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BIO-SEQUESTARTION OF CO_2 USING MICROALGAE

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Abstract

The threatening crisis of climate change and pollution resulting from various anthropogenic interventions has attracted worldwide attention over the last few decades. However, Carbon Capture and Storage (CCS) methods are still unclear. To overcome this global issue, biological Microalgae can be used for capturing of CO_2. This study involving the utilization of various sensors and boards, such as the MG811 CO_2 sensor, Arduino UNO, and DHT11 for monitoring temperature, humidity, and CO_2 levels. The results and discussions highlighted the impact of factors like temperature and air supply on algal growth and its CO_2 capture efficiency. Mixed culture microalgae showed maximum CO_2 removal efficiency of 23.36% with a low air flow rate at indoor conditions, for a run time of 180 minutes. At the end of the lab scale experimental study 3 gram of biomass from mixed culture was generated as result of CO_2 sequestration. The study emphasized the importance of microalgae and sensors in sustainable way to capture CO_2 from the ambient air. Algae can be extensively used to capture CO_2 from various point sources. Besides giving environmental and economic benefit. Overall, the project delved into the potential of mixed algal cultures for bio-sequestration of CO_2, showcasing promising results for environmental sustainability.

Key Words: **Climate change, carbon capture and storage (CCS), Microalgae, MG811, DHT11, mixed culture, spirulina, sustainability**

1.INTRODUCTION

Excessive release of greenhouse gases (GHG's) and increase in the concentration of anthropogenic carbon dioxide (CO_2) in recent time have aroused the attention of everyone due to the serious threat they represent to the environment and human health. According to the World Health Organization (WHO), it is estimated that seven million deaths a year are the product of environmental pollution arising from GHGs and it is predicted that these deaths may amount to up to nine million in 2060 if the growing trend in CO_2 and GHG emissions continues (Qin. 2022). In this regard, it is necessary to capture CO_2 through an environmentally sustainable process to reduce the damage on the environment. Among the different technologies for capturing CO_2, the use of microalgae, which are photosynthetic microorganisms that can naturally fix CO_2 from 10 to 50 times that of terrestrial plants to produce O_2 (Cheng et al., 2022). Bio-sequestration emerges as a promising solution to tackle the harsh effects of climate change on our environment, offering a natural and eco-friendly approach. It involves utilizing microalgae, tiny organisms found in water, to capture and store CO_2. Carbon sinks are these amazing natural systems that take in and soak up a whole bunch of carbon dioxide from the air. they're like the Earth's super cleaners. They come from places like forests, oceans, soil, wetlands, and grasslands

1.1 Carbon sequestration

Sequestration is generally of three types - physical, chemical and biological methods. Most of the technologies are used to reduce carbon dioxide emissions in the atmosphere, widely sequestration methods are used to capture carbon. Direct air capture, oxy-combustion, precombustion, post combustion is some of the carbon sequestration methods (Narinder Singh et al. 2023). By trim and fill analysis, it is estimated that carbon capture cost comprises of over 80% of total Carbon capture and storage (CCS) cost (Gal Hochman and Vijay Appasamy, 2024).

1.2 Role of microalgae in bio-sequestration

The role of microalgae in bio sequestration is pivotal for mitigating climate change, as these microscopic organisms efficiently capture and store carbon dioxide from the atmosphere. Through photosynthesis, microalgae convert CO_2 into biomass, which can be harvested and processed to sequester carbon for extended periods. Their rapid growth rates and high biomass productivity make them effective carbon sinks, while their versatility allows for various applications, including bioenergy production and bioremediation. Harnessing the potential of microalgae in carbon capture offers a sustainable solution to combatting rising CO_2 levels and mitigating the impacts of climate change.

Microalgae cultivation can contribute to bioremediation efforts by removing pollutants from waste water, indirectly aiding in reducing environmental factors contributing to climate change. Their adaptability to different aquatic environments ensures suitability for various geographical regions and climates. Implementing microalgae bio-sequestration techniques in urban region not only reduces carbon footprint but helps in enhancing its green belt.

