to produce animal feed, human nutrition, cosmetics, and pharmacy industry components. They also find applications in wastewater treatment, CO₂ fixation, and greenhouse gas emissions reduction. Microalgae can be used to produce biofuels, hydrocarbons, and hydrogen. They can be a clean and renewable energy source because of their high yield and low spatial requirements if compared to terrestrial plants. Some authors consider microalgae as biodiesel feedstocks for the future. The only natural process that allows the production of biomass using only sunlight as the energy source and CO₂ is photosynthesis. Unicellular photoautotrophic organisms are capable of using sunlight in a more efficient way than superior plants. The advantages of microalgae culture compared to superior plants are listed:

1. Microalgae biological systems are considered the most efficient for solar light capture, and the production of compounds through the photosynthetic process.
2. Whole microalgae biomass can be harvested and used because they lack complex reproductive organs and have no vascular systems.
3. Many algal species produce and accumulate particular compounds of high commercial value that can be induced, for example, proteins, carbohydrates, lipids, and pigments.

4. The isolation, genetic selection, and strain studies are relatively easy and less time consuming because microalgae reproduce themselves by simple cellular division and can fulfil their life cycles in just a few hours or days.

5. Microalgae can be cultivated with low inorganic nutrient concentrations. These make them of particular interest as a protein source, assuring protein availability in regions of low agricultural productivity due to the lack of water and nutrient-poor soils.

6. Systems for biomass production can be adapted or scaled up to different operation levels, allowing later incorporation of these systems into fully automated facilities for large scale production.

CHAPTER 4

MATERIALS AND METHODOLOGY USED

4.1 MATERIALS

SPECIMEN JAR Specimen Jars are similar to reagent bottles, made of thick Soda-Lime glass, a commonly used glass found in beverage bottles. The jar used has a capacity of 30cm*5cm.	
AIR PUMP MOTOR An air pump motor of 220-240V, 50/60Hz, 2.5W is a pump for exhausting air from a closed space or for compressing air or forcing it through other apparatus.	
SOLAR PANEL A solar panel of 20V is connected to PBR via battery	

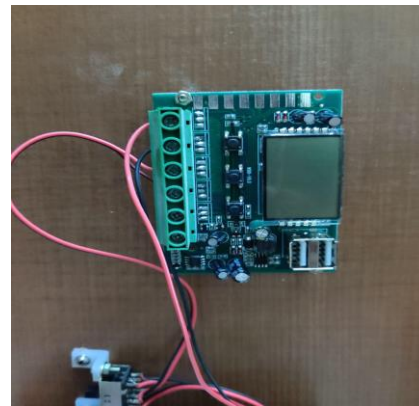
BATTERY

A battery of 12V is used with a maximum current of 1.4A



CHIP CONTROLLER

It controls the intensity of light, switching it on and off.



LED(light-emitting diode)

LEDs are used for cultures and artificial lighting. 10W DC LEDs are being used



4.2 METHODOLOGY

- To start with the design, take an acrylic specimen jar of diameter 5cm and a height of 30cm (5X30).
- Providing the system with an air pump motor, the air pump motor's wire is allowed into the tank to provide it with bubbles and friction for the growth of algae and also for the stirring of contents/nutrients in the solution with carbon-di-oxide as an input.

- Agitator is replaced with an air pump motor for the mixing of nutrient content.
- To provide supplements that help in the growth of microalgae we are using growth media that consists of major nutrients like 'phosphorus' and 'nitrogen' and carbon-di-oxide is added in the form of tablets.
- To illuminate the system we provide it with Light Emitting Diodes (LEDs) of 10-watt power (10 W).
- 10-watt LEDs are connected to solar power battery, the solar power batteries are in turn connected to the solar panel of 20-watt (20 W).

