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Conceptualization of Well-Building with Reference to Air-Filtration with Biomaterials

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Abstract

Aims: Over the last decade, green building standards and standard-setting organizations have made significant strides towards the market transformation of the building industry, resulting in a rapid expansion of green buildings and environmentally conscious building practices throughout the world. The WELL Building Standard focuses on the people in the building [1]. One of the biggest problems in the world today, that has devastating effects on human health and on global warming, is air pollution. By developing knowledge of biomaterials production, ways can be found to reduce these pollutants.

Methods: To write this article, a quasi-experimental research method has been used that examines the production of a biomaterial for air filtration in building skins. This shell, which is inspired by cell plasma membrane, meets WELL standards for the adsorption of air pollutant particles and their conversion into harmless particles, thereby optimizing indoor air quality, as well as helping to reduce air pollutants and improve global warming conditions. The use of peptoids -non-natural mimetics of peptides and proteins and like cell membrane phospholipids- to make this synthetic membrane is recommended in this article.

Findings: According to studies, peptoids can have side chains to adsorb air pollutant particles. The structure of peptoids allows them to exhibit certain features of cell plasma membrane, such as self-healing and self-assembly. These synthetic membranes can be fabricated with a structure like a cellular plasma membrane.

Conclusion: This research states that the time has come to elevate human health and comfort to the forefront of building practices and reinvent buildings that are not only better for the planet, but also for people [1]. Fabricating synthetic membranes, for buildings, with air filtration capabilities using peptoids, is one way to maintain human health and improve the planet.

Keywords: Air Filtratio; Building Skins; Bio-Inspired Materials; WELL-Building

Abbreviations: WHO: World Health Organization; ULPA filter: Ultra Low Penetration Air Filter; ACF: Activated carbon fiber; PCO: Photocatalytic oxidant; NTP: Non-Thermal Plasma; TiO_2: Nano-titanium dioxide

Introduction

Air pollution is among the major problems that has affected human life in today's world. For example, according to the latest WHO results, 4.2 million people die each year because of exposure to outdoor air pollution, and many more suffer from various diseases. Also, 9 out of 10 people, or about 99% of the world's population, live in places where the air quality exceeds the maximum amount of pollutant particles specified in the guidelines of the World Health Organization [2].

Factors such as population increase, use of vehicles, use of fossil fuels, increase of factories etc. have resulted to production of air pollutants. On the other hand, industrial development in the mid-nineteenth century led to the creation of these pollutants and results gradually appeared in different countries in the middle of the 20th century. Air pollution, both ambient (outdoor) and household (indoor) is the biggest environmental risk to health, carrying responsibility for about one in every nine deaths annually [3].

It has also devastated effects on the other organisms and causes climate change. Its destructive effects are also observed in the construction industry, For example, the destructive effects of these pollutants on building materials. Not paying attention to the destructive effects of air pollutants and lack of planning for reduction of these particles and failure to take action to create technologies to control pollutants, has led to reduced air quality.

Therefore, finding solutions to reduce these pollutants in various fields including architecture and construction, seems essential. In recent years, efforts have been made to achieve this goal. One of these solutions are purification technologies. Filtration is currently the most widely used purification technique. Air filtration, as an effective method to remove particulate matter and alleviate air pollution, has been widely studied over the last three decades [3].

The most effective and commonly used purification method for harmful gases is adsorption. Various types of air filtration materials have been produced in the construction industry, including 1. Glass fiber air filter material 2. Activated carbon fiber (ACF) 3. Nanometer fiber 4. ULPA filter (Ultra Low Penetration Air Filter) with super fine glass fiber 5. Film compound filter material 6. Nano-titanium dioxide (TiO_2) photocatalytic material 7. electret filter material etc., and other technologies like Trombe wall [4].

Air filtration membranes such as electrospun nanofibrous membranes are another category of filtration technologies that play an extremely important role in the filtration process which domains the filtration efficiency and filtration result [3]. Despite the existence of these filtration technologies in the construction industry, less research has been done in the field of bionic architecture to find a solution for air filtration [4].

With the expansion of bionics in various scientific fields such as architecture, the use of natural solutions to solve our problems, and the use of smart materials, solutions can be found to reduce air pollutants through technologies related to the building industry. It is believed that the bionics is a technological science to study the structures, characters, elements, behavior, and interaction of the biologic system [5], to provide the new design idea, working principle, and system structure for the engineering [5].

Bio-inspired biological materials are made in nano-, micro- and macroscales. These materials are inspired by the structure, form, function, or process of living nature and are made to meet human needs and problems and have different applications [6].