2. MATERIALS AND METHODOLOGY

The main objective of this report is to analyze environmental factors influencing algal growth through a project that integrates environmental engineering principles with sensor technology and biotechnology. The project involves a comprehensive literature survey on various methodologies for CO_2 capture and the installation of sensors to monitor CO_2 levels. The experimental setup, designed to study both indoor and outdoor environments, uses materials and methods to evaluate the efficiency of a bioreactor in capturing carbon dioxide, focusing on spirulina and mixed culture microalgae. This project highlights bio-sequestration using microalgae as a sustainable solution to mitigate climate change impacts.

The experimental setup integrates two main components: electrical components and laboratory equipment. Electrical Components such as Sensors (MG811) to Monitor temperature, humidity, and CO_2 concentrations, Arduino UNO Board which serves as the microcontroller, Connecting Wires, Air Pump, Flow Regulator, LCD Display, Adapters were used to Facilitate the overall functioning and real-time monitoring of the system. Laboratory Equipment's required are Closed Culture Media for cultivating microalgae, polymer Pipes to Transfer gases in and out of the culture media. Function and features of MG811 CO_2 Sensor: Senses carbon dioxide concentration by monitoring the infrared radiation absorbed by CO_2 in ppm. High sensitivity, stability, wide detection range, simple circuit, digital and analogue outputs, compatibility with Arduino UNO. Figure 2.1 shows the pictorial representation of MG811-CO_2 sensor. Specification of CO2 sensor is represented in table 1.

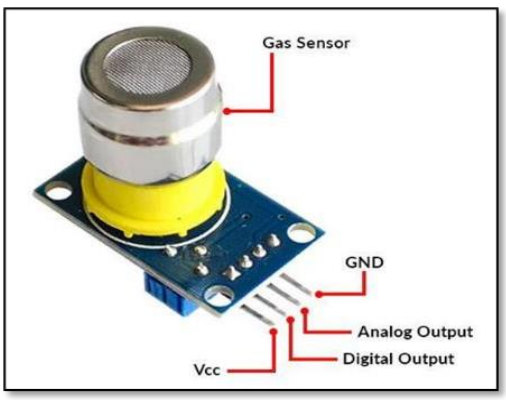

Figure 1: Pictorial representation of MG811-CO_2 Sensor

Figure 2.1 shows the pictorial representation of MG811-CO_2 sensor. Specification of CO_2 sensor is represented in table 1.

Table 1: Specifications of MG811-CO_2 Sensor

Sensor Type	Gas Sensor
Chip	MG811
Gas Sensitivity	Carbon Dioxide
Operating Voltage	6 Volt
Dimensions	3.2 X 2.2 X 2.9 cm
Weight	10 g

2.1 EXPERIMENTAL METHOD

The methodology implemented in the study is in two phases, i.e., Primary phase and Secondary phase. The primary phase comprised of selection of algal strains followed by algae cultivation and observation. On the other hand, design of experimental setup was in progress.

Following the completion of primary phase, the secondary phase of the project was initiated. As shown in figure 2, the phase consisted of selection of algal strains conducting the experiment, monitoring and collecting data and analyzing the results.

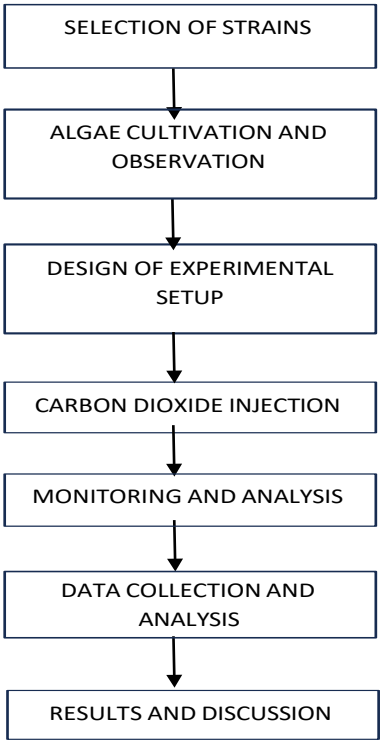

Figure 2: Flowsheet of methodology adopted for the project

2.2 Selection of Microalgal Strains

To identify suitable microalgal species for CO_2 bio-sequestration, an extensive literature review was conducted. The primary factors considered included strain availability, growth rate, cultivation conditions, lipid content, and tolerance to flue gas and extreme environmental conditions. Based on these criteria, Spirulina was selected. Additionally, a mixed culture approach was adopted by collecting algal samples from a local water body and cultivating them under laboratory conditions. This mixed culture contained various species of microalgae.

