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To Reduce the Annoying Light with Microalgae Window

Nafiseh Mohammadivahidi[1]

[1] MSc Student of Architecture, Department of Architecture, Tarbiat Modares University, Tehran, Iran

Correspondence: Nafiseh Mohammadivahidi, MSc Student of Architecture, Department of Architecture, Tarbiat Modares University, Tehran, Iran.

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Abstract

Aims: Improving energy efficiency and creating the quality of the indoor environment in buildings by using environmentally friendly energy sources instead of using fossil fuels that are impossible to recycle and cause environmental pollution is very important. The use of an algal facade system that generates energy sources through building components can be suggested as one of the new efficient alternatives to solve this system. ***Methods:*** Microalgae are a type of living microorganism that is in the simplest form of a plant sample and mainly single-celled. Compared to other plant species, these organisms have a very high ability to absorb air pollution due to the high surface-to-volume ratio. By absorbing carbon dioxide from air or water during photosynthesis, they produce about 60 to 75 percent of the oxygen needed by humans and animals, which is 10 times more than a mature tree and photosynthetic grass. ***Findings:*** In this research, in the first stage, based on valid scientific articles and library studies, new information is collected and produced, and then the behaviour of microalgae bioreactors is investigated and the possibility of replacing old panels with bioreactors is investigated. ***Conclusion:*** The use of alternative energy due to the reduction of energy resources and no destruction of the environment, and the use of environmentally friendly energy using microalgae, in addition to producing the required oxygen, by adding bioreactor panels as an additional view the building has been designed to create privacy and proper view of the building facade.

Keywords: microalgae, facade, bioreactor, reducing energy consumption, natural light

1. Introduction

The significance and the necesity of the subject of the study has a rich literature (Alabi, A. et al., 2009; Anderson DB. et al., 1986; Becker EW., 1984; Cole RJ. et al., 2009; Elrayies GM., 2018; IEA., 2012; Kumar K. et al., 2011; Malik A. et al., 2016; Cervera Sardá R. et al., 2016; Schipper, L. et al., 1984; Umdu ES. et al, 2018; Wolkers H. et al., 2011; Talaei M. et al., 2020; Talaei M. et al., 2017; Talaei M. et al., 2019; Talaei M. et al., 2021; Talaei M. et al., 2022; Arbab M. et al., 2020; Bazazzadeh H. et al., 2021; Ganji Kheybari A. et al., 2015; Goharian A. et al., 2020; Goharian A. et al., 2021; Mahdavinejad M. et al., 2012; Mahdavinejad M. et al., 2012; Pilechiha P. et al., 2020; Saadatjoo P. et al., 2021; Yazhari Kermani A. et al., 2018) that shows the importance of the issue. Architectural design methods are constantly changing and architects have always sought to introduce design techniques based on information technology, advanced materials and also environmentally friendly, which causes a change in the design process of architects from emphasizing form to function. In recent years, there has been a lot of research and design of advanced building facades, often with adaptive and kinetic features focused on environmental performance. One of the important factors in the phenomenon of climate change and its adverse effects in global warming is the increasing and excessive increase of carbon dioxide in the atmosphere (Lan, Malik, et al, 2016). Despite the fact that more than 70% of the carbon dioxide in the world is produced in urban areas (IEA, 2012), it is a very important issue to be able to reduce this volume of carbon dioxide and start producing oxygen instead. In this regard, it is possible to help provide comfort and reduce air pollution by addressing the factors influencing this environmental challenge in controlling and reducing the amount of carbon dioxide as well as oxygen production. Recent research shows that the construction sector is one of the largest energy consuming sectors with the consumption of approximately 40% of the world's energy and with the production of approximately 30% of greenhouse gases, it has surpassed the transportation and industry sectors and it is predicted that this number will double in the next 20 years. These results show that with the increasing urbanization, the building is one of the main environmental risk factors with a large contribution to the emergence of key phenomena; Including climate pollution, global warming, as well as the limitations of energy and natural resources, the world will be affected by the mentioned phenomena. In order to prevent more serious problems in the future, it is necessary to meet the current needs without jeopardizing the needs of future human generations by applying a sustainable approach in man-made environments. Microalgae, as one of the important candidates, has attracted a lot of attention in integrated designs in order to neutralize the adverse effects of the increasing human activities and to compensate for the damages caused by human hands on their living environment. Microalgae bioscapes can be used in the development of sustainable buildings and their active coexistence with the environment, as well as by implementing various considerations, they can put buildings in a beneficial interaction with the ecosystem and reduce its negative effects significantly. Among them, algae, as the simplest organisms with chlorophyll, which also have great diversity, using different metabolic pathways, the most important of which are photoautotrophic, photomixotrophic and photoheterotrophic pathways, by receiving light, absorbing $CO2$ and nutrients in Water grows and produces oxygen and biomass containing carbohydrates, lipids and proteins. Microalgae are considered as the powerhouses of the oxygen cycle on the planet and during photosynthesis by absorbing carbon dioxide from the air or water, they are able to produce about 60-75% of the oxygen needed by humans and animals (Wolkers, Barbosa, et al, 2011). Microalgae are able to carry out photosynthesis 10 times more than a mature tree and grass; So that in the production of one kilogram of microalgae biomass, 1.8 kilograms of carbon dioxide is absorbed (Elrayies, 2018). The produced biomass of algae contains 23-27 kilojoules of energy per gram of their dry weight and can be used as a raw material in the production of value-added materials. The ability of microalgae to produce oxygen and biomass is used in the production of carbon-neutral fuels and other biological products, by removing $CO2$ from flue gases and their ability to feed on polluting elements in wastewater make them an important candidate for multi-faceted solutions to environmental problems and the development of sustainable measures for the developments of today's world has become. The use of microalgae in the wall of the building as a type of living microorganisms that, due to the high surface to volume ratio, have a very high ability compared to the superior species of plants in absorbing air pollution (Bibeau, Tampier et al, 2009), city walls and buildings have wide surfaces are in contact with the polluted air of the city, the use of microalgae as biological facades in buildings, in addition to absorbing carbon dioxide in the air and producing oxygen, turns ordinary buildings into healthy buildings with a lively and dynamic appearance, and finally, the walls of the building become a become energy production factories (Sardá, Vicente, 2016).

