Designing Post COVID-19 Buildings

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The COVID-19 pandemic forced the accessibility, social gathering, lifestyle, and working environment to be changed to reduce the infection. The current state-of-the-art engineering control preventive measures presented include ultraviolet germicidal irradiation (UVGI), bipolar ionization, vertical gardening, and indoor plants. They have potential to improve the indoor air quality.

COVID-19 indoor air quality green plant healthy building

1. Introduction

The current COVID-19 pandemic has resulted in significant changes to every human life and caused economic crises and travel bans in most countries [1]. Further, these outbreaks, resulting from numerous forms of infections, have resulted in inferior living environments. This persisting situation can no longer be controlled by only employing a simple strategy, such as quarantining and physical distancing. This raise concerns over the effectiveness of the current strategies adopted to control the transmission of the. COVID-19 virus. Thus, it calls for a more contemporary, comprehensive, and innovative approach in dealing with COVID-19 virus/variants [2]. The COVID-19 infection is strongly linked to air quality, with proof that airborne transmission is possible [3]. COVID-19 pathogens are an aerosol size of less than 5 μm [4], which can be defined as ultrafine particles [5]. Since the ultrafine virus particles containing liquid are lightweight, they tend to be in the air in an aerosol form for about 30 min [6].

Recent investigations have demonstrated that people contract COVID-19 via indoor airborne transmission, especially in crowded and poorly ventilated environments [7]. Thus, maintenance of optimum air quality is required to eradicate the spread. This demands innovative changes to the existing indoor and outdoor infrastructure to positively impact the occupants in even the most densely populated spaces [8]. This also challenges the traditional design and construction approach to residential and public buildings in the post COVID-19 pandemic period [9]. Post COVID-19 architecture is a concept that is ongoing, which is applied to both future and existing building with healthy building aspects [8]. The healthy building concept mainly focuses on creating a comfortable and desirable indoor environment, which is measured in terms of the indoor environmental quality (IEQ) [10]. A healthy IEQ is expected to positively impact the occupants in most densely populated buildings in terms of physical, mental, and social aspects [11]. The IEQ refers to the quality of the living environment that exists within a building [12]. The level of indoor environment quality relies on several variables, such as thermal, visual, acoustic, and chemical [13][14][15][16]. The variables, which should be assessed individually and/or collectively, include indoor air quality, thermal comfort, ventilation, acoustic performance, lighting, and spatial layout [3][17].

A newly constructed or an existing building might not have the optimum levels of IEQ variables, as they can be altered during the usage of the building [18]. Buildings constructed without the required IEQ lead to unsafe buildings that ultimately cause poor health, learning difficulties, and productivity issues [19]. This is one of the major challenges during the COVID-19 pandemic that is present in most homes, schools, and workplaces. Thus, it is necessary to tune a building with a high IEQ level to ensure the health and well-being of its occupants [10][20].

Air quality is one of the factors that plays a major role in providing a healthy IEQ [21]. The quality of indoor air can be compromised by both outdoor and indoor sources of pollutants related to building materials, equipment, animals, and humans [22]. Indoor air can be contaminated with organic gases, such as volatile organic compounds, and inorganic gases, such as radon and ozone [23]. Furthermore, particulate matter, such as mold, asbestos, and silica dust, can also pollute the indoor air [24]. These indoor air pollutants result in a poor IEQ and induce health effects, such as asthma, throat pain, shortness of breath, and heart diseases [23]. Cancer, chronic lung diseases, and bronchitis are also some serious conditions caused by poor indoor air quality [25][26]. Moreover, these indoor air pollutants are often linked to mental conditions, such as increased negative feelings, intensified violent behaviors, degraded concentration, and mental exhaustion [27].