2.2.1 Spirulina

Spirulina (fig-3), a blue-green alga of the cyanobacteria class, is characterized by its spiral-shaped, multicellular filaments. Renowned for its high nutritional value, Spirulina contains significant levels of proteins, vitamins, minerals, and fatty acids. It is a photosynthetic organism that converts carbon dioxide and water into organic compounds in the presence of sunlight, and can tolerate temperatures of 35-38 C. Spirulina has a lifespan of approximately eight days and a doubling time of 2-3 hours

Fig: 3 a) Pictorial representation of Spirulina Algae

Fig : 3 b) Spirulina Algae under microscope

2.2.2 Mixed Culture

The project also utilized a mixed culture(fig-4) of various algal species, which included both unicellular and multicellular organisms. Cultivated in aquarium conditions at temperatures of 30-40ºC, the mixed culture had a lifespan of up to ten days and contained numerous algal species.

Plate 3.2 illustrates the mixed culture used in the project, which included species such as Oscillatoria, Diatoms, Chlorella, Euglena, Eudorina, Cynadommus quadriquada, Zygnema, Phacus, Anabaena, and Microcyst. º

Fig 4: Picture of Mixed Culture

2.3 Algae Cultivation and Observation

Cultivating algal species requires algal strains, sterilized water, nutrients, and sunlight, as illustrated in Figure 5. The strains used were Spirulina and mixed culture, with urea serving as the nutrient medium. After full growth, continuous aeration was provided to maintain the live culture. Bubbling air through the water, therefore algae get enough oxygen and don't settle at the bottom. The aeration helps to keep the nutrients and light evenly distributed throughout the culture, ensuring that all the algae can continue to thrive.