2. Literature Review

Responsive building envelopes have functional characteristics similar to intelligent building envelopes, which include real-time sensing, kinetic weather-adaptive elements, intelligent materials, automation, and the ability to override the user (L. Schipper et al., 1984). But they also include interactive features, which allow the building system to be adjusted over time, as well as the ability of occupants to physically manipulate building envelope elements to control environmental conditions (R. Cole & Z. Brown, 2009). Algal bioreactor panels are considered as a skin system that can adapt to environmental demands and provide opportunities to achieve energy efficiency and environmental comfort. It is possible to achieve sustainability by implementing advanced bio-reactive facades that use daylight, sunlight control and ventilation systems and by cultivating microalgae as an energy source in the bioreactor facade, using waste carbon and producing solar thermal energy in this process. The materials needed for the growth of algae include carbon dioxide, nitrogen, phosphorus and other organic materials that are present in the wastewater from buildings. The carbon dioxide needed for algae growth can be injected through pipes from under the building, created through combustion, because carbon dioxide is lighter than air and has a natural tendency to flow upward. Algae are considered the most effective transformers of sunlight, converting 3-8% of sunlight into energy, while land plants are only able to convert 0.5% (Becker EW, 1982). Algae are among the most efficient plants in converting solar energy and are able to use many nutrients. The presence of microalgae in water makes it flexible to move around the building and the growth of algae continuously produces oxygen and biomass, and due to its adaptive movement, bioreactors exhibit useful responsive behavior when exposed to sunlight. are considered functionally. (Anderson DB, 1985).

The integration of various functional aspects in the design of biocompatible facades can often act as a catalyst in the wide applications of this advanced technology. Here, the role of architects is necessary in creating a bridge between engineers and biotechnology specialists in order to create and produce this new design (Öncel et al., 2016). In this way, algae are able to produce a large amount of oxygen needed by animals and humans (Wolkers, 2011) and have a very high potential in fixing carbon dioxide gas (Umdu et al., 2018). This process leads to the absorption of carbon dioxide through photosynthesis (Umdu, et al. 2018) and oxygen is released (Klinthong et al., 2015).

3. Methodology

One of the important factors in the phenomenon of climate change and its adverse effects in global warming is the increasing and excessive increase of carbon dioxide in the atmosphere (Lan, Malik, et al, 2016). Despite the fact that more than 70% of the carbon dioxide in the world is produced in urban areas (IEA, 2012), it is a very important issue to be able to reduce this volume of carbon dioxide and start producing oxygen instead. In this regard, it is possible to help provide comfort and reduce air pollution by addressing the factors influencing this environmental challenge in controlling and reducing the amount of carbon dioxide as well as oxygen production.