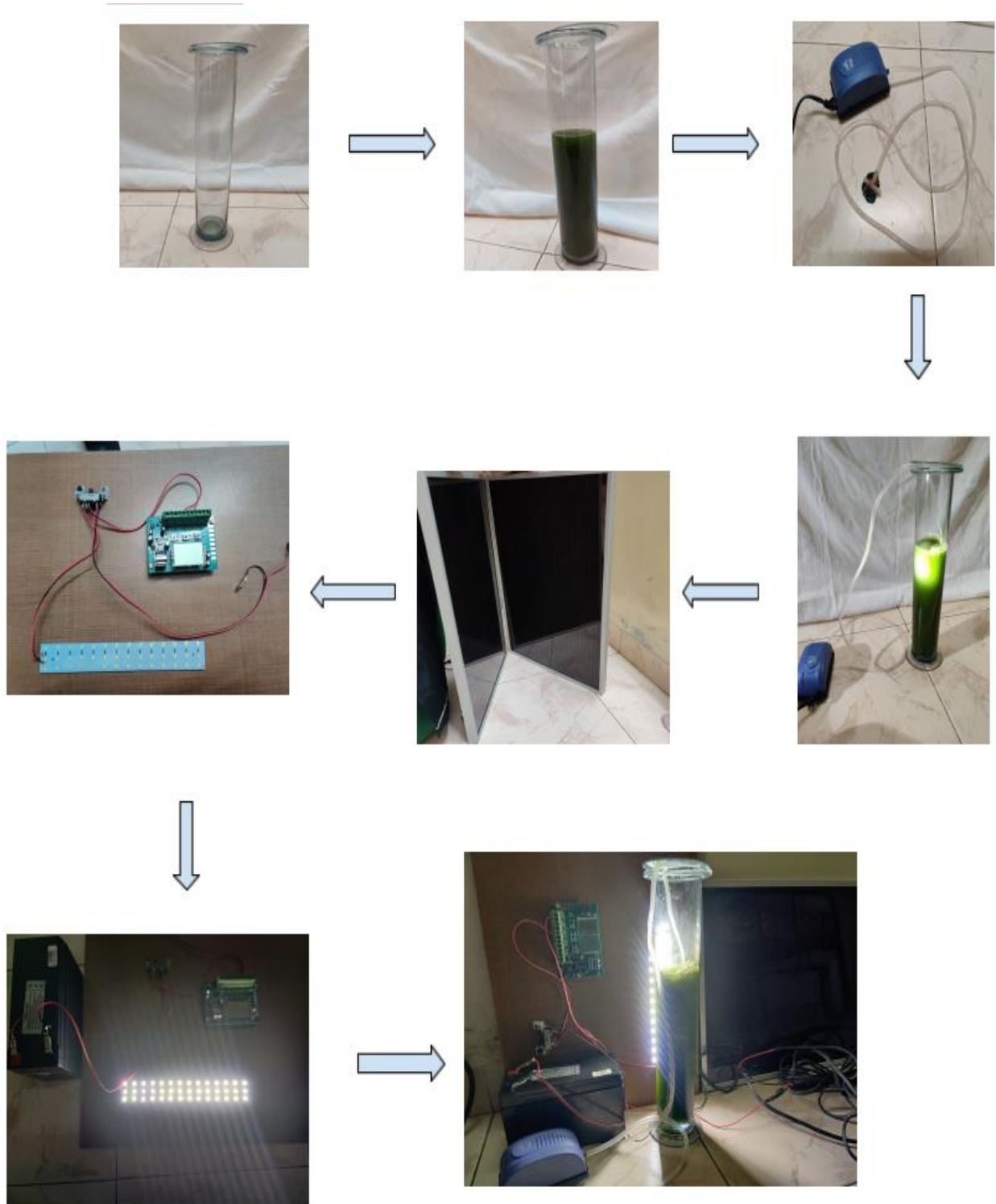
4.3 FURTHER DEVELOPMENT

- To make the algae photobioreactor operate for 24 hours
- Estimated budget: 40,000 Rupees

4.3.1 METHODOLOGY

- Use a solar panel of 60-watt (60 W) equipped with a 12 voltage battery and a distilled water inverter.
- With this source the motor and illumination facility (LEDs or vapour lamps) can be operated 24 hours a day (24/7) thus increasing the efficiency of the closed-system photobioreactor by maximizing the production by a few hours extra.