Herein, the possible use of the structure of cell's plasma membrane by means of biomimetics, to produce a shell for buildings that acts as air filter, is expounded. A shell that can adsorb pollutants and turn them into harmless particles. This skin can be produced using polymers called peptoids. Peptoids are synthetic polymers made of amines that mimic proteins and peptides. These lipid-like polymers can be layered like plasma membrane phospholipids and have similar functions [7].

This synthetic shell, like the plasma membrane, can have side chains that absorb pollutants, thereby removing them from the environment and turning them into harmless particles. This shell for several reasons including cheap and efficient production, the availability of amines needed to make peptoid chains, more chemical stability, and heat resistance of peptoids than phospholipids etc., will be an efficient technology in the construction industry [7]. This skin made of lipid-like peptoids, is in fact a bioinspired material that due to the research, have the ability of self-assembly and self-repair like plasma membrane. Soon lipid-like peptoids might benefit the building technology and application (Figure 1).

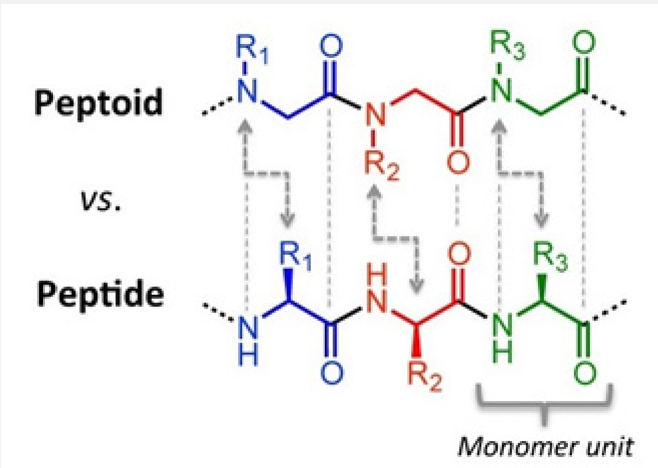

Figure 1: Comparison of the peptides and peptoids structure and how the peptide is converted to peptoid. [16].

Literature Review

As Orlando et al. [8] stated today, different technologies have been developed for air filtration inside and outside buildings, which have different functions, and each is to adsorb a specific type of pollutants. There are six air filter technologies including: 1. Mechanical filters 2. Electrostatic filters 3. Adsorbent filter 4. Photocatalytic oxidant (PCO) 5. Non-Thermal Plasma (NTP) 6.

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Electrospun nanofiber filters. These filtration technologies have different abilities for removing particles and gaseous compounds.

Adsorption filters are the best option for adsorbing gaseous pollutants in the air. As Lv et al. [3] stated, air filtration membranes have been highly investigated in the last two decades due to their important role in the filtration process, and simultaneous development of filtration technologies and filtration membranes were enhanced with the emergence of new materials with great physical and chemical properties [3].

These air filtration membranes are used in architecture and construction industry. For example, building skins can act as air filtration membranes. A variety of smart and environmentally friendly skins are made for buildings. One way to fabricate these building envelopes with efficient performance and structure is mimicking the samples found in nature and to use their form, function, and structure.

Biomimetics is a field that includes principles of sciences such as biology, chemistry, and engineering, which is based on the mimicking nature and is used in various fields, including architecture. As Al-Obaidi et al. [9] stated biology presents a new paradigm in various fields, such as engineering, as a novel basis for technological thinking and has been integrated with architecture through biomimicry that involves nature as a massive database of mechanisms and strategies to be implemented in designs [10].

As Imani et al. [11] stated construction technology has experienced a dramatic development in the use of bio-inspired materials. Around 0.25% of all known natural organisms have a current application in the industry. Mimicking structural, behavioral, functional, and morphological aspects of natural organisms can lead to numerous types of bio-inspired materials all introducing new methods for structural design, thermal insulation, waterproofing, etc.

One group of these bio-inspired materials are bio-inspired building envelopes that as Imani et al. [11] stated has different types that is categorized below:

a) imitating natural structures

b) direct use of natural organisms

c) imitating construction process [11] (Figure 2).