The use of microalgae in the wall of the building as a species of living microorganisms that, due to the high surface to volume ratio, have a very high ability compared to the higher species of plants in absorbing air pollution (Bibeau, Tampier et al, 2009), during the process of photosynthesis with Carbon dioxide absorption from air or water can produce about 60-75% of the oxygen needed by humans and animals (Wolkers, Barbosa, et al, 2011). Microalgae are able to carry out photosynthesis 10 times more than a mature tree and grass; So that in the production of one kilogram of microalgae biomass, 1.8 kilograms of carbon dioxide is absorbed (Elrayies, 2018). The walls of the city and buildings have large surfaces in contact with the polluted air of the city, the use of microalgae as biological facades in buildings, in addition to absorbing carbon dioxide in the air and producing oxygen, turns ordinary buildings into healthy buildings with a lively and dynamic appearance. Finally, the walls of the building become an energy production factory (Sardá, Vicente, 2016). Flat bioreactors are most widely used in the construction industry due to their suitable geometry and high surface-to-volume ratio. One of the important factors in the growth rate of microalgae is the way of mixing the culture medium, therefore, in plate bioreactors, by using the release of air bubbles from the bottom of the panels and the natural composition of the culture medium, as well as preventing the accumulation of dissolved oxygen in it, it increases the performance of the medium. Cultivation is assisted (Kumar, Goyal, 2011). Among the other benefits of using microalgae bioreactors in the facade of the building, in addition to absorbing carbon dioxide in the air, it is possible to produce part of the energy required by the building through the production of biomass, control the intensity of light entering the building, control the view and view of the building, thermal insulation properties and He also mentioned sound insulation, dynamism in the facade of the building, as well as reducing the overall cost of the building (Elrayies, 2018).

4. Case Studies

4.1 BIQ House-Arup

The world’s first bioreactive facade, unveiled in 2013 in a pilot project at the International Building Exhibition IBA in Hamburg, produces renewable energy from algal biomass and solar thermal heat. The structure, which features a bio-compatible algal facade, was built by international design firm Arup in collaboration with Germany’s strategic science consultants SSC and Austria-based Splitterwerk Architects. Algae grow and reproduce in a regular cycle until they can be harvested. Then they are separated from the rest of the algae and transferred to the BIQ technical room as a thick slurry. They can then be fermented in an external biogas plant and used to produce biogas. This apartment building was designed as part of a European movement to design carbon neutral, self-sustainable and renewable energy structures. Algae has been selected from all the technologies on display, the power of algae is perhaps considered the best ratio and greatest potential. Facades of the building that face the sun have a second outer skin that is placed in the facade itself. The microalgae used in the facades are placed in these flat plate glass bioreactors that form the “biological skin”. The dimensions of the used bioreactor are 2.5 meters by 0.7 meters. In total, 129 biological reactors are installed in the southwest and southeast of the building. This bioreaction plate is filled with 200 square meters of algae. The algae are continuously supplied with liquid nutrients and carbon dioxide through a separate water circuit that passes through the facade. With the help of sunlight, algae can photosynthesize and grow. This process creates a shiny and dynamic green facade for the building to produce sustainable and renewable energy. The panels can rotate along their vertical axis and track the position of the sun, and when fully closed, form a continuous outer skin that provides a thermal buffer.

The BIQ house takes all the energy needed to produce electricity and heat from the sun, leaving fossil fuels untouched. Bioreactors not only produce biomass that can then be harvested, but also absorb solar thermal heat, and both energy sources can be used to power the building. This means that photosynthesis is dynamically responding to the amount of solar shading required, while microalgae grown in glass bioreactors provide a clean source of renewable energy. When the algae reach a certain level of growth, some of the algae is harvested and transported indoors for processing, where the biomass is converted into biogas that can be burned to provide heat and electricity. Then, the carbon dioxide from the burning of biogas is used to feed the algae. This facade is the first of its kind in the world and uses the latest energy and environmental technology. Such innovative facades help reduce and eliminate 2.5 tons of CO2 emissions from buildings every year. Therefore, this remarkable concept of sustainable energy is capable of creating a cycle of solar thermal energy, geothermal energy and capturing biomass using a bioreactor view.