4.4 FLOWCHART



CHAPTER 5

INTERACTION OF SPIRULINA WITH BIOREACTOR

Closed photobioreactors play a major role in the culture of photosynthetic microorganisms because they allow better control of the cultivation conditions than open systems. Moreover, in these reactors, higher outputs are obtained and contamination can be easily prevented. Closed bioreactors are used for the production of high-value compounds such as unsaturated fatty acids, pigments, vitamins and polysaccharides and other nutrients. Optimization of the cultivation conditions of spirulina takes place constantly at a constant rate, to increase the yield of this valuable product. An important economic indicator of the process is the constant increase in the yield of biomass and a decrease in the cost of its production. For example, avoiding the need to cultivate spirulina at elevated temperatures with at least equal biomass yield.

The purpose of implantation of scale-up is for choosing the type of design conditions and procedures for operation and also to ensure that the effect of different variables of the process is the same in units of different sizes. Hydrodynamics and transfer properties of liquid content throughout the system using spirulina algae are usually used as criteria for scaling-up bioreactors, and the main variables that are frequently chosen to be kept constant are agitation power per reactor volume, the volumetric mass transfer coefficient, the shear stress level and the mixing time calculated.

Therefore, light distribution inside the photobioreactor is a critical parameter for its operation because light absorption by pigments and dispersion by the whole cells generate heterogeneity in the volume of the reactor and as a result volumes with illumination levels below the compensation point for photosynthesis by microalgae used here. In this work, we discuss the design and the operation of a small scale photobioreactor for the continuous culture of *Spirulina* algae.

CHAPTER 6

RESULT

The experimental results obtained from the algal photobioreactor demonstrated that this design strategy was successful, as the evolution of biomass concentration was in good accordance with describing the growth of *Spirulina* as a function of uniform illumination equipped with solar panels increasing the microalgae production.

CHAPTER 7

SUMMARY

Algal photobioreactor which was constructed providing aseptic conditions to algal growth is an eco-friendly and a closed system bioreactor which works under the mechanism of capturing light for photosynthesis

purpose. Among phototrophic microorganisms grown in PBRs, microalgae are the foremost popular ones with high potential for commercial applications, because they are considered third-generation feedstock for the assembly of biofuels and bio-based chemicals. Closed-type PBRs are generally not economical because of high installation and maintenance costs, but they are more efficient in light and gas distribution when appropriately designed and efficiently made to work. Types of bioreactors and their application have given a broad view on improving the productivity and quality of biotechnological products. We attempt to provide a comprehensive review of the relevant information and tools required for the optimal engineering of a photosynthetic microorganism employed in sustainable biotechnology applications.

CHAPTER 8

CONCLUSION

This work was carried out within the framework of the project guidelines for the sustainable development of recent technologies for the mass cultivation of microalgae for the needs of fish feed, pharmaceuticals, agricultural products, perfumery and other types of industries using an algae photobioreactor as their major system for production. This work presents the results of cultivating *Spirulina* in a continuous closed-system photobioreactor equipped with LEDs with an additional supply of carbon-di-oxide which thereby

removes the above-described disadvantages of periodic cultivation making the algal photobioreactor a potential system for microalgae cultivation. Considering the limitations of open ponds, such as high openness for contamination and pollutants, limitation in temperature control and availability of light, it is worth upgrading and putting more effort into developing outdoor closed-system photobioreactors. Although a great deal of work has been done to develop PBRs for algal cultures, more work is still required to improve PBRs technologies and the knowledge of microalgae culture production.

