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To Study the biological carbon sequestration using BHOPAL lakes microalgae

Deeksha vijayvargiya
Department: Botany

Abstract- Microalgae represent efficient photosynthetic microorganisms with the potential to serve as natural air purifiers by generating oxygen and reducing CO2 levels. Microalgae can play an important role in reducing carbon dioxide (CO_2) levels in cities. They grow fast, use sunlight, and absorb CO_2 during photosynthesis. When used in small urban spaces—like near traffic signals, on building walls, and in decorative fountains—microalgae can clean the air and improve the environment. This paper explains how microalgae can be used in such city setups, their advantages, and their challenges. It also discusses real and possible examples of building façades, fountains, and traffic junctions using algae-based systems to trap CO_2 and create cleaner air.

Keywords: Microalgae, Urban carbon capture, Traffic signals, Fountain.

I. INTRODUCTION

The increasing concentration of atmospheric CO_2 is a critical driver of global climate change. Photosynthetic organisms such as plants and microalgae represent the primary biological sink for CO_2, converting it into organic compounds. However, the rate of CO_2 assimilation is limited by several biochemical and genetic factors. the spent/flue gas is subjected to biological carbon capturing and sequestration involving micro-algae, it could be a cost-effective way of converting a potent GHG into a biomass. The efficiency of capture and sequestration of CO2 by microalgae ranges from 40% and 93% But its potential at large scale is yet to be harnessed at large scale. The proposed research attempts to the study biological carbon sequestration by micro algae under elevated concentration of CO2. Microalgae are microscopic, photosynthetic organisms found worldwide in water and soil. Microalgae may have different type of cell organization: unicellular, colonial and filamentous. Microalgae may be prokaryotic (no nucleus) or eukaryotic (with nucleus and other organelles). Cities produce a large amount of carbon dioxide due to vehicles, factories, and buildings. This adds to air pollution and global warming. Biological carbon sequestration is a natural process where plants and microorganisms absorb CO_2 and convert it into oxygen and biomass. Rapid urbanization has led to escalating carbon emissions predominantly from buildings, transportation, and industrial activities, causing severe environmental impacts. Traditional carbon capture technologies face limitations in scale and cost-effectiveness. Microalgae, through their highly efficient photosynthetic mechanisms and rapid growth rates, have emerged as a viable biological solution for CO2 sequestration.

Their capacity to convert carbon dioxide into biomass while requiring limited land area makes them particularly suitable for urban applications. These systems not only reduce indoor and outdoor CO2 concentrations but also contribute to urban greening. Research demonstrates that microalgal building enclosures can yield significant daily biomass productivity, indicating their real-world viability for carbon removal. Additionally, microalgae can be employed in wastewater treatment, thus addressing pollution while fostering a circular urban ecosystem.Among these, microalgae are one of the best options. They can grow in water, don't need soil, and can live in small systems like glass tubes or tanks. They can be used even in crowded urban areas. Therefore, it has a great potential for CO2 capturing and utilization directly from the air. On the other hand, microalgae have a higher rate of photosynthesis efficiency than other plants, lower

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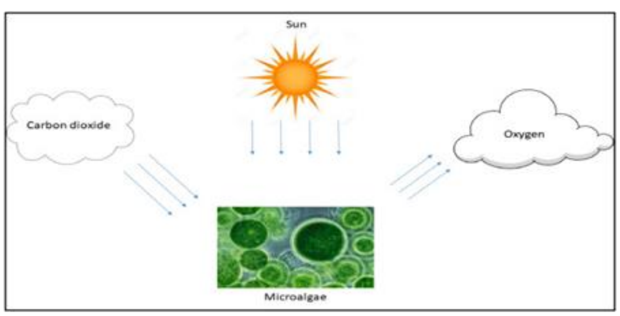
water consumption, and the ability to capture CO2 at low concentrations.