Figure 1. Bioreactive façade with algae filled panels, Damir Beciri

Source: http://www.robaid.com/tech/bioreactive-facade-with-algae-filled-panels.htm

4.2 Photosynthetics, Ecological Studio

Designed by EcoLogicStudio, an architecture and urban design studio based in London, in collaboration with the Urban Morphogenesis Lab - UCL and the Synthetic Landscapes Lab - Innsbruck University, PhotoSynthetica was presented at the Climate Innovation Summit week in Dublin. This shell absorbs about one kilogram of CO2 per day from the atmosphere, which is equivalent to 20 large trees. PhotoSynthetica is a photosynthetic building cladding system that uses solar energy to remove CO2 and pollutants from the atmosphere and produce a valuable food source in the form of algae, designed to be integrated into existing and new buildings, and consists of 16 modules (2 * 7 m), each of which acts as a photobioreactor using sunlight to feed live microalgae cultures and artificial light at night to create a dramatic effect. City air enters directly into the lower part of the facade and air bubbles naturally move upwards through the liquid inside the bioplastic photobioreactors. CO2 molecules and air pollutants are absorbed and stored by algae and converted into reusable biomass. The photosynthesized oxygen is then released from the top of each module. Algae give off a very spectacular faint glow at night.

The architects demonstrated a prototype of the system at the 2018 Climate Innovation Summit in Dublin in early November. The installation spanned the first and second floors of the main facade of the Printworks building in Dublin Castle. Like other EcoLogicStudio projects, the curtain is a form of biomimetic, a design that copies the structures and processes of nature.

Figure 2. The prototype installation of Photosynthetica created by EcoLogic Studio, covering the first and second floor of the historic building in Dublin

Source: http://www.ecologicstudio.com/

4.3 Waterlilly-Cesare Griffa

Designed by Cesare Griffa, the Water Lilly project features a system of intelligent architectural components designed as photobioreactors for growing microalgae inside buildings. This is a project that started in 2012 with the collaboration of a team of microbiologists from the University of Florence. The use of microalgae in architecture to create symbiotic behaviors such as reducing CO2 emissions, purifying air and gray water, and considering the much more intense photosynthetic activity of microalgae compared to plant organisms, WaterLilly is a system for breeding presented microalgae in architectural views. WaterLilly differs from other systems because all the necessary components for algae growth are included in a single element without the need for a service module.

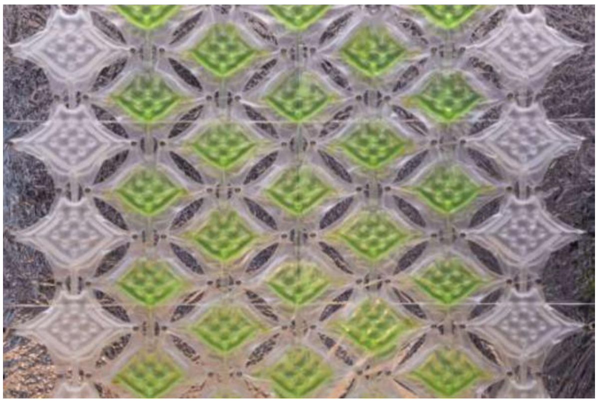

Figure 3. Prototype of assembled elements

Source: https://cesaregriffa.com/waterlilly

5. Conclusion

Despite the rising trend of global warming and significant changes in climate, which are the result of human damages in the nature of the planet, the need and necessity of peaceful coexistence with nature is felt. Architecture must respond, and to keep pace with this environmental challenge, architects must rethink design beyond digital media. Therefore, replacing existing panels with algal photobioreactors, despite the fact that the building under study is directly exposed to air pollution and inversion phenomena, as one of the important candidates, in order to neutralize the adverse effects, can compensate for the damages caused from the hand of man to the living environment, in the development of sustainable buildings and its active coexistence with the environment, beneficial interaction with the ecosystem and its negative effects, with the absorption of CO2 and also the production of oxygen required by the building and biomass containing carbohydrates, lipids and proteins. It should be a suitable alternative and adapt to climatic and functional changes in a flexible way, and based on this, the building shell becomes more efficient and dynamic. The research results confirms the current researches by the main pilars of the literature (Talaei M. et al., 2017; Talaei M. et al., 2019; Talaei M. et al., 2021; Talaei M. et al., 2022; Arbab M. et al., 2020; Bazazzadeh H. et al., 2021; Ganji Kheybari A. et al., 2015; Goharian A. et al., 2020; Goharian A. et al., 2021; Mahdavinejad M. et al., 2012; Mahdavinejad M. et al., 2012; Pilechiha P. et al., 2020; Saadatjoo P. et al., 2021; Yazhari Kermani A. et al., 2018).

Future work will include a series of experiments that will examine the rate of oxygen production under different conditions. This approach aims to develop a new design method and a feasibility study to design self-active responsive architectural shells that not only provide protection against nature but also provide positive interaction with humans. And in another research, the disorders and problems faced by this method are discussed and what challenges we face in the research process.

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