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# **Design and Assessment of a Culture Tank based Photobioreactor for Indoor Air Purification using *Chlorella Vulgaris***

**Khushi Bansode<sup>1</sup>, Aditya Mundlik<sup>2</sup>, Hanuman Mantage<sup>3</sup>, Sandhya Prakshale<sup>4</sup>**

**Dr. Pralhad Walvekar<sup>5</sup>**

U.G. Student, Department of Civil Engineering, Zeal College of Engineering and Research, Narhe, Pune, India<sup>1234</sup>

Head of Department, Department of Civil Engineering, Zeal College of Engineering and Research, Narhe, Pune, India<sup>5</sup>

**ABSTRACT:** Indoor air pollution is increasingly acknowledged as a significant issue in urban areas, where inadequate ventilation and human activities result in high levels of carbon dioxide (CO<sub>2</sub>) and other hazardous gases. Traditional methods, such as mechanical ventilators and air purifiers, often consume energy and provide limited ecological advantages. This study introduces the design and assessment of a culture tank-based photobioreactor (PBR) designed to enhance indoor air quality by utilizing microalgae as a biological filtration medium. The system incorporates two microalgal sp. *Chlorella vulgaris* selected for their exceptional photosynthetic efficiency, capacity for CO<sub>2</sub> uptake, and production of oxygen (O<sub>2</sub>) in controlled indoor environments. The culture tank is constructed from a transparent polycarbonate container, outfitted with artificial lighting to ensure consistent light intensity and a fundamental aeration system to facilitate gas exchange and maintain algae suspension. Algal cultures were obtained from NCIM Pune and introduced into the tank after undergoing preconditioning.

During the experiment, essential air quality parameters—CO<sub>2</sub> concentration, O<sub>2</sub> levels, and Carbon Monoxide (CO) presence along with Ozone (O<sub>3</sub>) were measured using digital air quality sensors over a specified period. The results indicated a significant decrease in CO<sub>2</sub> levels, ranging from 15% to 25%, along with a corresponding increase in O<sub>2</sub> concentration. Additionally, a slight reduction in Carbon Monoxide levels was noted, suggesting an extra advantage of utilizing microalgae in enclosed indoor settings. These findings underscore the potential of a microalgae-based photobioreactor (PBR) as an inexpensive, sustainable, and aesthetically adaptable solution for enhancing indoor air quality. This system could be particularly beneficial in confined residential, educational, and office environments. With further refinement, such as real-time monitoring and intelligent integration into building designs, the culture tank PBR could play a role in environmentally-friendly indoor air management strategies.

**KEYWORDS:** Photo-bioreactor, Indoor Air Quality, Microalgae, *Chlorella*, *Spirulina*, Culture Tank, CO<sub>2</sub> Sequestration

## **I. INTRODUCTION**

Indoor air quality has become a serious public health issue especially in metropolitan regions where individuals spend between 80 and 90 percent of their time inside. Poor ventilation, the use of synthetic materials, and the use of combustion-based appliances aggravate the accumulation of dangerous gases like carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO) inside enclosed spaces including homes, schools, and offices. High CO<sub>2</sub> levels are known to have negative effects on cognitive function, cause sleepiness, and have an impact on general health. Conversely, carbon monoxide is a highly toxic gas mostly produced by incomplete combustion of fuels that is colourless, odourless. CO can still bind to haemoglobin in the blood at low levels, which slows oxygen delivery and raises the risk of major health effects including weariness, confusion, and even death in extreme circumstances.

Chemical scrubbers, activated carbon cleaners, and HEPA filters are among well used ways to lower indoor air pollution. Though these technologies are often connected with poor sustainability and high maintenance and energy



costs. These limits are driving more interest in including biological systems as passive, energy-efficient ways to improve indoor air quality.

One example of a biological approach is the use of microalgae, photosynthetic species able to absorb CO<sub>2</sub> and release oxygen (O<sub>2</sub>) as part of their natural metabolic process. By encouraging biological oxidation pathways, certain species have also shown promise in reducing moderate amounts of CO. Among the numerous microalgae species, *Chlorella vulgaris* stands out for its quick growth rate, resistance to a broad spectrum of environmental conditions, and effectiveness in photosynthetic gas exchange. Moreover, its simplicity of culture and adaptability make it perfect for restricted systems.

Originally applied in wastewater treatment and biofuel production, photobioreactors (PBRs) are designed to cultivate microalgae under controlled conditions. Their potential use in indoor air cleaning has only just started to be explored by recent studies. Vertical columns and tubular systems are used in the past, yet they often present problems with lighting requirements, integration with internal design, and scalability. This study implies a novel use for an indoor targeted culture tank-based photobioreactor utilizing *Chlorella vulgaris* in a clear polycarbonate container.