Thus, to improve the indoor air quality, the spatial layout should be considered during building design [28]. Spatial design is a conceptual design approach that accounts for both the interior design and service design. This requires the flow of people between interior and exterior environments [29][30]. Design decisions are typically made by the designers to promote social interactions in accordance with the sociability and well-being of the occupants [28]. Furthermore, biophilic design ideas are also used to improve the indoor air quality through the view of nature with indoor plants, fresh air, and natural sounds [31]. These indoor plants and natural sounds are widely encouraged for the interiors of hospitals to promote a speedy recovery of patients and decreased hospital stay [3]. Hence, it can also be assumed that maintaining a better IEQ can even be effective against many of the infectious diseases that are caused by different virus types similar to the COVID-19 virus [11][12].

2. Recommended Solutions for the Post COVID-19 Buildings

2.1. Existing Buildings

The COVID-19 pandemic has had an impact on building construction techniques as it forced modification of the architectural design of buildings [8]. The existing buildings are neither designed nor constructed to effectively reduce the transmission of communicable diseases. Thus, it is important to consider new solutions to overcome such a situation in the way of adaptive reuse. This can be achieved in many ways, such as engineering controls and retrofitting of existing structures or improving the indoor air quality [9][21].

The holistic approach is the best way to control and minimize the impacts of the current COVID-19 outbreak [32]. This approach attracts people to work in buildings by considering their physical, mental, and social environments. Creating a healthy environment by retrofitting green plants inside building walls could be one of the best options to improve buildings' health. Plants are capable of absorbing and catabolizing many harmful environmental chemicals

[33]. Therefore, the use of indoor plants might be one of the most environmentally friendly air-purification techniques, with minimum energy use and a low cost. However, more specific research is still required to define the standard requirements for an indoor plant. The creation of indoor portable green walls is another solution used to achieve healthy buildings. This technique uses botanical biofilters and bioreactors, which neutralize pollutants through an active biofiltration process. In this process, the contaminated pathogens are moved into the biological active region, which is installed behind the wall system.

Cortes et al. [34] reported that the use of copper helps to prevent the transmission of coronavirus. The creation of antimicrobial copper touch surfaces within existing buildings can help to reduce the spread of coronavirus. This can be achieved in many ways, such as retrofitting and/or replacing door handles and handrails of doors and windows, lift surface, and control buttons with copper alloys products. This action requires an additional cost as copper is an expensive material and it require expenses to maintain [35]. These issues can be avoided by using “cold spray technology”. Hutasoit et al. [36] investigated the use of a cold-spray process to manufacture copper coatings onto steel plates. This can shorten the coronavirus’s lifespan to less than 5 h. Therefore, this cold spray technique could represent an option to replace contact surfaces in a building. The cold spray technology is one of the most promising solutions for creating a hygienic built environment in post covid buildings.

Another potential solution to reduce the transmission of COVID-19 disease is the application of surfaces with antimicrobial paint. These paints can destroy bacteria and viruses that come into contact with the surface of the paint [37]. However, commercialization of this paint requires an understanding of the nature of paints and their endurance. Incorporation of antimicrobial particles into regular paints before application to building surfaces is another method that reduces the transmission of the disease. Silver ions and glass ceramic ions can be used as antimicrobial particles mixed with paints, which have the ability to reduce the growth of harmful bacteria and coronavirus [37]. Further antimicrobial chemicals, polymers/composites, and nanoparticles (i.e., with antibacterial, antifungal, and antiviral action) can be directly applied to existing building surfaces or integrated into coatings to reduce the spread of coronavirus [38].

The air cleansing technique using air ionization, which includes the injection of ions into a room, has the capability to improve the indoor air quality and reduce the transmission of coronavirus [39]. Bipolar ionization appears to be one of the most commonly utilized ionization techniques to avoid the spread of the virus in air. Bipolar ionization devices have been recommended by many engineers due to their low cost regarding initial purchase, installation, maintenance, and materials expenses. Another advantage in this system is the low pressure drop for the air handling equipment [39][40]. This system can be installed in any existing building at any location without causing any disruption.

