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Microalgae Building Enclosures: Design and Engineering Principles

Daekwon Park

Book Review / TECTONICS

Microalgae Building Enclosures: Design and Engineering Principles
By Kyoung Hee Kim
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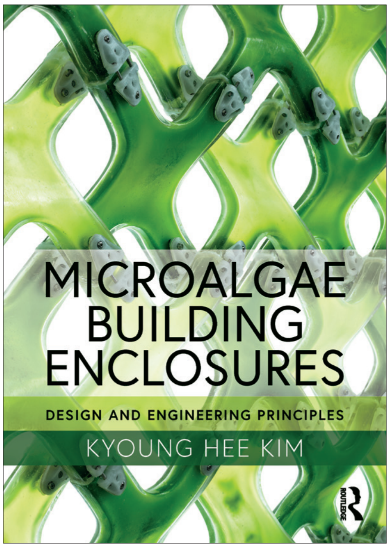

The book *Microalgae Building Enclosures: Design and Engineering Principles* (2022) by Kyoung Hee Kim explores the symbiotic relationship between microalgae and the built environment. Microalgae is a living and breathing photosynthetic microorganisms found in lakes, oceans, and even wastewater. Microalgae provide many advantages over terrestrial plants with a wide range of biochemical diversity (more than 25,000 known species), excellent growth rate, and biomass productivity. Hence, researchers in pharmaceutical, nutraceutical, food, cosmetics, and alternative energy industries are actively developing creative and novel ways to use these fascinating tiny organisms.[1]

Dr. Kim, an architect, building façade specialist, and STEM researcher, is among the leading experts in microalgae research. Her primary target is the built environment, ranging from furniture and interior space to architecture and urban infrastructure. The multi-faceted and broad experience of the author provides a unique perspective and contribution to this field of research.

The wealth of knowledge contained in this book results from more than a decade of hands-on research conducted by Dr. Kim. In a sense, the book is the in-process report summarizing her meticulous research notebooks during this time. It is also important to note that her research is ongoing and gaining momentum. Despite more than ten years of dedication, I could see how passionate the author is about the topic. The attitude of the book is to introduce, educate, inspire, and invite current and future researchers and designers into the fascinating world of microalgae research and design.

Overall, the book provides a comprehensive case study and information related to microalgae and investigates the challenges and opportunities of integrating these fascinating organisms in our buildings and cities. A wealth of charts, tables, figures (which are all reproduced by the individuals in the team formed by the author), and references provide comprehensive knowledge on the topic. As such, this book is a one-stop source of state-of-the-art research on microalgae applications. Anyone interested in learning about microalgae and its applications will benefit from reading this book, including architects, designers, scientists, engineers, educators, and students.

Compared to other architectural publications that often target designers using inspirational case studies or engineers using scientific and technical data, this book merges both audiences. The wide range of experiences that Dr. Kim has had broadens the spectrum of this book, ranging from comprehensive engineering research data to speculative design case studies. Perhaps the most intriguing part of the book is the ongoing research project the author carried out from the conceptual phase to the working prototype phase. This research serves as the most compelling and promising real-world case study that highlights the potential of microalgae building enclosure applications.

The first part,”Microalgae Architecture Introduction,” describes the fundamental attributes of microalgae and how these can contribute to sustainable cities and buildings. The author emphasizes that although the performative benefits of microalgae are enabling a wide range of innovative applications, there needs to be more effort in both the private and public sectors to take this promising technology to the next step. This includes fostering net-zero energy carbon-neutral practices and continuously researching and developing energy-efficient technologies such as microalgae technology.

The second part, “Microalgae Architecture Case Studies,” presents a wide range of microalgae applications in the built environment at multiple scales (i.e., urban, architecture, and product). Applications in the urban infrastructure include larger-scale environmental remediation, fostering biodiversity, food production, and producing renewable energy sources. The urban intervention applications include microalgae photobioreactors integrated with rainwater collection systems and urban landscape features such as canopies and street furniture. Microalgae systems integrated with the façade and water management system are discussed at the architecture scale. Finally, the product intervention scale discusses microalgae applications, including micro-farming, commodities, plastics, furniture, and food.

The third part, “Microalgae Building Enclosure Design,” focuses on microalgae building enclosure design. The design criteria and the design and fabrication process are comprehensively presented using the multi-year research of the author. The author highlights the need for cost-effective mass cultivation to maximize the benefit of microalgae integrated building enclosures. To achieve this, the semi-continuous production mode (as opposed to batch or continuous production) is recommended with the potential for using wastewater and flue gas as nutrients. It is also important to implement biotechnical engineering and system optimization (e.g., light density, temperature, CO_2, nutrients, and pH, among others) and bioclimatic design strategies (i.e., a design that considers site and building orientation in relation to the local climate). Finally, the author emphasizes that it is critical to understand and satisfy the technical requirements such as structural integrity, energy attributes, water control, and airtightness during the design phase.

