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Clean Air Preservation through an Eco-Art Installation utilizing Microalgae Cultivation Media

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Abstract
This article presents the creation of an eco-art installation that integrates microalgae cultivation through a photobioreactor (PBR) system. Motivated by ecological empowerment and clean air preservation, the work combines artistic research with technological innovation. Inspired by Tatlin's work and a previous eco-art project, the piece titled "Repeating Pillar Structure" uses transparent acrylic pipes to circulate microalgae for CO_2 absorption and O_2 production. The installation serves a functional environmental purpose and offers contemporary aesthetic value suitable for public spaces. This project demonstrates how art can engage ecological issues by blending scientific methods and creative practice to foster environmental awareness.

Keywords: Eco-art; photobioreactor; microalgae; cultivation

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1.0 Introduction

In contemporary art, ecological empowerment and awareness have become significant issues. As a result, the ideology of eco-art has emerged as a relevant and meaningful genre, particularly in the context of ongoing environmental crises. Contemporary art that explores ecological themes often emphasizes the diversity of visible natural forms, creating direct visual experiences (Stoltz, 2023). However, eco-art that focuses on the biodiversity of microscopic organisms is still relatively rare; one example of this is the use of microalgae as a medium.

Microalgae are microscopic organisms that can perform photosynthesis and thrive in both seawater and freshwater environments. Their appeal lies in their wide range of applications, as they contain valuable compounds useful for producing carbohydrates, bioenergy, and pharmaceuticals (Thoré et al., 2023). Additionally, microalgae play a crucial role in preserving clean air by helping to reduce pollution. The combustion of fossil fuels, particularly in industrial activities, generates carbon dioxide (CO_2) emissions. Managing these emissions is essential. Microalgae absorb CO_2 during photosynthesis, using it to reproduce their cells.

In Indonesia, PT Semen Indonesia Tbk (SIG) has implemented microalgae cultivation to absorb CO_2 emissions from industrial exhaust gases at its plant in Cilacap, Central Java. This initiative is conducted through its subsidiary, PT Solusi Bangun Indonesia Tbk (SBI), in collaboration with the Center for Energy Studies, Universitas Gadjah Mada (UGM). The cultivation uses an open pond system and represents an innovative step as part of broader decarbonization efforts to reduce CO_2 emissions at the Cilacap plant (Ihsan, 2023).

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In addition to open pond systems, microalgae cultivation for CO_2 absorption can also be conducted using a photobioreactor (PBR) system. A PBR is a type of bioreactor that harnesses light to cultivate phototrophic microorganisms. These reactors are constructed from transparent materials such as glass, acrylic, or plastic and are equipped with systems to supply culture media and channel gas emissions, facilitating CO_2 absorption by microalgae. Compared to open pond systems, PBRs tend to be more effective at reducing CO_2 emissions. One significant advantage of PBRs is their ability to precisely control internal conditions, which optimizes microalgae growth, leads to faster cultivation, and minimizes contamination. Typical designs of PBRs often feature winding columns made from transparent pipes, arranged either vertically or horizontally (Razzak et al., 2024).

The development of microalgae cultivation media for CO_2 absorption has also been advanced by Institut Teknologi Bandung (ITB), Indonesia through the creation of a phototank bioreactor. This system is inspired by artificial tree concepts developed abroad, which use microalgae-based liquid media to absorb CO_2 in urban areas with limited space. In densely populated urban environments or indoor settings, phototanks present an alternative solution for capturing CO_2 and producing oxygen (O_2) through photosynthesis (Bawono, 2024).

Building on this background, a collaboration between the Center for Energy Studies, Universitas Gadjah Mada and Institut Seni Indonesia Yogyakarta has led to the idea of designing a photobioreactor (PBR) that not only meets the technical and functional requirements of an effective PBR but also serves as an installation artwork with contemporary aesthetic appeal. This approach integrates artistic creativity with technological innovation, resulting in a microalgae photobioreactor envisioned as an eco-art installation. The objective of this creative work is to design a contemporary visual artwork inspired by the concept of microalgae cultivation in the form of a photobioreactor. The resulting installation will combine both functional value in the form of CO_2 absorption, O_2 production, and artistic merit. Furthermore, this microalgae photobioreactor installation is intended to be displayed in building lobbies or other public spaces, contributing to the preservation of clean air while enhancing the cultural and visual environment.