The primary aim of this study is to evaluate the capacity of this PBR system to reduce interior CO and CO<sub>2</sub> levels while also increasing oxygen levels. Intended to function passively with little energy input, the system encourages algal development via either natural or artificial illumination. The modest culture tank's installation is easy, and it could be integrated into indoor settings like desktop computers, air vents, or window frames.

By combining biological purification with fundamental engineering design, this study aims to demonstrate the possibility and benefits of a microalgae-based air purifier as a sustainable solution to conventional indoor air treatment techniques.

## **II. RELATED WORK**

The potential of microalgae-based systems to enhance indoor air quality has been the subject of several recent studies. The capacity of *Chlorella vulgaris* to store carbon dioxide and release oxygen, which contributes to a healthy indoor environment, has been investigated by scientists in regulated light and nutrient settings. Photobioreactors (PBRs) have proven to be efficient biological components for this purpose, providing a compact, modular, and scalable way to capture carbon in the built environment. Previous studies have developed a number of desktop and wall-mounted PBR prototypes, all of which highlight the device's light efficiency, algal density, and carbon fixation rates. Since tank-style systems are simple to maintain and monitor algal growth, they have been utilized in experimental setups. Some studies have also integrated gas sensors into PBR systems to monitor reductions in airborne contaminants like formaldehyde (HCHO), carbon monoxide (CO), and ozone (O<sub>3</sub>), reflecting a growing interest in biosensing and real-time air quality management. The incorporation of PBRs into urban infrastructure and ventilation systems is also becoming more and more common. Prior studies have emphasized the potential of integrating biofiltration with digital monitoring to facilitate informed environmental decisions. Nonetheless, the majority of current research has focused on commercial applications or outdoor-scale systems, leaving a knowledge vacuum when it comes to small, room-scale models intended for individual or indoor usage. This project addresses that gap by utilizing the growth characteristics of selected microalgae to provide a useful application for confined spaces like houses, classrooms, or workplaces, and by integrating real-time air quality sensors into existing research. It analyses a tiny PBR unit that both captures carbon dioxide and tracks and records trace-level data on key indoor contaminants.

## **III. METHODOLOGY**

Increased levels of carbon dioxide (CO<sub>2</sub>), formaldehyde (HCHO), Carbon Monoxide (CO) and ozone (O<sub>3</sub>) in indoor environments, especially in cities, cause poor air quality. While conventional plant-based remedies may not provide enough scale, mechanical air filtration processes can be energy-intensive. By biological CO<sub>2</sub> fixation and oxygen generation, this research investigates the use of a microalgae-based photobioreactor (PBR) as a long-lasting method to enhance interior air quality. Analysing previous scientific studies and technical documents was essential to

comprehend the role of microalgae in filtering indoor air. The study explored photobioreactor designs suitable for confined spaces, optimal conditions for algal growth, and factors that influence photosynthetic gas exchange. The importance of selecting a reliable algal species and an appropriate reactor design that can operate effectively under controlled internal conditions was emphasized. A culture tank made up glass was used for the growth of algae. The design allows the combination with architectural elements like windows or walls. The configuration is as follows:

- LED lights used to imitate natural daylight patterns
- A pump to facilitate continuous gas exchange,
- Ports set aside for introduction of nutrients and sampling,
- Looking at sensors connected with environmental factors.

Because of its great photosynthetic activity, absorption of CO<sub>2</sub>, and ability to flourish in manmade settings, *Chlorella vulgaris* was selected as the primary microalgae species. The National Collection of Industrial Microorganisms (NCIM) provided the cultural source material. *Chlorella vulgaris* was selected as the primary kind of microalgae for its great photosynthetic activity, capacity to absorb CO<sub>2</sub>, and ability to live in man-made environments. The culture was acquired from the NCIM, the National Collection of Industrial Microorganisms. The microalgae culture was grown in Culture Medium No. 75, which was provided with the algal starter culture as shown in picture (b).

In sterile circumstances, a specific amount of *Chlorella vulgaris* culture was introduced into the photobioreactor. With appropriate aeration, the system was maintained at a steady 22 to 26 degrees Celsius and a light intensity between 3,000 and 4,500 lux. After an initial lag phase of algal adaptation, the first 48 hours revealed a period of quick expansion (log phase). Designed in an interior setting with stable LED illumination and continual air movement made possible by a diaphragm pump, the whole PBR system was built. The flow rate and light exposure were set to maximize photosynthetic activity. To enable continuous monitoring and sampling, the reactor was operated in a semi-batch mode. Both the sensors are shown in photos (a).