Finally, the fourth part, “Microalgae Building Enclosure Applications,” explores and speculates the potential application of microalgae building enclosures in the low-rise, high-rise, and retrofit contexts. In presenting the low-rise enclosure applications, the author emphasizes how the system should contribute to energy efficiency, create interactive and learning experiences, and improve the indoor air quality of residential, commercial, and educational facilities. On the other hand, the high-rise applications discuss the potential of microalgae integrated building skin, vertical landscape, and sky garden. These applications have the potential to provide adaptive daylight control, dynamic thermal insulation, indoor air quality improvement, and biomass production. Lastly, microalgae enclosures can serve as an energy-efficient retrofit strategy that reduces energy load, sequester carbon, and remediate contaminants in wastewater.

In a broader context, this research can fit in with the recent interest in natural materials. This trend is amplified by widespread environmental awareness of climate change, urban overpopulation, deforestation, and water deterioration. Most building materials such as metal, cement, brick, and glass need extensive energy to produce. They need to be processed in an extremely high-temperature and high-pressure environment created mainly using fossil fuel. Compared to that, natural materials grow all by themselves in ambient temperature and pressure.[2] Because of this, natural materials such as trees, plants, and microalgae can even be argued as having a negative embodied carbon as they sequester carbon when growing.[3]

Most materials from nature are composite materials with hierarchical structures. These biological materials are evolved to fulfill the functional requirements of the organism.[4] If you zoom in to a tree section, the first thing you notice is the tree rings, followed by countless pores covering the entire surface. At this scale, the woody tissue of the tree is a cellular solid that resembles a bundle of straws. However, if you further zoom in using a microscope, you can see that the cell walls are made of fiber-like cellulose suspended in thick glue-like lignin. These multi-scaler features make wood a versatile material. We cut down and dry trees to produce lumber for building construction. We also extract the cellulose to make paper and plastic or simply burn the tree logs to cook or warm our homes.

However, the microalgae material technology this book focuses on goes further than merely using the dead tissue of living organisms, such as the tree example. The growing process itself provides benefits in addition to providing its biomass as a building material. Similar research and applications include green façades, fungal mycelium composites,[5] and self-healing concrete using embedded bacteria.[6] In the case of microalgae, the growth acts as a dynamic façade system that creates ever changing opacity and shading. Wastewater or rainwater can be filtered through the system, getting purified and providing nutrients simultaneously. The microalgae can also use flue gas or indoor air as the source of CO2. Even after the life of serving, microalgae provide us with biomass that can be used to produce food and biofuel.

Microalgae applications need to be mini grow chambers or mini biological factories. In addition to serving a specific function (e.g., building envelope), the component or system itself needs to provide the environment for the microalgae. Therefore, microalgae applications are sensitive to the surrounding environment. In particular, microalgae façades have special needs, including daylight, temperature, oxygen, nutrients, and water, among other things. Dr. Kim argues that although these requirements mean more cost and complexity to construct and maintain the system, the potential benefits (e.g., energy production, thermal and daylighting potentials, food, biomass, and wastewater treatment) outweigh the challenges.

The author closes the book by restating the challenges, including cost, performance, longevity, operation, and maintenance requirements. She also points out that this field of research is still young, with only limited examples like speculative design proposals or laboratory-scale experiments. Hence, there are a plethora of avenues for architects, designers, engineers, and scientists to investigate. These include reducing maintenance and operation costs via system optimization, achieving multifunctionality, combining biomass production, maximizing energy savings, strengthening carbon sequestration, and fostering occupant health. The conclusion of the book is a call for further research and an open invitation to join the fascinating field of microalgae building envelope research. Dr. Kim, who is undoubtedly a leading expert on microalgae building envelopes, wants both the design and scientific community to participate and join her effort to make this promising technology a feasible and viable application.

Notes

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5. Libin Yang, Daekwon Park, and Zhao Qin, "Material Function of Mycelium Based Bio-Composite: A Review," *Frontiers in Materials* 8 (2021): 374.
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Daekwon Park is the Undergraduate Chair and an Associate Professor at Syracuse University School of Architecture. He is a Faculty Research Fellow and Director of the MATR LAB (Material Archi-Tectonic Research Laboratory) at the Syracuse Center of Excellence. Daekwon is a registered practicing architect based in New York and received his Doctor of Design degree at Harvard Graduate School of Design. E-mail: dpark103@syr.edu