2.0 Literature Review

2.1 Installation Art

Oliveira et al., as cited in Burhan et al. (2021:151), discuss installation art from a historical perspective, tracing its origins in Marcel Duchamp's readymade *Bicycle Wheel* (1913). They argue that installation art emerged more prominently from the 1960s onward, in conjunctions such as *assemblage* and *site-specific* to describe collective artistic practices that produce works capable of occupying, intervening in, and transforming spatial environments. Furthermore, the 20th century concept of *gesamtkunstwerk* (total work of art) is identified as significant influence on major artistic movements including Futurism, Dada, Constructivism, and the Bauhaus, marking important milestones in the development of installation art. Through this integrative framework, installation art evolved into a visual practice capable of synthesizing and engaging with a wide range of other art forms. Oliveira et al. also examine early prototype installation by Vladimir Tatlin and extend its discussion to more advanced practices such as Minimalism, Land Art, and Conceptualism, highlighting their respective methodologies and contributions to the evolution of installation art.

Installation art is characterized as a hybrid discipline that integrates various media and fields both within and beyond the arts. It is inherently three-dimensional, engaging with and transforming the physical space it occupies. One notable earlier work often referenced is Vladimir Tatlin's *Model for Monument to the Third International* (1919–1920) (Figure 1). While it can be considered a piece of Constructivist sculpture, it is also recognized as a precursor to installation art. This work features a spiral steel structure incorporating cylindrical, conical, and cubist elements. Beyond its formal qualities, it also possesses functional aspects, allowing people to climb, stand, or sit on it (Harrison & Wood, 2003:336-339).

Fig. 1: Vladimir Tatlin's *Model for Monument to the Third International* (1919–1920)
(Source: https://www.phillips.com/article/43416956/vladimir-tatlin-monument-to-the-third-international).

2.2 Eco-Art

In *Nature Art* (Eross, 2011) in the section *Nature Art: Essaying a Definition*, Eross explains that the definition of *nature art* has not yet been widely accepted. This definition arises from varied sources and an inconsistent body of literature. In the United States, the term *nature art* itself is not commonly used; instead, the broader term *land art* is generally applied. Related terminologies include *eco-art*, *environmental art*, *earth art*, *resource art*, and others.

Eco-art places particular emphasis on activism, functioning as a movement of environmental advocacy and campaigning. Typically, eco-art projects address more specific environmental issues such as climate change, air pollution, deforestation, and similar concerns. Some guiding principles of eco-art include:

a. Reconsidering the relationship between humans and nature to establish new ways of coexistence with other living beings on Earth.
b. Creating works using natural materials and incorporating natural elements such as light, wind, water, and so forth.
c. Seeking to raise public awareness of existing environmental problems while proposing new methods to help ensure the planet's sustainability.

In the present work, the eco-art principle to be applied is the creation of an installation that utilizes water and light elements within the cultivation of microalgae, aiming to foster environmental awareness by contributing to clean air conversion. The work is a further development of a previous eco-art project made by the author (see Burhan et al., 2021) in collaboration with the Center for Energy Studies, Universitas Gadjah Mada. The earlier eco-art work was an eco-art photobioreactor installation designed with a configuration of "Vertically Twisted Spiral Lines" (see Figure 2). With a specific inclination, this arrangement of lines forms a constant curve. This form was chosen as it combines elements of geometric linear shapes and organic forms, blending rigid straight lines with dynamic curves. The work shown in Figure 2, along with Vladimir Tatlin's installation in Figure 1, will serve as references for conceptual ideas, formal design, and technical creation processes.

Fig. 2: Eco-art photobioreactor installation with "Vertically Twisted Spiral Lines" configuration
(Source: Burhan et al., 2021).

2.3 Microalgae and Photobioreactor

Microalgae are microscopic organisms capable of photosynthesis and can thrive in both seawater and freshwater environments. Microalgae contain various compounds such as carbohydrates, lipids, and proteins (De Oliveira & Bragotto, 2022). These compounds have significant potential for producing energy sources like bio-crude oil, alcohol, or hydrogen (Pandey et al., 2024). Certain active compounds found in microalgae, such as astaxanthin (Villaró et al., 2021) and phycocyanin (Yu et al., 2024), are also used in the pharmaceutical and cosmetics industries. Additionally, several types of microalgae can assist in water treatment processes (Amaro et al., 2023). The advantages of microalgae are further supported by other properties: they have high photosynthetic efficiency, require relatively little water, and can be cultivated in marginal lands unsuitable for agriculture (Dolganyuk et al., 2020).