CHAPTER 9

LITERATURE SURVEY

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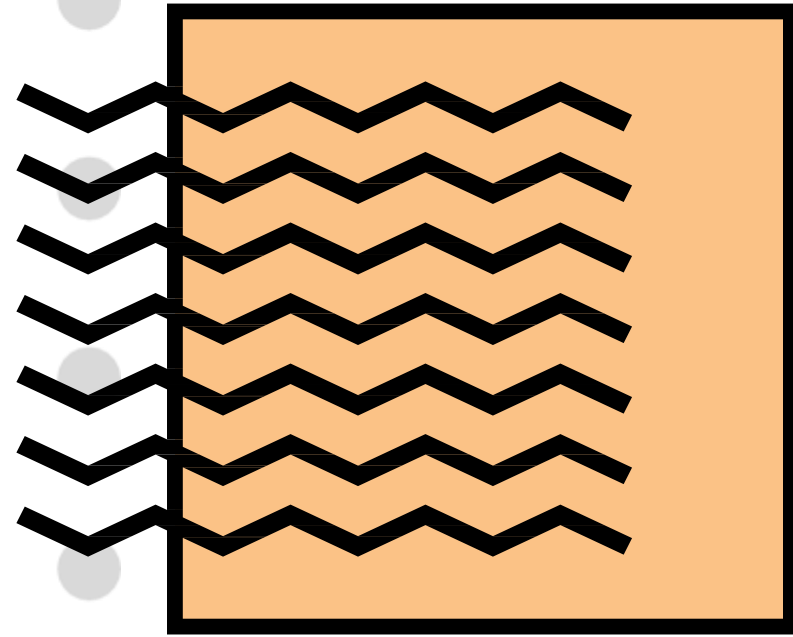
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SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY



ALGAE PHOTOBIOREACTOR



INTERNAL GUIDE

DR. V. RAMESH KUMAR

HOD

DEPARTMENT OF BIOTECHNOLOGY

EXTERNAL GUIDE

DR S SATHISH

HOD

DEPARTMENT OF CHEMICAL ENGINEERING

DEPARTMENT OF BIOTECHNOLOGY

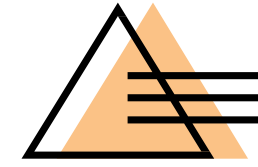
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INTRODUCTION

