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Eco-Friendly Innovation: Hydra-Enhanced Miniature Photobioreactor for Air Pollution Reduction

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Abstract: According to the WHO data in 2019, nearly all of the global population resides in areas that do not meet the WHO guidelines for air quality. This study is to address the issue of indoor air pollution through the use of Photobioreactor technology and Hydrilla Verticillata plants. The experimental findings demonstrate that the rate of photosynthesis and production of oxygen bubbles by the Hydrilla plants are significantly influenced by adequate light intensity and exposure to CO2. By employing this innovative Photobioreactor technology, it is anticipated that indoor air quality can be enhanced, thereby contributing to the resolution of air pollution problems. This research adopts a combination of descriptive and experimental methods, utilizing a prototype scale for conducting experiments. Secondary data, in the form of published scientific articles from both international and national journals, serve as the source of data. The collected data is then qualitatively analyzed through descriptive means. Based on the results of data analysis, it can be concluded that this research offers valuable insights into the use of Hydrilla plants in innovative technologies for the improvement of air quality and human health, particularly by implementing photosynthesis processes within Photobioreactor technology.

Keywords: Air pollution; *Hydrilla*; Photobioreactor

Introduction

Environmental diseases pose a significant risk to the overall well-being of society and contribute significantly to mortality (Febria et al., 2023). However, this environmental disease is expected to be minimized by the SDGs goal, namely goal number 3, which is related to ensuring a healthy life and increasing well-being for all people without exception, anytime, and anywhere (Bappenas, 2021). This means that humans have the right to a decent life and according to their needs. However, in the implementation of human life, they still do not get their rights properly.

This is because in practice many components of human life are affected by pollution. Pollution itself is defined as the introduction of substances into the environment that are harmful to humans and other living organisms (Laksono et al., 2023). An example of this pollution is water pollution, which is an important component of human life (Saniti, 2012; Suparno et al., 2023; Zahra et al., 2017). However, not only water, air is also another important component that is often polluted.

All this is closely related to the development of the global economy and industrial progress, the severity of air pollution in urban areas is increasing (Dong et al., 2023; Liu et al., 2020; Yu et al., 2022). If we look further, Indonesia itself is also facing high levels of air pollution, which greatly threatens our lives and other living things (Mirawati et al., 2016; WHO, 2021). According to WHO data in 2019, 99% of the world's population lives in

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places that do not meet WHO air quality guidelines (WHO, 2021). Based on information from the Pangkajene District Health Office in 2021, when viewed from the top 10 diseases based on their incidence, after hypertension, the next most common disease is ARI with 638 cases (Banegas et al., 2017; Burki, 2006; Hasanuddin et al., 2023). From this data alone, it can be concluded that ARI is a serious threat to Indonesia. If we look further, air pollution is certainly an environmental issue highlighted in the declining satisfaction of urban residents (Alvanchi et al., 2019; Wang et al., 2009).

Given this problem, this research is based on a background that indicates the problem of air pollution as one of the most serious environmental issues today. High levels of air pollution have caused adverse impacts on human health, the environment, and the global climate. Based on the Global Burden of Disease (GBD), an estimated 9 million deaths were caused by environmental pollution (4.2 million due to ambient air pollution and 2.9 million deaths due to indoor air pollution) (Murray et al., 2020; Rajagopalan et al., 2018).

Indoor air quality is an important factor for human health, as indoor air pollution has a more harmful impact than outdoor air pollution (A'yun et al., 2023). A recent World Health Organization (WHO) declaration highlights that indoor and outdoor air pollution pose significant threats to human health. To effectively mitigate the global incidence and impact of diseases such as lung cancer, stroke, and asthma, improving air quality is essential (WHO, 2021).

Over the past 35 years, there has been growing recognition of the importance of addressing indoor air pollution. This is particularly important given that in high-income countries, it is estimated that we spend around 90% of our time indoors (Klepeis et al., 2001). In recent years, there has been a push to make buildings more energy efficient and reduce carbon dioxide emissions to combat the effects of climate change (Carslaw et al., 2024). As a result, buildings are becoming more sealed off from the outside air.