Microalgae cultivation can be carried out using either an open pond system or a closed tank system. One notable advancement in microalgae cultivation technology is the use of a photobioreactor (PBR). A PBR is a type of bioreactor that uses light sources to cultivate phototrophic microorganisms. Microalgae utilize light and carbon dioxide to conduct photosynthesis. One of the key advantages of a PBR is its ability to precisely control reactor conditions to suit the growth requirements of the cultivated microalgae. This means that

PBRs can promote faster growth while minimizing the risk of contamination (Budiman et al., 2019:61–63). The standard design of a PBR consists of transparent glass or plastic pipes arranged to form vertical or horizontal columns. A PBR built according to these technical standards can be seen in Figure 3.

Fig. 3: Microalgae photobioreactor
(Source: https://id.m.wikipedia.org/wiki/Berkas:Photobioreactor_PBR_4000_G_IGV_Biotech.jpg).

3.0 Methodologies

In this paper, the creation of an eco-art installation employs the method of artistic research, which encompasses a process of inquiry starting from the emergence of the creative concept, the development of form, medium, and technique, through to the presentation format and the description of the work. Artistic research positions the artist as a researcher who does not merely confront the object but actively engages with it throughout the creative process. This approach involves profound, powerful, and aesthetically attuned contemplation carried out through an ongoing, reciprocal process (the principle of in and through) to produce the artwork. Artistic research must also refer to scientifically recognized creative methods that have been published, ensuring that the resulting work holds innovative value and that its process can be examined and acknowledged by others (Hannula et al., 2005:109-118).

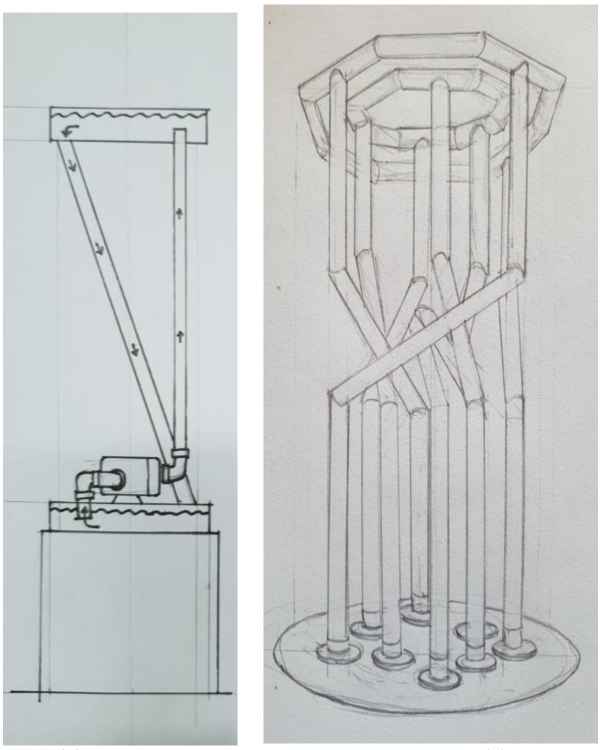
The creation method follows the framework proposed by Mace and Ward (2002), which comprises 4 key stages:

a. **Artwork conception** refers to the preliminary phase in which an initial concept or artistic intention is identified and explored.
b. **Idea development** involves expanding and refining the initial idea through continuous decision-making, problem-solving, information gathering, experimentation, and critical evaluation.
c. **Making the artwork and idea development** is the stage where the authors begin engaging with the material and physical aspects of the artwork while simultaneously allowing the concept to evolve through practice.
d. **Finishing the artwork** is the final stage in which the work is resolved aesthetically and conceptually, including refinement, final adjustments, and preparation for presentation or exhibition.

This artistic research is limited to the design and prototyping of a microalgae photobioreactor as an eco-art installation and does not quantitatively measure its long-term efficiency in CO_2 absorption or O_2 production under varying environmental conditions. The study focuses on artistic research outcomes, aesthetic considerations, and functional feasibility at the prototype scale, rather than on large-scale industrial or environmental impact assessments. Additionally, variations in sunlight exposure, temperature control, and microalgae growth performance were observed but not systematically analyzed through controlled scientific experimentation. However, according to Raharja (as cited in Grehenson, 2021), the CO_2 absorption capacity of a single PBR installation is equivalent to that of 4 four-year-old acacia trees.

4.0 Findings

From various analyses and aesthetic considerations, the idea emerged to create the bioreactor design titled “Repeating Pillar Structure”. This form consists of a configuration of pillars arranged into a double structure: the outer structure is made up of four pillars crossing to the right, while the inner structure comprises four pillars crossing to the left, together creating a dynamic visual impression. This design corresponds to the nature of the object itself, which combines eco-art installation and algae cultivation technology. The design development and problem-solving process can be seen through the sketch of the water flow installation, the microalgae cultivation installation sketch, the top view plan sketch, and the mockup of the microalgae cultivation installation (see Figures 4 to 6).