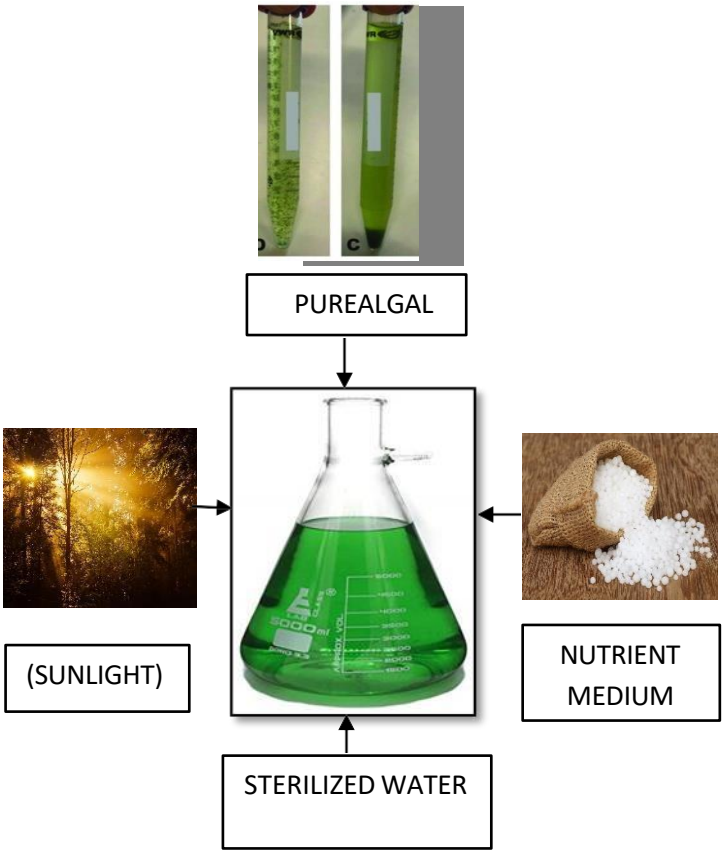

Figure 5: Flowsheet representing requirements for culture of algae

2.4 Design of Experimental Setup

The overall design (Fig-8) includes an inlet chamber, an outlet chamber, and the algal culture medium, all of which are placed on an acrylic sheet for stability. The inlet chamber (fig-6) is equipped with an air pump, flow regulator, Arduino UNO board, MG811 CO_2 sensor , DHT11 Temperature and Humidity sensor, LCD display, and connecting wires. These components are enclosed with a white sun-board to prevent external environmental interference, The outlet chamber (fig-7) contains an Arduino UNO board, MG811 CO_2 sensor, DHT11 Temperature and Humidity sensor, and LCD display, all enclosed with a sun-board to avoid external contact and the Algal culture medium consists of a 1-liter cylindrical container with a cap that has openings for the inlet and outlet. Tubes connect the inlet and outlet holes to the air pump in the inlet chamber and the air trapping colony in the outlet chamber, respectively.

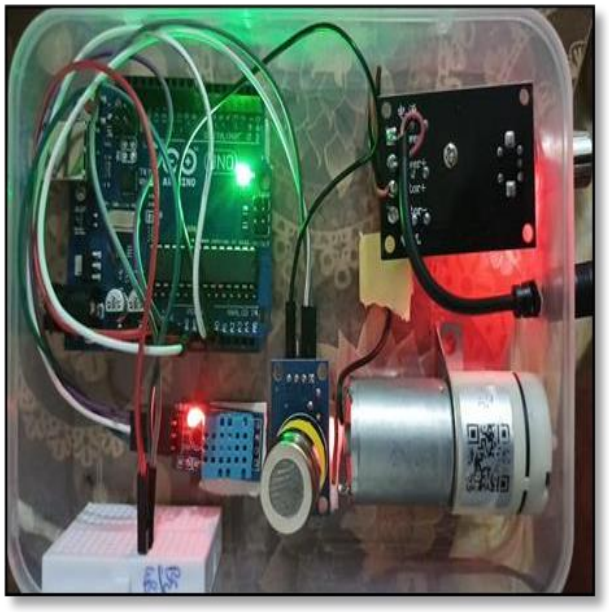

Fig 6 : The design inlet chamber

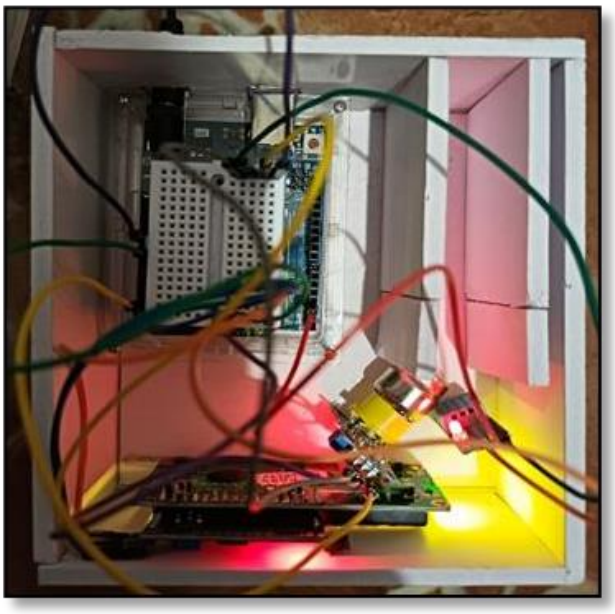

Fig 7 : The design outlet chamber

Fig 8 : Pictorial representation of experimental setup

2.5 Carbon Dioxide Injection

The secondary phase of the project involves conducting the carbon dioxide injection experiment. The 1-liter culture medium is filled with 800 ml of algal sample. Air containing CO_2 is pumped into the chamber, allowing the algae to absorb CO_2 for photosynthesis and release excess gas through a pipe to the outlet chamber. The temperature, humidity, and CO_2 levels transferred into and out of the culture medium are monitored by the DHT11 sensor and MG811 sensor, respectively. The operational conditions for the carbon dioxide injection experiment are summarized in Table 2.

