Innovative Liquid Tree System for Enhanced Indoor Air Quality: A Sustainable Design Approach

Mutiara Ayu Larasati*
Institut Teknologi Bandung,
Kota Bandung, Jawa Barat
Indonesia
Corresponding author
Email: *mayularasati@itb.ac.id*

Rindia Maharani Putri*
Institut Teknologi Bandung,
Kota Bandung, Jawa Barat
Indonesia
Email: *rindia.m.putri@itb.ac.id*

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*****These authors contributed equally to this study*

ABSTRACT

In pursuing innovative and sustainable interior design solutions, our research introduces the concept of a "liquid tree" as an alternative to traditional vegetation implementation in an interior room. This study explores developing and implementing a liquid tree system to enhance indoor air quality by capturing carbon dioxide (CO2) and producing oxygen (O2). The liquid tree integrates a water flow system and advanced sensors to monitor and optimize CO2 absorption and O2 production capacities. The system consists of a transparent container filled with a specially formulated liquid that supports the growth of microalgae, known for their high photosynthetic efficiency. The container is also equipped with a water flow system to ensure constant motion and optimal conditions for the microalgae. Additionally, sensors continuously monitor CO2 and O2 levels. Our findings demonstrate the liquid tree's potential to significantly improve indoor air quality, offering a viable and aesthetically pleasing solution for modern interior environments. The implications of this research suggest a promising avenue for sustainable design practices that contribute to healthier living spaces. Future studies will focus on optimizing the system and exploring its applications in various settings.

Keywords: *Indoor Air Quality, Interior, Liquid Tree, Sustainable Design*

INTRODUCTION

The integration of plants into interior spaces has long been a favored practice in interior design. This approach is rooted in the belief that incorporating natural elements indoors can intuitively blur the boundaries between indoor and outdoor environments. Such integration is not only aesthetically pleasing but also aligns with the principles of biophilic design, which has gained popularity due to increasing

sustainability concerns. Biophilic design emphasizes the connection between humans and nature, promoting well-being and environmental responsibility through thoughtful design practices.

In recent years, the field of interior design has increasingly recognized its significant impact on environmental sustainability. As a result, there has been a growing emphasis on incorporating sustainable practices and elements into design projects. One such practice is the placement of plants within indoor spaces. This approach is believed to offer numerous benefits, both for the environment and for the occupants of the space. Plants are known to improve indoor air quality by converting carbon dioxide (CO2) into oxygen (O2) through the process of photosynthesis. This natural air purification process can contribute to a healthier indoor environment, reducing the concentration of pollutants and enhancing overall air quality.

Moreover, the presence of plants in interior spaces has been associated with various psychological and physiological benefits. Research has shown that exposure to natural elements, such as plants, can reduce stress, improve mood, and enhance cognitive function. The visual appeal of plants also plays a crucial role in creating aesthetically pleasing and inviting spaces. The incorporation of greenery can add texture, color, and a sense of tranquility to interior environments, making them more enjoyable and comfortable for occupants.

In conclusion, the integration of plants into interior design is a multifaceted approach that offers both environmental and human benefits. By bringing elements of nature indoors, designers can create spaces that are not only visually appealing but also promote health and well-being. As sustainability continues to be a driving force in design, the use of plants in interior spaces will likely remain a key strategy for achieving environmentally responsible and human-centered design solutions.

The placement of plants within indoor spaces presents challenges, particularly when live plants require special care and, as they grow larger, occupy more space. To address these issues, we sought alternative solutions and discovered that the air-purifying function of plants can also be found in microalgae. Microalgae, even in small quantities, can efficiently convert CO2 into O2. For instance, 100 tons of microalgae can sequester 183 tons of CO2 when cultivated over 8-10 days (Chauvy, et.al., 2019), thereby accelerating the conversion of CO2 to O2. As living organisms, microalgae do not require special maintenance to survive; they only need light and water, and even artificial light can facilitate their rapid growth.