(a) (b)

Fig. 4: Sketch of (a) the water flow in the microalgae cultivation installation and (b) the microalgae cultivation installation.

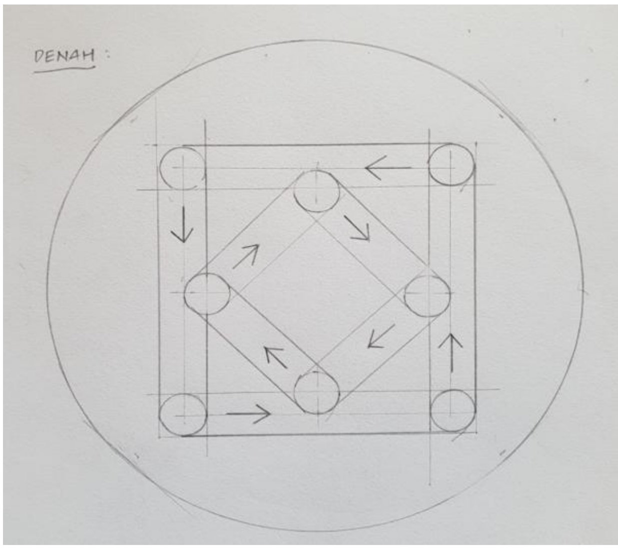


Fig. 5: Top view layout sketch of the microalgae cultivation installation.

The working principle of this installation is based on a photobioreactor, in which a thin layer of microalgae inside acrylic tubes absorbs light used for photosynthesis, while the CO_2 consumed is drawn from ambient air through the media–air interface in the reservoir tank beneath the installation. The geometric form idea of the work “Repeating Pillar Structure” was inspired by considerations of the function of conventional photobioreactors, Vladimir Tatlin’s *Model for Monument to the Third International* (1919–1920), and the earlier photobioreactor installation “Vertically Twisted Spiral Lines” (see Burhan et al., 2021). The form was developed by creating site plans and sketches, which were then translated into a mockup using PVC pipes (Figure 6).

The installation material selection includes 3-inch diameter acrylic pipes and clear PVC pipes with a wall thickness of 5 mm, with a supporting reservoir tank and connecting tank made of polyester resin. Transparent acrylic is used to allow ultraviolet sunlight to penetrate the microalgae water, which is circulated by a 220-volts water pump with specifications of 0.40 kilowatts, 2850 rpm (revolutions per minute), a 1.5” inlet, and a 1.5” outlet. Polyester resin is used to construct the water reservoir tank and pipe connectors because microalgae cannot be exposed to materials containing iron. The installation measures 300 cm in height, with a base tank measuring 120 cm x 120 cm x 120 cm. The final form is the eco-art installation “Repeating Pillar Structure” which uses a water pump to circulate water according to the basic technical procedure of photobioreactor function. Transparent acrylic pipes serve as the main water flow channels supporting the microalgae's photosynthesis process, while PVC pipes function as inlets leading to polyester resin connectors attached to the transparent acrylic pipes.

Fig. 6: Mockup of the microalgae cultivation installation "Repeating Pillar Structure".

The production process was carried out at the Noor Jayadi Studio, Bantul, D. I. Yogyakarta, Indonesia (Figure 7). Subsequently, the eco-art photobioreactor installation was assembled and tested at the Microalgae Biorefinery Center, Center for Energy Studies, Universitas Gadjah Mada. The failure of the first work, "Vertically Twisted Spiral Lines" in Burhan et al. (2021), was taken into consideration to be anticipated. That failure stemmed from the initial design, which used a single water inlet hole driven by the water pump and a single outlet hole, resulting in leaks at the pipe connectors due to excessively high-water pressure in the 20 mm diameter pipes. Improvements were made by redesigning the pipe connector construction and the microalgae water flow system, so that the pump's outlet resistance could be balanced without impeding the flow of the microalgae water.

Fig. 7: The production process at the Noor Jayadi Studio, D. I. Yogyakarta, Indonesia.

5.0 Discussion

The research and design process that has been carried out, starting from initial sketches and designs, has achieved results that can be reported. The overall form of the photobioreactor is a configuration of columns whose artistic solution is based on the need to enable the photosynthetic function of microalgae. Through various explorations of eco-art installation ideas and references from previous works, the final design was created, applying elements in the form of column configurations that form a double structure. The outer structure consists of four columns crossing to the right, while the inner structure has four columns crossing to the left, thus creating a dynamic impression. This form was chosen because it combines linear geometric elements with organic shapes, as well as straight, rigid lines with dynamic curves. This reflects the nature of the object itself, which is a fusion of eco-art installation and microalgae cultivation technology.