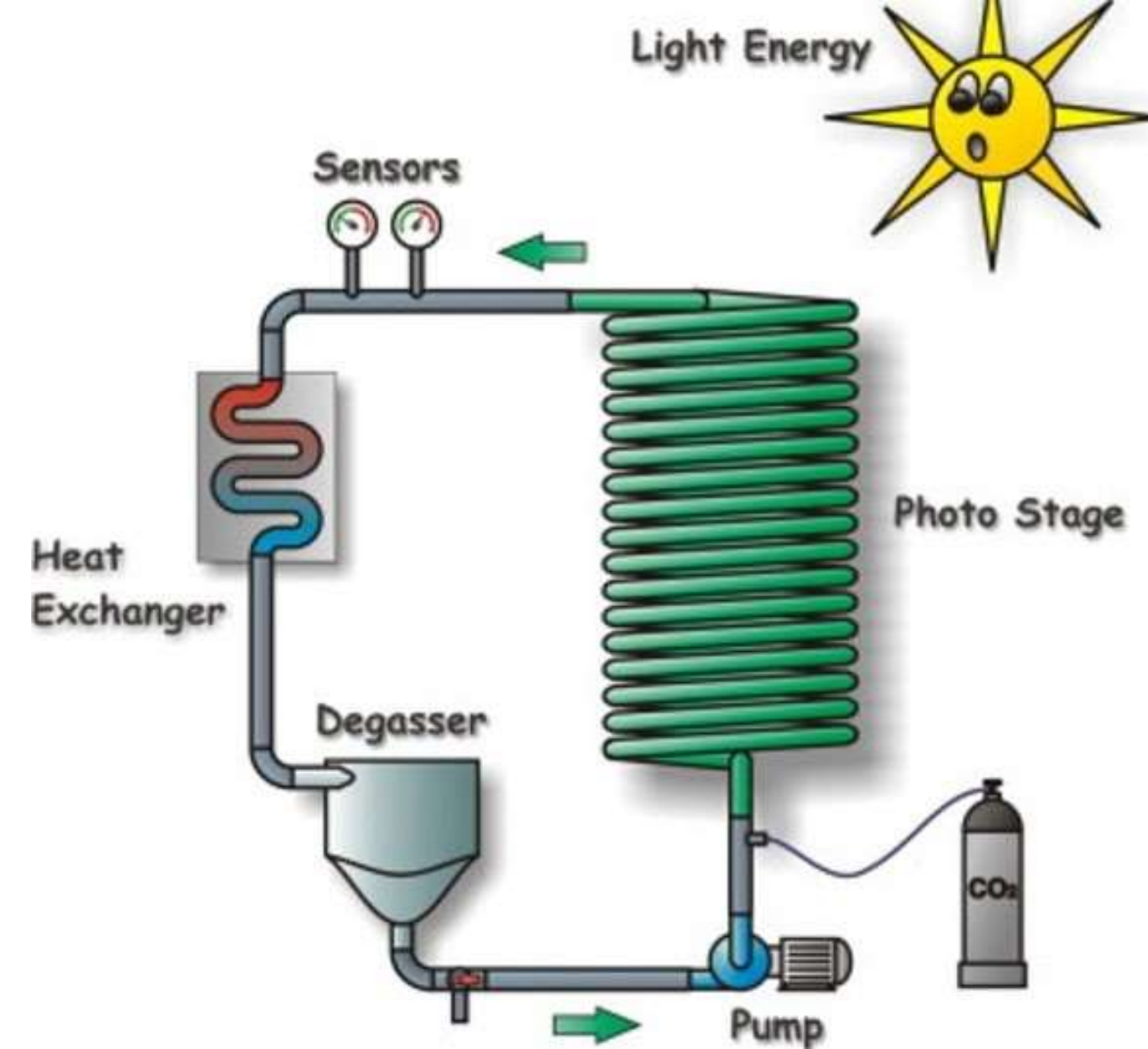


Algae have been estimated to include over 50,000 to 1million species in the world. Algae serve as an important group of organisms for the biotechnological field's exploitation. They grow primarily in freshwater and marine environments, but despite it, they tend to grow in diverse habitats withstanding harsh climatic and environmental conditions as in soil, glaciers, and rocks. Microalgae can remove metal ions from contaminated water bodies and can achieve greater production at lower expenses than commercial wastewater treatment technologies. For the past decade, several photobioreactors have been designed to maximize the growth of algae to obtain high-intensity photosynthetic systems. Some studies have proved the significance of algae in carbon dioxide fixation. Closed system PBRs have been proved to be advantageous over open ponds by the number of closed type PBRs being operated in pharmaceutical laboratory and biotech biotechnological firms as the closed system give out better cultivations under controlled conditions such as pH, temperature, amount of nutrients, illumination intensity, etc., Photobioreactors such as airlift, stirred tank and bubble-column have high scalability because they have low-illumination surfaces.