Water, as the growth medium for microalgae, necessitates a container to hold it. This can be addressed by creating an aquarium, which can be integrated with furniture such as cabinets, thus becoming a part of the interior design. The inclusion of a specialized microalgae aquarium as an interior element is expected to provide users with a natural air purifier that is easy to maintain and does not require much space to grow.

LITERATURE REVIEW

Innovative And Sustainable Interior Design With Green Elements And Microalgae

The integration of natural elements into interior design has been extensively studied, driven by the need for sustainable and aesthetically pleasing environments. This literature review explores various studies on the use of green plants and microalgae in interior spaces, highlighting their benefits and applications

In *Algae-Powered Buildings: A Review of an Innovative, Sustainable Approach in the Built Environment*, Sedighi et al. (2023) discusses the potential of algae-powered buildings to enhance energy efficiency and reduce CO2 emissions. The study emphasizes the use of photobioreactors (PBRs) integrated into building façades, which can sequester CO2 and produce biomass, contributing to sustainable urban environments. Sedighi's research highlights the dual benefits of these systems: environmental sustainability and energy production. The integration of PBRs into building designs not only addresses the pressing issue of urban air pollution but also provides a renewable energy source, making it a multifaceted solution for modern cities.

In *Analyzing the Role of Indoor Plants in the Design of Interior Spaces*, Mohammad Arif (2023) examines the psychological and physiological benefits of indoor plants. The study highlights how plants improve air quality, reduce stress, and enhance the aesthetic appeal of interior spaces. Kamal's research underscores the importance of biophilic design, which seeks to connect humans with nature through the incorporation of natural elements into built environments. The presence of plants in indoor spaces has been shown to have a calming effect on occupants, reducing stress levels and improving overall well-being. This aligns with the broader goals of sustainable design, which aims to create environments that are not only environmentally responsible but also conducive to human health and happiness.

In *Application of Green Plant Elements in Office Space,* Wang et al. (2023) explores the use of green plants in modern office environments. The research focuses on the ecological performance of plants, their ease of maintenance, and their ability to create a relaxing and fresh atmosphere. Wang's study highlights the practical benefits of incorporating plants into office spaces, such as improved air quality and increased employee productivity. The presence of greenery in the workplace has been linked to higher levels of job satisfaction and reduced absenteeism, suggesting that plants can play a crucial role in creating healthier and more productive work environments.

In *Application of Green Plants in Interior Design*, Li (2016) provides an in-depth analysis of the current research status and application forms of plant landscapes in interior design. The study emphasizes the role of plants in enhancing the quality of life and creating a vibrant indoor environment. Li's research explores various design strategies for integrating plants into interior spaces, from vertical gardens to potted plants, and examines their impact on indoor air quality and occupant well-being. The study also discusses the challenges associated with maintaining indoor plants, such as the need for adequate lighting and regular watering, and suggests solutions to overcome these obstacles.

In *Biophilic Interior Design: A Case Study on the Relation Between Water Elements and Well-Being of the Users in an Educational Building*, Nevzati (2021) investigates the impact of water elements on the well-being of occupants in educational settings. The study finds that water elements can reduce stress and improve mood, highlighting the importance of biophilic design principles. Nevzati's research demonstrates that the presence of water features, such as fountains and aquariums, can create a soothing and calming environment, which is particularly beneficial in educational settings where students and staff may experience high levels of stress. The study suggests that incorporating water elements into interior design can enhance the overall well-being of occupants and create a more conducive learning environment.

In *Design and Microalgae: Sustainable Systems for Cities* by Peruccio & Vrenna (2019) discusses the integration of microalgae systems in urban environments. The study explores the potential of microalgae to improve air quality, provide renewable energy, and enhance the aesthetic appeal of urban spaces. Peruccio & Vrenna's research highlights the versatility of microalgae systems, which can be integrated into various architectural elements, such as building façades and rooftop gardens. The study also examines the economic feasibility of these systems, suggesting that the initial investment in microalgae technology can be offset by the long-term benefits of improved air quality and energy savings.