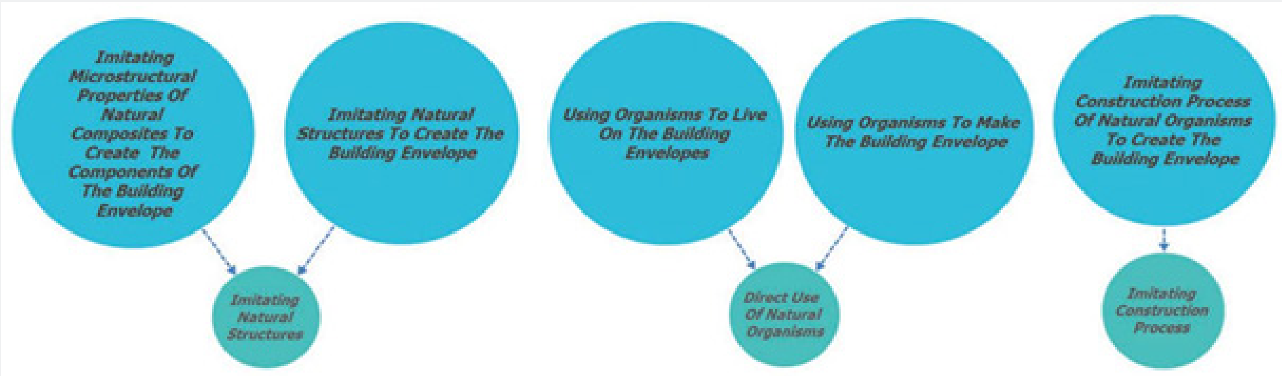

Figure 2: Types of bio-inspired building skins [11].

Natural microstructures and nanostructures could be imitated to produce better and more functional products in the field of architecture and construction industry [11]. As Bhushan et al. [6] stated in nature, there are materials, objects, structures, and processes in different scales, such as animals, plants, etc., that can be the model of engineers and lead to the production of processes and materials with special properties. One of the patterns for the fabrication of synthetic membranes is the structure of cell's plasma membrane.

As Jin et al. [7] stated due to its special structure, cell membrane is a very suitable model for making synthetic membranes. This synthetic membrane can be fabricated in different scales using particles like membrane lipids, such as lipid like peptoids [12].

The plasma membrane's structure is made of a phospholipid bilayer. Phospholipid molecules are composed of glycerol, a phosphate group, and two fatty acid chains. The plasma membrane has different features as self-assembly and self-healing. As Jin et al. [7] stated one of the key factors in maintaining stability in the structure and function of natural structures is the molecular self-assembly. Another property of cell membranes that make them a suitable model to produce synthetic shells is self-healing.

As Creasy et al. [13] stated biological systems like plasma membrane demonstrate autonomous healing of damage and are an inspiration for developing self-healing materials that can diagnose their own structural integrity and "self-heal" when damage occurs and it's potentially beneficial to many engineering disciplines [13]. On the other hand, as Sych et al. [14] stated

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plasma membrane represents an outstanding example of self-organization in biology. Its major building blocks are proteins and lipids, which self-assemble to a fluid lipid bilayer driven mainly by hydrophobic forces.

As AaronáLau et al. [15] stated materials that can be conveniently tuned to present the biochemical, morphological, and mechanical features of native biological systems are of special interest to biomaterials science. Peptoids or poly-N-substituted glycine's, a class of highly customizable peptidomimetic macromolecules, could also potentially enable significant advances in biomaterials science (Figure 3).

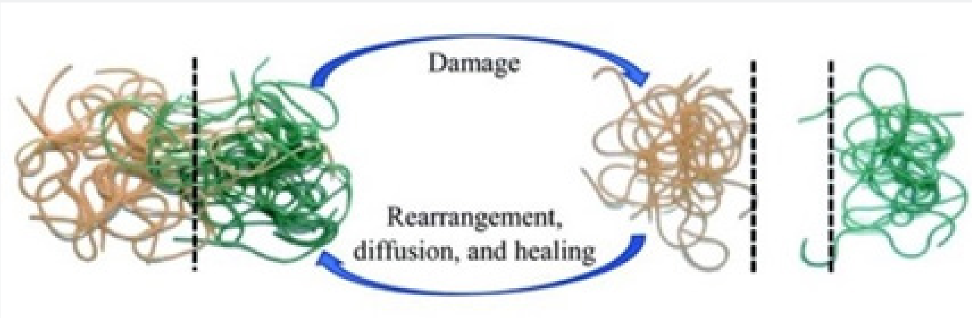

Figure 3: Schematic of physical self-healing process [17].

As Jin et al. [7] stated peptoids, can be utilized to fabricate synthetic membranes. Peptoids are particles with a structure like peptides and proteins. In fact, these particles can be made by imitating peptides and proteins using many amines available in the commercial market at low prices. Among the characteristics of these particles are their thermal and chemical stability and their ability to absorb side chains for various functions [16-18] (Figure 4).