• **Carbon sequestration: Carbon sequestration** is the process of capturing and storing atmospheric carbon dioxide to mitigate global warming, reducing the ~45% of human-emitted that remains in the atmosphere. It involves natural sinks (forests, soil, oceans) and artificial technologies (direct air capture, geological storage) to stabilize climate change.

II. BIO-CAPTURE OF CARBON BY MICROALGAE:

Microalgae uses photosynthetic process to capture solar energy and store it in the form of chemical fuels (Mussgnug et al., 2007] shows that based on the mechanism of photosynthesis, microalgae utilise water from the environment, light energy gotten from the sun and carbon dioxide from the atmosphere as a carbon source to produce oxygen and energy which is stored in the form of starch and fatty acids inside the cell. As a result, both atmospheric and industrial CO2 can be captured and converted biomass and bioenergy using microalgae ponds. The key factors influencing microalgal photosynthetic efficiency and CO2 assimilation include heat, light, and mass transfer of CO2 and nutrients (Daneshvar et al., 2021). Others are the properties of flue gas such as CO2 concentration, temperature and toxic compounds.



III. KEY MECHANISMS AND PATHWAYS:

Photosynthetic CO2 fixation: microalgae convert CO2 into organic biomass using light energy, offering rapid uptake per unit area compared to many terrestrial plants. Microalgae capture CO2 from the environment through photosynthesis, where CO2 and water are converted into biomass and oxygen using sunlight energy.

Biomass valorization: captured carbon becomes biomass that can be processed into biofertilizers, bioenergy, or feedstocks for materials, enabling a circular economy around the sequestration effort.

Industrial and wastewater integration: microalgae can utilize CO2-rich flue gases and nutrients from wastewater streams, combining emissions reduction with pollutant removal and resource recovery.

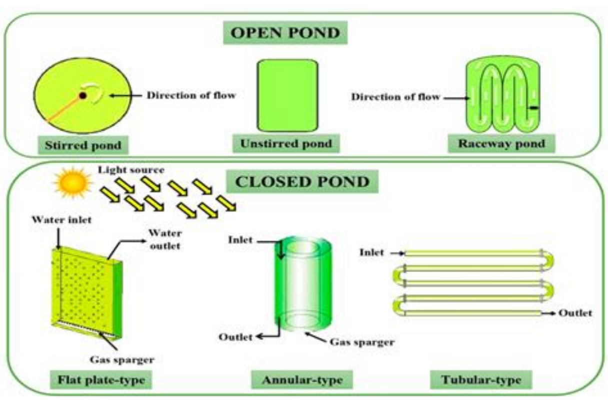
Urban and public-space applications: modular bioreactors, façade panels, fountains, and water features can operate in cities, providing visible demonstrations of carbon capture while delivering co-benefits such as greening and public engagement. Microalgae can fix CO2 at rates 10–50 times greater than terrestrial plants due to faster growth rates and higher photosynthetic efficiencies. Growth rates and carbon fixation depend on factors like light intensity, nutrient availability, temperature, and CO2 concentration.

IV. CULTIVATION SYSTEMS FOR MICROALGAE: OPEN SYSTEM AND CLOSED SYSTEM:

This involves a combination of an open system and a closed photobioreactor for the cultivation of large quantities of microalgae under better growing conditions for effective biomass production and resource recovery (Bora et al., 2024 Thereafter, the turbid microalgal culture is moved to an open system for mass production of biomass. This approach is practiced to mitigate the challenges of open and closed systems.

Open systems: The open systems, also known as outdoor facilities, include lagoons, lakes, artificial commercial tanks, raceway ponds, and circular ponds. The microalgae are cultivated open to the atmosphere under uncontrolled growth conditions. These conventional open microalgae cultivation systems are simple, cheap, and easy to operate and maintain (Sarwer et al., 2022; Udaypal et al., 2024). It is the most commonly employed technique for microalgae cultivation, contributing to 95 % of the world's microalgae biomass production (Mehariya et al., 2021). However, open systems are characterized by low CO2 fixation capacity owing to high evaporation losses, biological contamination, poor mixing, inadequate light utilization, poor mass transfer efficiency, and limited diffusion of atmospheric CO2. Other limitations include low biomass productivity due to variations in environmental conditions and oxygen build-up, leading to inhibition of algal growth.