This decrease in ventilation rates means that if indoor sources are a major contributor to indoor air pollution, then we are more likely to be exposed to higher concentrations of pollutants. In fact, lower ventilation rates have been linked to negative health impacts indoors (Ashmore et al., 2009; Sundell et al., 2011). Not only that, air pollutants can also come from outdoors.

This can be seen in that nitrogen oxides (NOx) can enter buildings from outside, and when combined with additional sources such as cooking on gas stoves, this can lead to higher levels of NOx indoors than outdoors, depending on the specific conditions (Dimitroulopoulou et al., 2001). Another pollutant, ozone (O3), can also infiltrate buildings from outside sources. Although there are indoor sources such as photocopiers and laser printers, most ozone comes from outdoors. In indoor environments, ozone concentrations are typically 20-70% compared to outdoors (Nazaroff et al., 2022). Lower concentrations indoors occur because ozone can attach to indoor surfaces and undergo reactions, and trigger chemical reactions by oxidizing volatile organic compounds (VOCs) (Weschler et al., 2018).

This has not been properly indicated and addressed as Indonesia currently does not have a national standard on air pollution levels (Putri Oganda et al., 2023). Based on the Air Quality Index (AQLI), the Indonesian population will lose 2.5 years of life expectancy due to current air pollution (Cabinet Secretariat of the Republic of Indonesia, 2023). With this problem, this research is associated with innovations related to Photobioreactor to reduce air pollution.

The presence of Indonesia's strategic geographical location has earned Indonesia the nickname Mega Biodiversity country, or a country that acts as the center of biodiversity in the world (Masyitoh et al., 2023). One of the biodiversity that can be utilized is microalgae. In general, Photobioreactor utilizes microalgae as the main ingredient. Microalgae are a group of photosynthetic microorganisms (Barsanti et al., 2022). Microalgae of the genus Scenedesmus is an organism that belongs to the group microalgae have the potential to be utilized in various fields of human life (Tambunan et al., 2023). This is done to reduce the concentration of CO_2, including the utilization of microalgae which can be used as a renewable natural resource because it can be cultivated and abundant (Cahyadi et al., 2023).

However, this research innovation will utilize *Hydrilla verticillata L.* or commonly known as *Hydrilla* algae. *Hydrilla verticillata (Hydrocharitaceae)* is a monotypic species of submerged freshwater flowering plants (Patrick et al., 2021). *Hydrilla verticillata (L.f.)* is also an aquatic plant consisting of 20-25 different cell types from three different stem cell lineages: ectodermal epithelial stem cells, endodermal epithelial stem cells, and stromal cells (Ghaskadbi, 2020). *Hydrilla verticillata L.* is commonly found in stagnant waters such as rice fields and swamps. The presence of this plant in large quantities can obstruct the flow of water so that plants are often uprooted and thrown away. In this innovative Photobioreactor, *Hydrilla* growth is controlled and utilized to create photosynthetic engineering. This aims to improve air quality, especially indoor air quality.

Utilization of *Hydrilla* verticillata in Photobioreactor is a new innovation developed. In this innovation, photosynthesis engineering will be assisted by artificial CO2. The selection of *Hydrilla verticillata* has the main purpose besides being a plant that lives in water, easily observed when many oxygen air bubbles appear from the photosynthesis engineering process, also this plant as a Phytoremediator. Phytoremediator is a technology that is useful for improving the quality of polluted water (Nurmaya, 2023). According to research, *Hydrilla* verticillata can also reduce ammonia and reduce nitrates in water (Dwiputra et al., 2021). This will provide 2 advantages in its use, namely the generation of indoor oxygen, and can ensure that the water quality in the Photobioreactor can be maintained due to the control of *Hydrilla verticillata* growth.