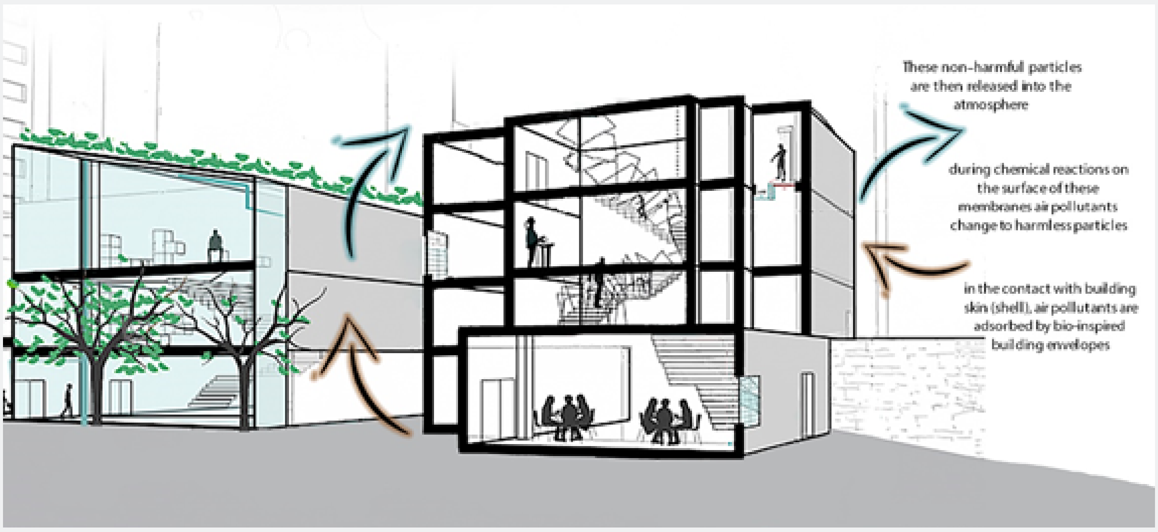

Figure 4: Air filtration through building skins.

Jin et al. [7] demonstrated membrane-mimetic materials and synthetic membranes imitating cell membranes that have special features such as self-assembly and self-healing. The self-assembly feature of these materials allows them to add side chains in different sections depending on their need. In general, membranes made of peptoids have the structural strength of lipid bilayers and function like membrane proteins. These side chains could adsorb air pollutant gases and turn them into harmless molecules [19-22] (Figure 5).

Methodology

Using a qualitative method, this prescriptive research aims to show how lipid-like peptoids might benefit the building technology and application and explane how the lipid-like

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peptoids based technologies could be adopted in architecture and building industry. With documentary analysis of various written records as mentioned in the text and investigate case studies, this research looks to show the possibility of production of synthetic shells for buildings that can adsorb air pollutants and have features like self-healing, self-assembly and air filtration [23-26].

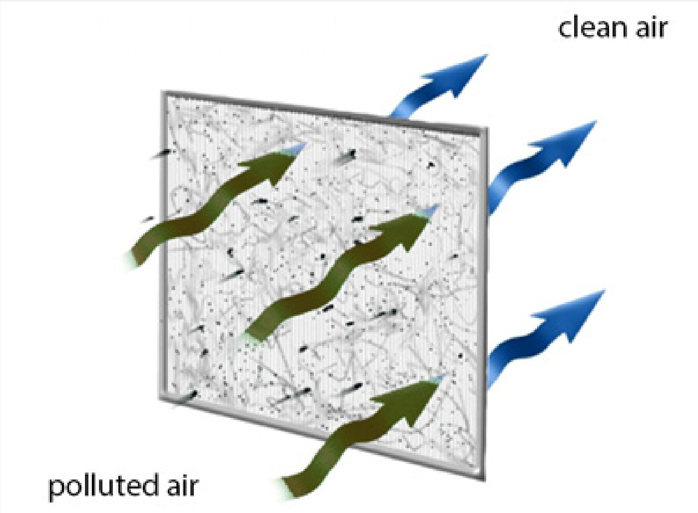

Figure 5: The concept of air filtration through synthetic membranes [18].

Result and Conclusion

Air pollution is among the major problems people face today, which has resulted many problems for the environment, buildings and human's health. Nowadays, finding solutions to control air pollution seems necessary. One of these solutions is filteration technologies and the use of building air filteration membranes. This literature review introduces the possibility of utilization of the plasma membrane's structure by means of biomimetics, to produce a shell for buildings that acts as air filtration and have self-assembly and self-repairing features. It also explains the possible use of the lipid-like peptoids in the building industry [27-30].

However, so far, bio-inspired materials have not been used in air filtration technologies. Bio-inspired materials like synthetic membranes fabricated from lipid-like peptoids could be used as building skins to adsorb air pollutants and turn them into harmless molecules. Developing a theoretical framework which addresses current issues of [11] using bio-inspired materials and specifically synthetic membranes fabricated from lipid-like peptoids as air filtration membranes in building industry, is required [31].

Using this framework, the way of fabrication and utilization of synthetic membranes made of lipid-like peptoids and the way of adding side chains to the synthetic membrane's structure for adsorption of air pollution particles, is determined. Further investigations about color change of these membranes caused by amount of air pollutants and warnings of increasing pollutants, would be conducted [32].

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