The table 2 outlines the different parameters considered for the experimental run for both Spirulina and mixed culture algae. The parameters include environmental conditions (indoor and outdoor), flow rate (low and high), nutrient medium (urea), experimental duration (3 hours), and volume of culture (800 ml).

Environment	Indoor/Outdoor	Indoor/Outdoor
Parameters	Spirulina	Mixed Culture
Flow rate	Low/High	Low/High
Nutrient Media	Urea	Urea
Experimental duration	3 hours	3 hours
Volume of algal Culture	800ml	800ml

Table 2: Operational conditions for Carbon dioxide injection

2.6 Monitoring and Analysis

The experiment was conducted for 3 hours under indoor and outdoor conditions with low and high flow rates, using 800 ml samples. During each 3-hour experimental run, continuous monitoring of CO_2 levels entering and exiting the chamber was performed. Real-time data was displayed on LCD screens every 2 seconds, showing temperature (in degrees Celsius), humidity (in percentage), and CO_2 concentration (in parts per million). Readings were recorded every 5 minutes for both the inlet and outlet, resulting in 36 readings over the 3-hour period. The collected data was then analyzed to derive the results

3. RESULTS AND DISCUSSION

From the above experiment the algae reduction efficiency of different algae at different at different operation conditions like Outdoor/Indoor, Minimum/Maximum CO_2 injection (Air flow rate). Among the different algae and at different operating conditions the mixed culture alga performed well by achieving the CO_2 reduction efficiency of 23.36 % at indoor environment and at minimum air flow rate this mixed culture algae achieved the 34.36 % as shown in figure 9. This is because of the mixed culture consists of multiple algae. Among them the diatom algae were the major one for the efficiency of CO_2 reduction the diatom algae are the comes under Protista kingdom, the diatom algae generate about 20 to 50 percent of the oxygen produced on the planet each year. After the mixed culture the Spirulina algae achieved the maximum CO_2 reduction efficiency of 13.93 % at Outdoor at maximum air flow rate. The suitable temperature 26°to 37°.

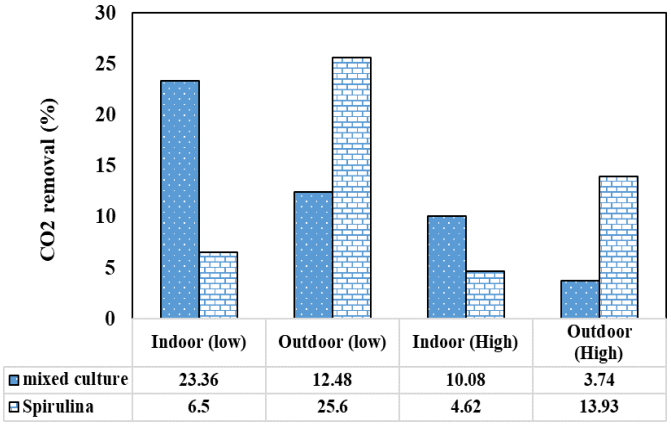

Fig 9: Removal Efficiency of Microalgae

4. CONCLUSION

Biological carbon sequestration is crucial for mitigating climate change, and among the two algal cultures selected for CO_2 sequestration, the mixed culture demonstrated a CO_2 removal efficiency of 23.36% under indoor conditions with a low air flow rate. This removal rate remained steady

throughout the 180-minute experimental run. In comparison, the Spirulina algae culture achieved a removal efficiency of 25.61% under outdoor conditions at temperatures around 34°C to 36°C. The optimal temperature range for Spirulina, between 30°C and 35°C, supports high biomass production with significant protein content. It was observed that high air flow rates do not favor proper CO_2 sequestration for either algal culture; therefore, a steady and low air flow rate is recommended for maximum CO_2 capture. Algae can effectively sequester CO_2, producing biomass that can be converted into biofuel. The energy requirement for carbon sequestration using micro-organisms like algae is minimal, and utilizing solar energy for this process makes it fully eco-friendly. The application of microalgae for CO_2 sequestration not only reduces atmospheric carbon but also contributes to mitigating global warming trends. This method is considered economical and eco-friendly, particularly when implemented at point sources.

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