Closed system: the closed systems, also known as photobioreactors, are illuminated vessels consisting of transparent materials under light exposure and are employed for mass cultivation of microorganisms (e.g., microalgae) for the production of biomass (Razzak et al., 2013; Chanquia et al., 2022; Manu et al., 2024). In comparison to open systems, photobioreactors maintain the sterility of the culture medium, improve gas transfer, attain high biomass productivity, reduce biological contamination, ensure precise control of bioprocess conditions, and prevent evaporation loss.



V. THIS PAPER LOOKS AT HOW MICROALGAE CAN BE USED IN DIFFERENT URBAN AREAS SUCH AS:

Traffic signals and roadside installations: Microalgae-based photobioreactors or tanks can be installed on or near traffic signal poles, bus stops, and roadside structures to capture carbon dioxide from vehicle emissions at congested intersections. These systems are designed as compact, vertical units that require minimal ground space and can be solar-powered, seamlessly integrating into existing urban infrastructure. Photobioreactors or microalgae tanks at high-pollution locations like intersections can directly absorb exhaust CO_2, with pilot studies reporting up to 1 kg CO_2 removed per day per unit.

Public fountains and decorative water bodies: Urban fountains and artificial ponds present ideal locations for cultivating beneficial strains of microalgae due to the availability of light and circulating water. Algae can be cultured in decorative ponds and fountains, using natural sunlight and circulating water to absorb nearby CO_2 while simultaneously purifying urban water sources.

How Microalgae Capture CO_2:

- Microalgae use photosynthesis, which means they take in carbon dioxide (CO_2) and sunlight to produce oxygen and biomass.
- For every 1 kg of microalgae biomass, about 1.8 kg of CO_2 is absorbed.
- They can grow faster than trees and use much less space.
- Benefits of Using Microalgae in Cities
- Carbon Capture: Helps lower CO_2 and improve air quality.
- Oxygen Release: Adds oxygen to polluted urban air.
- Wastewater Cleaning: Removes nutrients and heavy metals.
- Aesthetic Value: Green façades and fountains make cities look more natural.
- Educational Value: People can see biological systems working in real life.

VI. ENVIRONMENTAL AND ECONOMIC BENEFITS:

Microalgae-based carbon sequestration offers multiple co-benefits including reducing urban heat, improving air quality, and producing renewable biomass for bioenergy and biofertilizers.

Economically, integrating microalgae systems in urban planning supports sustainable development and could enable cities to achieve net-zero carbon goals more efficiently. The biomass generated from CO2 capture can create revenue streams, offsetting operational costs and supporting local bioeconomy. species found different lakes of Bhopal:

Upper Lake (The Clean Lake): Has very little "food" (nutrients like Nitrogen). The algae here are like efficient scouts; they have evolved to catch every tiny bit of CO_2 even when it's hard to find. Very clean and clear. The algae here are like "marathon runners"—they are very efficient even though there isn't much "food" (nutrients) around.

Species found in upper lake are: microcystis sp., Anabaena, Nostoc, Ocillatoria, Lyngbya, Spirogyra, Volvox, Chlorella, Scenedesmus, Pediastrium, Closterium, Ulothrix, Navicula, Synedra, Cyclotella, Cymbella, Melosira, Fragilaria Euglena acus, Phacus, Trachelomonas {Sangma, A. C. A., Yadav, M. K., Saxena, S., & Kher, D. (2025).

Pani, S., & Misra, S. M. (2000). Eutrophication in Upper and Lower Lakes of Bhopal.

Lower Lake (The Middle Ground): Has some sewage. The algae here are balanced. A bit dirty from city drains. The algae here are "average eaters."