In *Effects of Indoor Plants on Self-Reported Perceptions: A Systemic Review* by Han & Ruan (2019) reviews empirical studies on the psychological benefits of indoor plants. The findings indicate that indoor plants can increase positive emotions, reduce negative feelings, and improve overall well-being. Han's review synthesizes the results of multiple studies, providing a comprehensive overview of the psychological benefits of indoor plants. The review highlights the importance of incorporating greenery into interior design to create environments that promote mental health and well-being.

In *Enhancing Indoor Air Quality with Portable Green Living Partition*, Ain Natasha et al. (2023) examines the effectiveness of portable green living partitions in improving indoor air quality. The study highlights the benefits of using green plants to reduce CO2, formaldehyde, and VOC levels in indoor environments. Ain Natasha's research suggests that portable green partitions can be an effective solution for improving air quality in various settings, from offices to residential spaces. The study also discusses the practical considerations of implementing these partitions, such as their placement and maintenance requirements.

In *Liquid Trees: Investigating the Unique Adaptations and Evolutionary Significance*, Patil et al. (2023) explores the concept of liquid trees as a sustainable solution for air pollution mitigation. The study emphasizes the high photosynthetic efficiency of microalgae and their potential to improve indoor air quality. Patil's research highlights the innovative design of liquid trees, which combine the benefits of traditional plants with the efficiency of microalgae. The study suggests that liquid trees can be a valuable addition to sustainable interior design, providing a natural air purification system that is both effective and aesthetically pleasing.

In *Human Emotional and Psycho-Physiological Responses to Plant Color Stimuli* by El Sadek et al. (2013) investigates the impact of plant colors on human emotions and physiological responses. The study finds that different plant colors can evoke various emotional responses, contributing to the overall well-being of occupants. Elsadek's research suggests that the color of plants can play a significant role in interior design, influencing the mood and emotions of occupants. The study highlights the importance of selecting the right plant colors to create environments that promote positive emotional and physiological responses.

In *Microalgae: Prospects for Greener Future Buildings* by Elrayies (2019) discusses the potential of microalgae in creating sustainable building façades. The study highlights the benefits of microalgae in reducing CO2 levels and providing renewable energy. Elrayies' research explores the various applications of microalgae in building design, from green walls to integrated photobioreactors. The study suggests that microalgae systems can be a valuable addition to sustainable architecture, providing both environmental and aesthetic benefits.

In *Microalgae as a Sustainable Facade for Occupants' Health,* Hariyanto (2023) explores the use of microalgae façades to improve indoor air quality and occupant health. The study emphasizes the low maintenance requirements and high efficiency of microalgae systems. Hariyanto's research highlights the potential of microalgae façades to create healthier indoor environments by reducing pollutants and improving air quality. The study also discusses the aesthetic benefits of microalgae façades, which can add a unique and visually appealing element to building designs.

In *Photobioreactors for Building Integration: An Overview of Designs and Architectural Potential,* Arora (2024) provides an overview of various photobioreactor designs and their potential applications in building integration. The study highlights the benefits of using photobioreactors to enhance energy efficiency and air quality. Arora's research explores the architectural potential of photobioreactors, suggesting that they can be seamlessly integrated into building designs to create sustainable and aesthetically pleasing environments.

In *Sustainable Approach to Efficient Green Interiors: Exploring The Effects Of Green Plants On The Indoor Air Quality,* Obakin (2023) examines the impact of green plants on indoor air quality. The study finds that green plants can significantly reduce indoor pollutants and improve air quality. Obakin's research suggests that incorporating green plants into interior design can create healthier indoor environments by reducing levels of CO2, formaldehyde, and other pollutants. The study also highlights the aesthetic benefits of green plants, which can enhance the visual appeal of interior spaces.

In *The Artificial Tree: Integrating Microalgae into Sustainable Architecture for CO2 Capture and Urban Efficiency—A Comprehensive Analysis*, Cervera et al. (2023) discusses the integration of artificial trees with microalgae systems in urban architecture. The study highlights the potential of these systems to capture CO2 and enhance urban sustainability. Cervera's research explores the design and implementation of artificial trees, which combine the benefits of traditional plants with the efficiency of microalgae. The study suggests that artificial trees can be a valuable addition to sustainable urban design, providing both environmental and aesthetic benefits.