Method

Research Scheme

This research method uses a combination of descriptive and experimental methods by conducting experiments on a prototype scale. Experimental science in its field is a science consisting of several fields such as physics, chemistry, and biology. The concepts and theories involved in science come from experiments conducted by scientists based on scientific procedures. (Arrohman et al., 2021). The following is the research flow of the Hydra-Enhanched Photobioreactor.

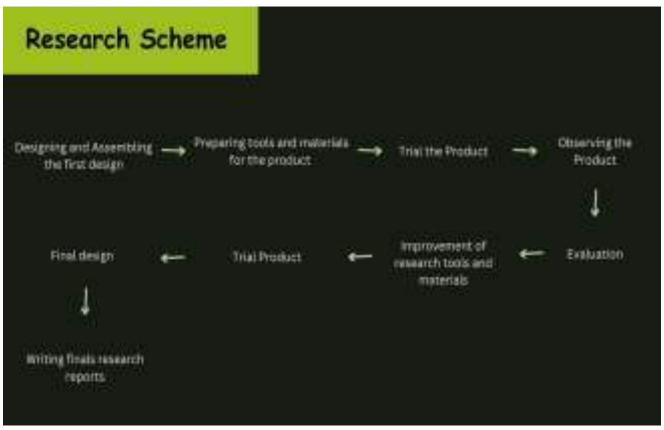

Figure 1. Research scheme

This research consists of several stages, namely making the first design where this design will later be tested to find out the gaps in this design. After that, there is a stage of preparation of tools and materials used in this product, followed by assembling the tools needed in the experiment, then entering into the product trial stage. At this stage, there were several errors in both the assembly of the tools and the dosage of the composition of the experimental materials to be used so that during the first trial, it could be said that it was not successful. So that the product observation and evaluation were carried out again to go to the second stage of trial improvisation. After success, the final design and report writing were carried out. The entire research flow can be seen in Figure 1.

Hydra-Enhanced Miniature Photobioreactor Design

This design is designed and adapted to the needs that exist in the room. And this design is a development of photobioreactor development research with the help of solar energy or for outdoors (Cahyadi et al., 2023).

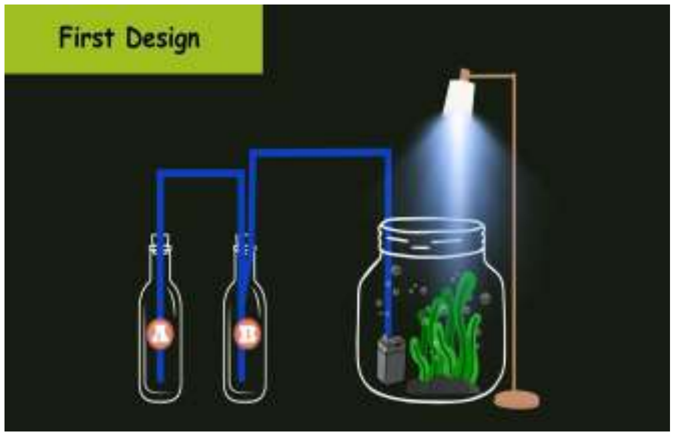

Figure 2. First design

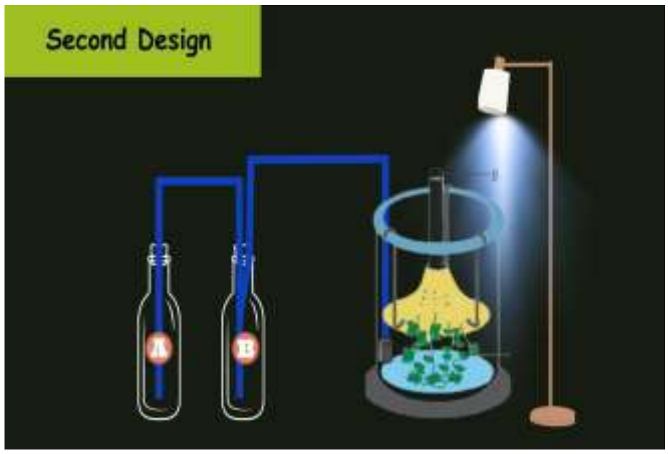

Figure 3. Second design

In realizing the first design, there are two main materials that are needed. First, artificial CO2 as one of the important components in the photosynthesis process. Artificial CO_2 will be used as a carbon source required by plants or microorganisms in their growth. Artificial CO_2 can be generated through industrial processes or by using carbon capture technology.