Installation of the UVGI technology in existing buildings is another direct approach to preventing airborne transmission [7]. This technology is considered to be applicable for large buildings to reduce virus concentrations by utilizing human-safe UV radiation intensity. UVGI has the ability to provide considerable protection at a low cost and is particularly well-suited for retrofitting older buildings. However, further research is needed to improve this technology in a safe and commercially viable manner. In the absence of people, mobile UVGI devices can be used

to clean surfaces and indoor air, and passageways. This device can also be placed on the floor, pulling air at lower levels, and it contains a G4 filter that removes particles to keep the UV lamp clean inside. However, before utilizing a mobile UV device, one should ensure the surrounding are not exposed to UV radiation as it harms the inhabitants.

Recently, a smart Soterius Scout bio sensor was induced to detect viruses in buildings [41]. This can deliver results in under a minute, giving someone the green light or alerting them to the need for a test and self-isolation. The sensor is small enough to be placed on a personal fob card, and it is simple to use. A simple swipe over the sensor can help to detect the presence of a virus. This represents a crucial tool that can be used to combat COVID-19, allowing for precise early identification.

Separation of a large open building space with a plastic barrier with a zipper door is another option that could be used to reduce disease transmission. This system contains a particle counter, portable HEPA filter, aerosol generator, and pressure gauge. This strategy is more suitable for use in offices, hospitals, schools, and university buildings. Adapting this system to existing buildings will help to reduce the cost and activity induced by workplace capacity limits imposed during the COVID-19 pandemic.

2.2. Future Buildings

The post pandemic period highlights the importance of thinking forward to advances in construction techniques that speed up emergency building development. Effective ventilation is an essential part of engineering solutions for future buildings. The most cost-effective method that provides fresh air is natural ventilation. This can be considered at the building design stage. While it may appear that leaving windows and doors open to facilitate a continual flow of fresh air into a structure is a viable option, to construct healthy buildings, the building must be re-evaluated for appropriate ventilation.

The modular construction strategy has been successful at coping with pandemics or natural disasters and producing cheaper and faster-built construction [42]. Parking areas and other structures are converted into emergency centers and temporary hospitals during pandemic. These adaptive strategies will be beneficial for future crises [43]. Lightweight and adaptable structures are also preferable for their speed and portability in response to a pandemic [42]. These temporary structures are designed and installed by designers to build field hospitals that can be moved and installed easily for COVID-19 patients.

It is important to think of every potential location and the risk of becoming a source of pathogens inside the building at the design stage. More cleaning strategies focused on new technologies could be implemented by post-pandemic architecture. Virus transmission can also be reduced by applying touchless technology on potential contact surfaces of buildings. The use of Toe-To-Go elevator systems in future buildings is one innovative technology that will avoid contact with operating lift keys. This technique was recently adopted in a Chicago building [44]. Further, automation, voice technology, and artificial intelligence-based facial recognition can be adopted in the design of post Covid architecture [3]. Post Covid building design principles should aim for more

contactless routes, such as smartphone control lifts, door and window locks, and automatically opening doors with face identification. These systems could include other space temperature control programs and clean them automatically to destroy pathogenic substances, viruses, and bacteria. Even though there is an additional expense associated with incorporating these techniques into future buildings, it will improve occupants' health and provide value regarding the money being used.

In Australia, residential houses are constructed with a hip end roof [45]. Part of this roof cladding can be designed with UV filter glass with a transparent solar panel in post COVID-19 pandemic building design. This enables sunlight to travel into the building, which helps the growth of indoor plants and boosts vitamin D levels for humans. This glass roof has the capability to produce power, which can reduce electricity costs and greenhouse gas emissions. Thus, this proposed roof design could be an option to improve the health and quality of built environments.

Post COVID building design should consider the use of bipolar ionization systems, UVGI technology, building products with copper alloy, and antimicrobial paint. Further, the interior and exterior building design should adopt indoor plants and vertical planting strategies. These approaches will enable fresh air and improve occupants' health, thus controlling virus spread. Consequently, this may reduce lockdowns and improve the economy of a country.

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