In conclusion, the integration of natural elements, such as green plants and microalgae, into interior design offers numerous benefits, including improved air quality, enhanced aesthetic appeal, and increased occupant well-being. The studies reviewed in this literature review highlight the potential of these elements to create sustainable and visually pleasing environments. As sustainability continues to be a driving force in design, the use of green plants and microalgae in interior spaces will likely remain a key strategy for achieving environmentally responsible and human-centered design solutions. Future research should continue to explore innovative applications and optimize these systems for various settings, ensuring that they can be effectively integrated into modern interior design.

METHODOLOGY

Research Design

This study employs a design-based research approach to develop and evaluate the microalgae phototank as an innovative and sustainable interior design element. The research focuses on the aesthetic and functional aspects of the system, aiming to enhance visual appeal and create a unique interior feature.

System Development

Materials and Components

Container Design: The container used to house the microalgae is made of tempered glass with a thickness of 1.8 cm and a capacity of 100 liters. The container is designed to be aesthetically pleasing and functional, allowing for optimal light penetration and visibility. The container is housed within a cabinet frame that features several shelves. It has doors for maintenance access to the container and a mirror on the back to attract young users (can be used for selfies). The cabinet frame is made of plywood and finished with High Pressure Laminated material with a wood pattern to give a natural impression.

Water Flow System: A water flow system is integrated into the container to ensure constant motion, which is crucial for maintaining optimal conditions for the microalgae.

Sensors: Advanced sensors are embedded within the system to monitor environmental parameters such as temperature and light intensity, ensuring the health and vibrancy of the microalgae.

Liquid Formulation

The liquid medium used is salt water, which provides the necessary environment for the microalgae to thrive. This simple formulation ensures that the microalgae can grow and perform photosynthesis effectively.

Design Process

Conceptualization

The design process begins with the conceptualization of the microalgae phototank. This involves brainstorming and sketching initial design ideas that integrate the phototank seamlessly into interior spaces. The goal is to create a visually appealing and functional element that enhances the overall aesthetic of the room (Figure 1). The front and back view of the phototank can be seen on Figure 2.

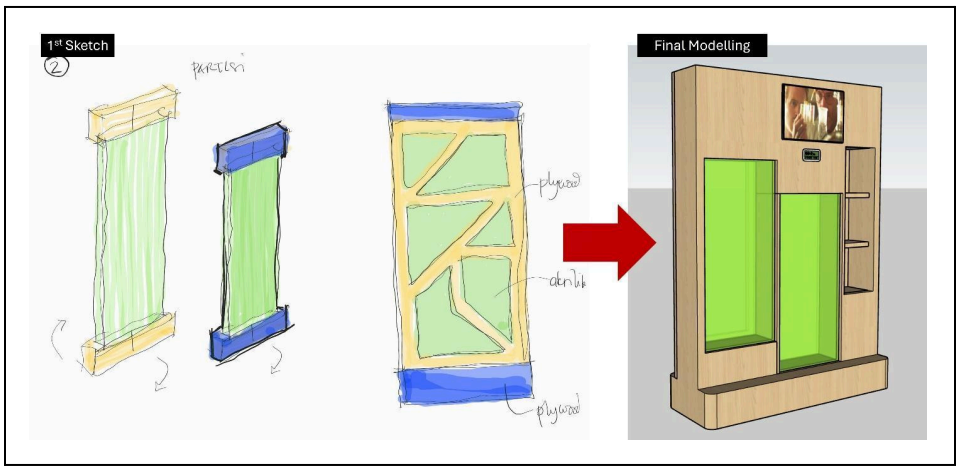

Figure 1. Microalgae Phototank Conceptualization
(Source: Author's personal collection)

Figure 2. Front, Back and Inside View of Microalgae Phototank Conceptualization Prototyping
(Source: Author's personal collection)

Based on the conceptual designs, a prototype of the microalgae phototank is developed. The prototype includes the tempered glass container, water flow system, and sensors. The design is tested for its visual appeal, functionality, and ease of integration into various interior settings. The prototyping process is as shown in Figure 3.