RESEARCH PROBLEM

- NOT FEASIBLE
- NEED HIGH SOLAR PANEL CAPACITY
- HIGH INTENSIVE INVERTER AND BATTERY TO BE USED

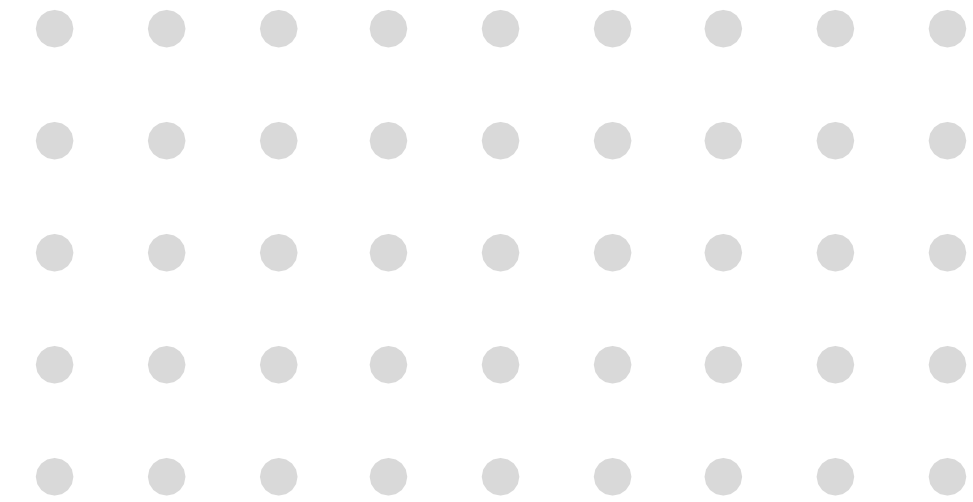




AIM



TO CONSTRUCT A SUSTAINABLE ALGAE PHOTOBIOREACTOR TO INCREASE THE GROWTH EFFICIENCY OF MICRO ALGAE DURING THE DAY AS WELL AS THE NIGHT TIME USING LIGHT EMITTING DIODE CONNECTED WITH SOLAR PANELS IN A CLOSED TYPE PHOTOBIOREACTOR.



OBJECTIVES

- TO UNDERSTAND THE FUNCTIONING AND WORKING CONDITIONS
- TO GAIN SKILLS AND KNOWLEDGE OF ALGAE PHOTOBIOREACTOR
- TO SEE IF THIS KIND OF WORK IS A POSSIBILITY FOR OUR FUTURE CAREER
- TO LEARN ABOUT RESEARCH METHODOLOGIES
- THE MAIN OBJECTIVE OF THIS PART WAS TO FIND FEASIBLE INITIAL CONDITIONS BASED ON THE BEST CASE; THE DESIGN METHOD DEPENDS ON THIS INITIAL CONDITION TO AND FEASIBLE SOLUTIONS TO MAXIMIZE THE GROWTH OF ALGAE.



MATERIALS REQUIRED

SPECIMEN JAR

Specimen Jars are similar to reagent bottles, made of thick Soda-Lime glass, a commonly used glass found in beverage bottles. The jar used has a capacity of 30cm*5cm.



BATTERY

A battery of 12V is used with a maximum current of 1.4A



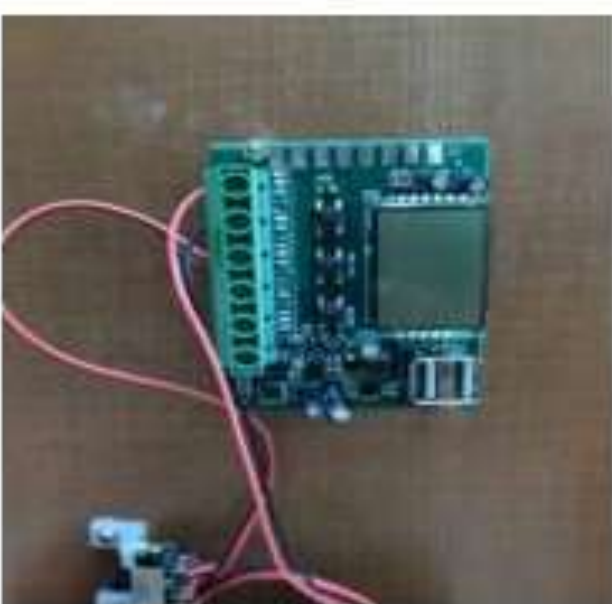
AIR PUMP MOTOR

An air pump motor of 220-240V, 50/60Hz, 2.5W is a pump for exhausting air from a closed space or for compressing air or forcing it through other apparatus.



CHIP CONTROLLER

It controls the intensity of light, switching it on and off.