The second material required is the Photobioreactor. A photobioreactor is a specialized container or system designed to efficiently grow and manage plants or microorganisms. Photobioreactors can control temperature, nutrients, humidity, and other conditions that are optimal for the growth of plants or microorganisms. In this context, the Photobioreactor will be used to capture artificial CO_2 and allow plants or microorganisms to use that CO_2 in the process of photosynthesis.

Table 1. Tools and Materials CO_2 Kit First Design

Tools and Materials	Weight
Tube A (citrun) gersikan brand	20gr
Tube B (Baking soda) cendrawasih brand	15gr
Small hose	2 pieces
Fanta bottle	2 pieces (390 ml)
Bottle cap with 2 holes	2 pieces
Water	350 ml

Table 2. Tools and Materials for Photobioreactor First Design

Tools and materials miniature photobioreactor kit	Weight
Hydrilla verticillata	2 Hydrilla
2.50 watt blue red light	2 pieces
Hydrilla tube	1 pieces
Water	390 ml

Table 3. Tools and Materials CO_2 Kit Second Design

Tools and Materials	Weight
Tube A (citrun) gersikan brand	20gr
Tube B (Baking soda) cendrawasih brand	15gr
Small hose	2 pieces
Fanta bottle	2 pieces (390 ml)
Bottle cap with 2 holes	2 pieces
Water	350 ml

Table 4. Tools and Materials for Photobioreactor Second Design

Tools and materials miniature photobioreactor kit	Weight
Hydrilla verticillata	2 Hydrilla
100 watt Philips Standard bulb	2 pieces
Glass funnel	1 pieces
Test tube	1 pieces
Goblet glass	1 pieces
Water	900 ml

Result and Discussion

First Trial

Before the experiment, the pH of the water in CO_2 kit tube A was measured. The initial pH of the water was 7. After that, mixing with citronella was done, and the resulting pH was 2 (acidic solution). In this first experiment, using the first design, the bubbles produced by the CO_2 kit can last 30 minutes, then it takes a little pressure on tube A to push so that the citron solution can enter tube B and produce CO_2 in the hydrilla tube. After 30 minutes had passed the oxygen bubbles did not come out of the Hydrilla plant. After 1 hour of the experiment no oxygen bubbles emerged from the Hydrilla plant.

Based on the findings of the first experiment, it can be concluded that the attempt to engineer photosynthesis was unsuccessful. The main reason for this failure was the inadequacy of light intensity provided during the experiment. Photosynthesis heavily relies on light energy for the conversion of carbon dioxide and water into glucose and oxygen. Insufficient light intensity inhibited the process, resulting in a lack of significant changes in the rate of photosynthesis.

Figure 4. First design, first trial

Furthermore, it was observed that excessively high light intensity can have detrimental effects on the photosynthesis process (Handoko et al., 2013). When the intensity of light surpasses the optimal range, it can damage the chlorophyll present in the plant cells. Chlorophyll is an essential pigment that captures light energy for photosynthesis. Damage to chlorophyll hampers its ability to absorb light effectively, leading to a reduction in the overall photosynthesis process.

This information suggests that finding the appropriate light intensity is crucial for successfully engineering photosynthesis. The light intensity needs to be optimized to ensure that it is neither too low nor too high. It should be noted that different plant species may have varying optimal light intensity requirements, so further research is necessary to determine the optimum range for specific plants.