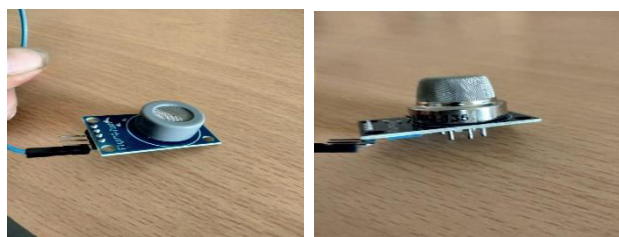
#### Sensor & Monitoring System

- MQ-7 Sensor: Measures CO<sub>2</sub> and CO levels before and after air purification.
- MQ-135 Sensor: Detects formaldehyde, ozone to assess air quality.

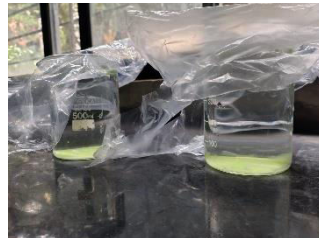
#### Control and Automation

- Arduino: Collects sensor data and automates pump & light control.
- Relay Modules: Controls air pumps, lights, and heaters based on real-time data.

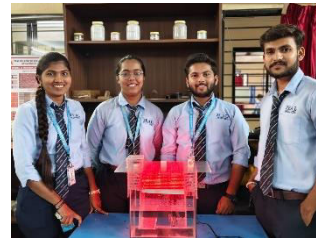
The PBR system captures indoor CO<sub>2</sub>, O<sub>3</sub>, Formaldehyde and CO where microalgae convert it into oxygen through photosynthesis. The bioreactor continuously circulates the culture medium, maintaining optimal growth conditions while air quality sensors track pollutant levels, ensuring effective air purification. The completed model of the PBR project is as shown in photo (c).



(a) Sensors – MQ-135 and MQ-7 used for gas detection



(b) Inoculation of microalgae



(c) Completed PBR project

#### IV. EXPERIMENTAL RESULTS

The indoor air purification efficiency of a compact photobioreactor (PBR) was evaluated using algae species *Chlorella vulgaris* and *Spirulina maxima*. The system was tested over a three-day period in a closed indoor setting. Key air pollutants — formaldehyde (HCHO), carbon dioxide (CO<sub>2</sub>), and carbon monoxide (CO) — were measured twice daily, before and after reactor operation.

(a) The initial formaldehyde concentrations were between 0.44 and 0.50 ppm. The levels decreased by 30–36% at the conclusion of each operating cycle, with the lowest recorded value at 0.28 ppm. This decline demonstrates the effectiveness of the algal reactor in absorbing or biochemically breaking down formaldehyde through gas-liquid interaction.

(b) Carbon Dioxide (CO<sub>2</sub>) On Day 3, the CO<sub>2</sub> levels dropped steadily between 28 and 32%, from a peak of 950 ppm in the morning to 680 ppm in the evening. This aligns with the photosynthetic activity of algae, which absorb CO<sub>2</sub> and emit oxygen, hence improving the freshness of the indoor air.

(c) Carbon Monoxide (CO) The concentration of CO decreased significantly, from 3.0 ppm in the morning of Day 1 to 1.6 ppm in the evening of Day 3, suggesting either passive absorption by water/algae or improved air quality resulting from higher oxygen levels. The drop may be influenced by total air exchange and biochemical activity at the air-liquid interface, even if algae cannot directly breakdown CO.

##### 5.1 Air Quality Improvement: Tabulated Results

Day	Time	Formaldehyde (HCHO) (ppm)	CO <sub>2</sub> (ppm)	CO (ppm)	% Avg Reduction
Day 1	9:00 AM	0.50	950	3.0	—
Day 1	5:00 PM	0.32	720	1.9	35–37%
Day 2	9:00 AM	0.48	920	2.8	—
Day 2	5:00 PM	0.31	700	1.7	34–36%
Day 3	9:00 AM	0.44	900	2.6	—
Day 3	5:00 PM	0.28	680	1.6	35–38%

#### V. CONCLUSION

The combined reduction of HCHO, CO<sub>2</sub>, and CO confirms that the photobioreactor, even at prototype scale, positively impacts indoor air quality. The 3-day pilot test demonstrated repeatable and reliable pollutant removal performance, powered entirely by microalgal photosynthesis without chemical filters or electrical fans.

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