SOLAR PANEL

A solar panel of 20V is connected to PBR via battery



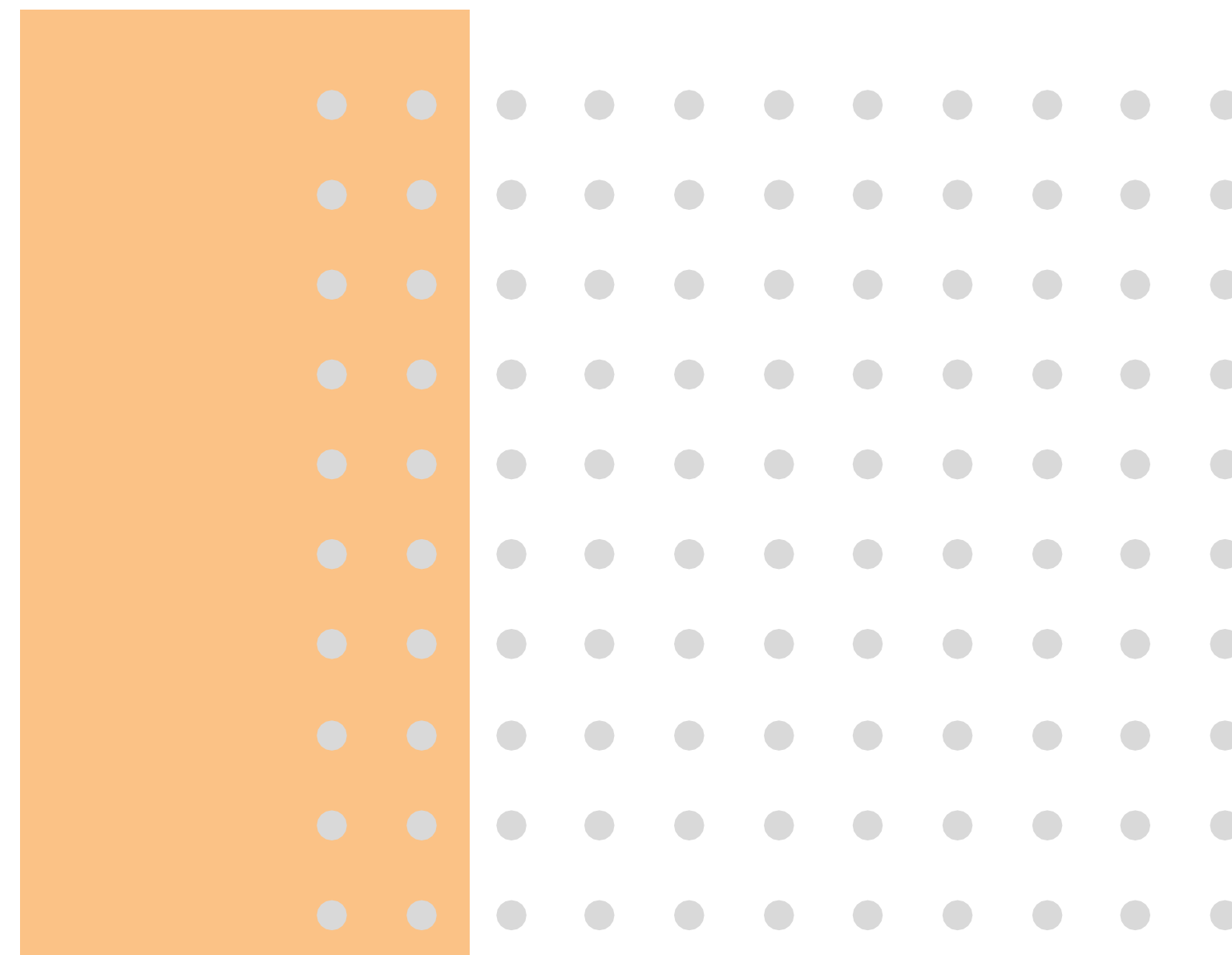
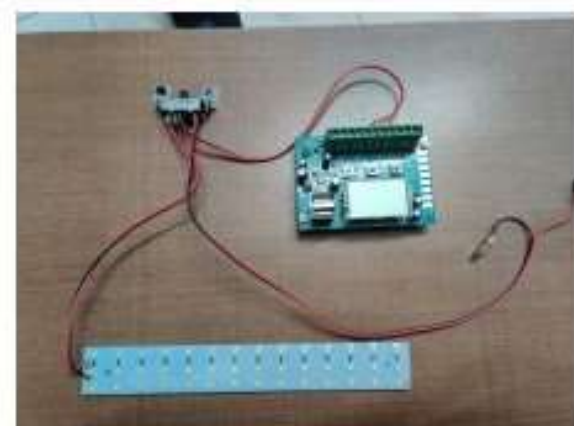
LED(light-emitting diode)