In conclusion, the first experiment indicates that photosynthesis engineering failed due to a lack of sufficient light intensity. Additionally, it was found that excessively high light intensity can be damaging to the chlorophyll and hinder the photosynthesis process. These findings reinforce the importance of carefully controlling light intensity in any future attempts to engineer photosynthesis. Further studies should focus on optimizing light intensity to achieve successful manipulation of the photosynthesis process.

Second Trial

Before the experiment, the pH of the water was measured again. In this second experiment, using the second design, the bubbles produced by the CO_2 kit could last 30 minutes, then it took a little pressure in tube A to push the citron solution into tube B and produce CO_2 in the hydrilla tube. Using a 100 watt lamp for the first 30 minutes, bubbles appeared from between the Hydrilla stems. The first bubbles appeared after 3 minutes of the lamp being turned on. The bubbles that appeared every minute after 5 minutes passed were 10 bubbles. After 15 minutes, the bubbles produced per minute were more consistent and appeared faster.

Conclusion of the second experiment: successful photosynthesis engineering. In this second experiment, using the second design, using 1100 watt lamp can produce photosynthesis in Hydrilla plants. The main factor of photosynthesis in Hydrilla plants is light intensity (Maftukhah et al., 2023).

Figure 5. Second design, first trial

Third Trial

The steps taken were the same as the second experiment with the second design. However, two 100-watt lamps were used here. In this third experiment, the bubbles produced by the CO_2 kit can last 30 minutes, then a little pressure is needed in tube A to push so that the citron solution can enter tube B and produce CO_2 in the hydrilla tube. Using a 200-watt lamp, the first bubbles appeared at 2 minutes into the experiment. Bubbles that appeared every minute after 5 minutes passed as many as 20 bubbles. After 15 minutes had passed, the bubbles produced per minute were more consistent and faster to appear, and more bubbles appeared from a larger stem size and slightly brownish with a little gap. After the experiment, the pH of the water changed and decreased to 6 (more acidic) due to the exposure to CO2 during the 4-hour experiment.

Figure 6. Second design, second trial

Conclusion: the results recorded in the third experiment with the second design model are more complete. In this decrease in pH, it can be reinforced by expert opinion that the higher the content of CO_2 exposure in water, the lower the pH value will be (Gruber et al., 2019; Sarmiento, 2006; Yudho Andika et al., 2023). In addition, the design of photobioreactors using Hydrilla or Microalgae plants can absorb the highest CO_2 emotion produced (Yustiningsih, 2019).

Conclusion

Based on the observations in the second and third experiments, it can be concluded that the tubes placed in a room without sufficient light intensity using a 100 Watt lamp, the first bubbles appeared after 3 minutes the lamp was turned on. Bubbles that emerged from Hydrilla plants after 5 minutes passed as many as 10 bubbles. This proves that in addition to CO_2, light intensity can also affect the rate of photosynthesis process. While the tubes placed outdoors with sufficient light intensity treatment of 200 watts, the first bubbles appeared after 2 minutes of the experiment and the bubbles produced after 5 minutes passed as many as 20 bubbles. It can be seen that the experiment conducted outdoors produced more bubbles. This is reinforced by the opinion that changes in oxygen concentration are influenced by the length of energy irradiation that can facilitate photosynthesis. In addition, the pH of the water became more acidic or decreased due to exposure to CO2 for 4 hours of the experiment. Decreased or low pH water generally has a low dissolved oxygen content as well. This can affect the photosynthesis process in Hydrilla plants, as we know that CO_2 and light intensity greatly affect the photosynthesis process, supported by the opinion that light intensity greatly affects the photosynthetic efficiency of a plant. Water pH can also affect the photosynthesis process indirectly. With the proof of this photosynthesis engineering, it is very possible if the miniature of the photobioreactor using Hydrilla plants can reduce air pollution in the room, so that the air can be cleaner and better for health. With the growth or arrangement of green plants such as Hydrilla in polluted locations can control air pollution more optimally.

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