Acrylic pipes serve as the channels for water containing microalgae, allowing ultraviolet light from sunlight above the reservoir surface to penetrate and support the photosynthesis process needed for microalgae growth. PVC pipes act as the water inlets, pumping water vertically into the acrylic pipe connectors. Water movement is driven by a water pump to circulate the water, thus enabling O_2 mixing and light exposure necessary for microalgae photosynthesis. Polyester resin is used to build the reservoir tanks and connectors between the PVC and transparent acrylic pipes. The outlets of the acrylic pipes are directed into the reservoir tank below the eco-art installation. The reservoir tank is designed to be open so that the microalgae cultivation process can be monitored, and it can be harvested through an outlet tap located at the bottom of the structure.

The microalgae photobioreactor eco-art installation can also function as an alternative to conventional indoor air conditioners. Its form is based on aesthetic principles found in installation art. The eco-art concept and the spatial construction of the bioreactor installation balance conventional functional requirements with aesthetic elements. Water flowing from the acrylic pipes cascades like a waterfall into the reservoir tank, creating the soothing sound of trickling water as part of the eco-art installation concept.

The prototype design has been developed into an installation in the form of photobioreactor construction with a height of 300 cm, using acrylic pipes to facilitate the process of photosynthesis. The lower microalgae reservoir base measures 120 cm x 120 cm x 120 cm. Water circulation is supported by a 220-volt, 0.4-kilowatt pump, through which the seeding and growth of microalgae gradually transform the water into a leafy green hue. This green coloration may reduce psychological stress and enhance visual comfort, as biophilic green elements have been shown to positively influence mood and perceptual experience (Warren et al., 2023). Due to its adaptable size, the installation can serve as an aesthetic element in a building lobby or as a monumental public art installation. Figure 8 shows the appearance of the eco-art installation "Repeating Pillar Structure".

Challenges in constructing the photobioreactor installation "Repeating Pillar Structure" included assembly issues such as drainage and uneven pressure from gravity in the layout, which led to inconsistent microalgae production across the pipes. These problems were compounded by varying sunlight exposure on the installation. Additional challenges included leaks at pipe elbows and occasional pressure-related issues at the submersible pump outlet, which had to operate continuously for 24 hours. Cooling proved inadequate due to the small reservoir size or limited microalgae water volume, causing the circulating water to heat up quickly and affecting both the pipes' durability and the microalgae's survival. Regular cleaning of pipes and pumps was also essential, as accumulated microalgae increased flow resistance. All these issues were gradually mitigated through repeated testing and adjustments.

Fig. 8: The final eco-art photobioreactor installation "Repeating Pillar Structure".

6.0 Conclusion & Recommendations

The design of this contemporary artwork, inspired by the idea of cultivating microalgae through the form of a photobioreactor (PBR), is a response to the challenge of preserving air from CO_2 pollution. Therefore, technological solutions involving microalgae are needed to help reduce the high levels of CO_2 emissions in the atmosphere, while also serving as a cultivation medium with many benefits. The design process of the microalgae cultivation installation artwork using a photobioreactor led to the form of a "Repeating Pillar Structure", whose artistic resolution was based on the need to support the photosynthetic function of microalgae. Through various explorations of creative ideas, the photobioreactor design emerged as a configuration of pillars forming a double structure: an outer structure of four pillars crossing to the right and an inner structure of four pillars crossing to the left, thus creating a dynamic visual effect. This design aligns with the nature of the object itself, which blends eco-art installation and microalgae cultivation technology, combining functional and artistic value.

The photobioreactor microalgae installation artwork is also intended to be displayed or placed in building lobbies or public spaces. Ultimately, this eco-art microalgae bioreactor installation, beyond serving as a medium for cultivating microalgae, can also function as a tool and medium for preserving clean air from pollution. Eco-art is an art practice that extensively uses natural materials and elements such as light, wind, water, and so on. Eco-art also consistently seeks to raise human awareness of existing environmental issues and to offer new approaches that ensure the sustainability of the natural environment.

Future work is recommended to develop new designs grounded in local wisdom and philosophical values inherent to the site of artwork placement. This approach emphasizes the integration of local symbolic identity as a significant aesthetic dimension within the design process. Such an integration may further enrich eco-art installation practices by aligning environmental considerations with culturally embedded knowledge and values.

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Paper Contribution to Related Field of Study

This paper contributes to eco-art that serves a functional environmental purpose and offers a contemporary aesthetic.

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