Figure 3. Phototank Prototyping and Testing
(Source: Author's personal collection)

Installation and Integration

Location and Environment

The microalgae phototank is installed in a controlled indoor environment to simulate typical interior conditions. The location is equipped with artificial lighting to provide the necessary light spectrum for microalgae growth. The phototank is installed in the main lobby of PAU building in Institut Teknologi Bandung (Figure 4).

Figure 4. Phototank Installed in Main Lobby of PAU Building (Institut Teknologi Bandung)
(Source: Author's personal collection)

Integration with Interior Design

The phototank is integrated into the interior design of the space, considering factors such as placement, lighting, and overall aesthetic harmony. The goal is to create a cohesive design that enhances the visual appeal of the room while providing the functional benefits of the microalgae system.

Visual Assessment
Observational Studies

The visual appeal of the microalgae phototank will be evaluated through observational studies. Participants will be asked to observe the phototank in different interior settings and provide feedback on its aesthetic qualities, such as color, movement, and overall design. This process will start within March 2025 (after this article is submitted to the conference).

User Feedback

User feedback will be collected to assess the impact of the phototank on the overall interior design. Participants will rate the phototank based on various criteria, including its visual appeal, integration with the interior, and perceived benefits. This process is also not initiated yet.

Exhibition and Patent Submission

The microalgae phototank design has been showcased at a local exhibition (Figure.5), where it received positive feedback for its innovative approach and aesthetic appeal. Additionally, the design has been submitted for a patent to protect its unique features and ensure its commercial viability.

Figure 5. The Microalgae Phototank was Displayed at Local Academic Exhibition
(Source: Author's personal collection)

ANALYSIS & RESULTS

Our study focus was on its aesthetic appeal, integration into various interior settings, and the overall user experience (limited number of interviews because the interview process is still ongoing).

Aesthetic Appeal: The microalgae phototank system was designed to be visually striking, with a transparent container that allows for an unobstructed view of the microalgae. The dynamic motion of the water flow system, combined with the vibrant green color of the microalgae, created a captivating visual effect. Users reported that the microalgae phototank added a unique and modern touch to the interior spaces, enhancing the overall ambiance.

Integration into Interior Settings: The microalgae phototank system potentially installed in various interior environments, including residential, commercial, and public spaces. In residential settings, the microalgae phototank can be served as a focal point in living rooms and dining areas, seamlessly blending with contemporary or minimalist design styles. In commercial spaces, such as offices and lobbies, the microalgae phototank provided a refreshing and calming element, contributing to a more inviting atmosphere. Public spaces, including libraries and waiting areas, will be benefited from the microalgae phototank's ability to create a sense of tranquility and connection to nature.

User Experience: User appreciated the low maintenance requirements compared to traditional indoor plants. The advanced sensors and automated water flow system ensured that the microalgae remained healthy and vibrant with minimal intervention. Users also stated the positive psychological effects of having a natural element in their indoor environment, reporting reduced stress levels and an overall sense of well-being. For note, this is based on limited interviews with some users.

Environmental Impact: While the primary focus of this study was on the aesthetic and experiential aspects of the microalgae phototank, it is worth noting that the system also contributed to improved indoor air quality. The microalgae's photosynthetic activity helped to reduce CO2 levels and increase oxygen production, albeit to a lesser extent than traditional plants. This added environmental benefit further supports the microalgae phototank's role as a sustainable design element.

CONCLUSION

The results of our study demonstrate that the microalgae phototank system is a viable and innovative interior design element. Its aesthetic appeal, ease of integration into various settings, and positive impact on user experience make it a valuable addition to modern interior design. Future research will focus on optimizing the system's performance and exploring its applications in a wider range of interior or built-environments.

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