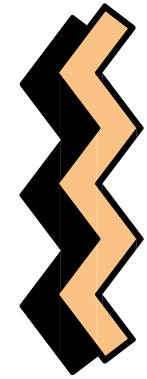
LEDs are used for cultures and artificial lighting. 10DC LEDs are being used





FLOW CHART





METHODOLOGY



- **TO START WITH THE DESIGNING, TAKE AN ACRYLIC SPECIMEN JAR OF DIAMETER 5CM AND A HEIGHT OF 30CM (5X30).**
- **PROVIDING THE SYSTEM WITH AN AIR PUMP MOTOR, THE AIR PUMP MOTOR'S WIRE IS ALLOWED INTO THE TANK TO PROVIDE IT WITH BUBBLES AND FRICTION FOR THE GROWTH OF ALGAE AND ALSO FOR THE STIRRING OF CONTENTS/NUTRIENTS IN THE SOLUTION WITH CARBON-DI-OXIDE AS AN INPUT.**
- **AGITATOR IS REPLACED WITH AN AIR PUMP MOTOR FOR THE MIXING OF NUTRIENT CONTTO PROVIDE SUPPLEMENTS THAT HELP IN THE GROWTH OF MICROALGAE WE ARE USING GROWTH MEDIA THAT CONSISTS OF MAJOR NUTRIENTS LIKE 'PHOSPHORUS' AND 'NITROGEN' AND CARBON-DI-OXIDE IS ADDED IN THE FORM OF TABLETS.**
- **TO ILLUMINIZE THE SYSTEM WE PROVIDE IT WITH LIGHT EMITTING DIODES (LEDS) OF DC-WATT POWER (10 W).**
- **10-WATT LEDES ARE CONNECTED TO SOLAR POWER BATTERY, THE SOLAR POWER BATTERIES ARE IN TURN CONNECTED TO SOLAR PANEL OF 20-WATT (20 W)ENT.**



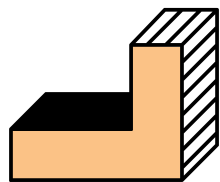


FURTHER DEVELOPMENT

**TO MAKE THE ALGAE PHOTOBIOREACTOR OPERATE FOR 24 HOURS
ESTIMATED BUDGET: 40,000 RUPEES**

METHODOLOGY:

USE A SOLAR PANEL OF 60-WATT (60 W) EQUIPPED WITH A 12 VOLTAGE BATTERY AND A DISTILLED WATER INVERTER. WITH THIS SOURCE THE MOTOR AND ILLUMINATION FACILITY (LEDS OR VAPOUR LAMPS) CAN BE OPERATED FOR 24 HOURS A DAY (24/7) THUS INCREASING THE EFFICIENCY OF THE CLOSED-SYSTEM PHOTOBIOREACTOR BY MAXIMIZING THE PRODUCTION BY A FEW HOURS EXTRA.



OUTCOME

ALGAE PHOTO BIOREACTOR

The experimental results obtained from the algal photobioreactor demonstrated that this design strategy was successful, as the evolution of biomass concentration was in good accordance with describing the growth of *Spirulina* as a function of uniform illumination equipped with solar panels increasing the microalgae production.