Species found in lower lake are: microcystis aeruginosa {dominant}, Anabaena, Merismopedia, Oscillatoria, Scenedesmus sp., Ankistrodesmus, Chlorella, Crucigenia, Actinastrum, Cyclotella, Melosira, Navicula, Nitzschia, Pinnularia, Euglena oxyuris, Euglena virids, Phacus.

{Beigh, B., Wanganeo, A., Pandit, A., & Wanganeo, R. (2020).

Pani, S., & Misra, S. M. (2000). Eutrophication in Upper and Lower Lakes of Bhopal.

Shahpura Lake (The Heavy Eater): This lake is full of "food" (sewage and waste). Because there is so much nutrition, the algae grow like wildfire. This lake usually has the highest "Carbon Sequestration" because it creates the most "green weight" (biomasper day. Very polluted with sewage and chemicals. The algae here are "competitive eaters"—they grow incredibly fast because there is so much "food" (waste) for them to eat.

Species found in shahapura lake are: microcystis aeruginosa {heavy bloom}, Anabena, Arthrospira, Phormidium, Nostoc, Scenedesmus obliquus, Chlorella vulgaris, Pediastrum, Spirogyra, Chlorococcum, Volvox, Euglena sp., {often found in high organic waste areas}

{Agrawal, B. (2016). Seasonal variations of physico-chemical factors and diversity of desmids (Algae) in Shahpura lake of Bhopal, India. Environment Conservation Journal, 17(1&2), 67–72. https://doi.org/10.36953/ECJ.2016.171208}

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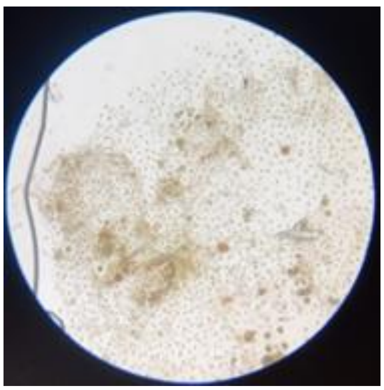
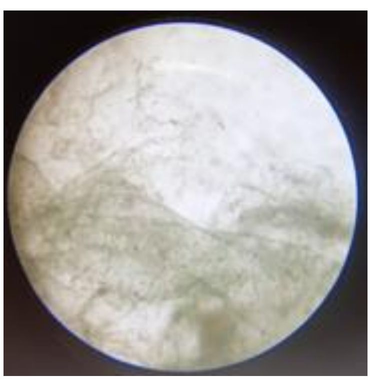
VII. MICRO ALGAE UNDER MICROSCOPE:





VIII. CONCLUSION:

- Microalgae offer a smart, biological solution for capturing carbon dioxide in cities. By using spaces like traffic signals, fountains, rooftops, and wastewater plants, we can turn polluted areas into small "green lungs."

Although the technology still faces cost and maintenance issues, with the right planning and support, cities can use algae-based systems to move toward a cleaner and more sustainable future. Microalgae present a promising and practical route for biological carbon sequestration in urban environments. Their rapid photosynthetic rates, adaptability to integrated urban systems, and production of value-added biomass position them as key players in combating urban carbon emissions. Strategic deployment of microalgae cultivation technologies, supported by ongoing research innovations, could transform urban carbon management and contribute significantly to global climate change mitigation efforts.

- Microalgae's high efficiency in CO2 uptake, combined with versatile cultivation methods and biomass valorization opportunities, position them as a versatile biological tool for carbon sequestration. Their carbon fixation mechanics hinge on photosynthesis, intracellular carbon concentration, and effective utilization of inorganic carbon pools, enabling urban and industrial applications to mitigate greenhouse gas emissions effectively.
- By leveraging traffic signals, roadside sites, fountains, and decorative water bodies, cities can create networks of small but powerful "green lungs," positioning microalgae as a visible, sustainable, and multi-functional solution for urban carbon management and environmental enhancement.

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