Rethinking of the Adaptability in Mass Housing for Pandemic Situations

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Abstract— Pandemics spread due to poor housing conditions. Diseases have resulted in inducing the concept of mass housing, evident from housing projects initiated after the Great Plaque in London. Current pandemic, i.e., the spreading of the COVID-19 virus affected physical health of humans at alarming rates. The relationship between the spread of pandemics and living environments is unexplored. The study intends to bridge the gap in literature, and explore methods that could be implemented to mitigate situations in future scenarios. The parameters by the WELL Building Standard®, of air, water and light have been considered. Results explicitly prove mechanical systems of residential housing units need a (MERV) of 8, as 70-85% of particles can be captured. Relative humidity between 40%-60% can limit spreading of COVID19 within housing interiors. Pressure difference between corridor spaces and rooms will prevent air circulating from source to another in hospitals, minimising spreading of pathogens. Similar strategy can be adopted into the housing context via mechanical ventilation systems. The most effective method to limit spreading of pathogens from room to room in hospitals is to design a buffer space. This can be adopted in the housing context, such as powder rooms in apartments. Airborne viruses that contain single-stranded RNA are reduced by 90% with a low dose of UV light and is eliminated through building glass layers. A set of adaptive guidelines have been derived, to be applied in designing mass housing and also in managing Built Environment in similar situations.

Keywords*: pandemic, mass housing, adaptability*

I. INTRODUCTION

The rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2) has caused massive destruction across the globe. The virus has affected physical health at most alarming rates and imposes emotional, social, and economic crisis for the people living in the world. Thus, the world has taken global and national measures to minimize the spread of the Virus. However, global recognition of mitigation measures for the COVID-19 pandemic has not been translated into effective planning of housing built environments.

From history, it is evident that the transmission of diseases have inspired architects in the design of healthier hygiene oriented living built environments. These have led to development of cities, as in 17th century, as almost 87% of the city of London was destroyed by the Great Plague of 1665 and the Great Fire of 1666. These disasters resulted in the destruction of a large number of houses, however it also provided opportunities for housing. Architect Christopher Wren proposed replacing crowded buildings and narrow streets (once a hotspot and launching pad for plague and the fire) with wider avenues and richer spaces. Unplanned crowded housing, lack of proper sanitation and a lack of health knowledge of the people resulted in haphazard and poor living conditions in early industrial cities of Europe. In 1882 , tuberculosis bacillus was discovered and the disease associated with the unhealthy, crowded conditions in which the working-class people lived in urban areas. In the 20th century the modern movement in architecture was influenced by historical factors such as the need for healthcare to fight diseases like tuberculosis, and the success of modernism is inseparable from its close relationship with health.

However, the modernisation of the interior spaces of houses and other buildings do not primarily mitigate the spread of diseases. As

modern buildings propose several risks in health, as Legionnaires' disease outbreak in Philadelphia, Pennsylvania. The disease spreads due to the contamination of cooling water in air conditioning systems. The current spread of COVID-19 in buildings is associated with poor building design, ventilation and planning.

World Health Organization (WHO)'s investigation of the spread of COVID-19 in China indicated that 78% to 85% of transmission occurs within families rather than communities as a whole. Lockdown restrictions lower the lockdown restrictions lower the chances of the virus being transmitted outside of a family home. However, self-isolation can be difficult when living with other family members, and there is a high risk of household transmission. Thus, it is of paramount importance to provide mitigation methods to minimize the risk of household transmission.

In the 1990s, WHO put forward the concept of "healthy housing", which means "housing that enables the occupant to be in a completely good condition physically, mentally and socially. In 2014, the United States issued the WELL Building Standard®, the first standard for healthy buildings and the world's first people-oriented building certification standard focused on living conditions. The WELL Building Standard® is a performance-based assessment system that measures, certifies, and monitors the characteristics of the built environment that affect human health and wellbeing, such as air, water, nourishment, light, fitness, comfort, and mind.

Out of these assessment concepts, air, water and light are closely associated with the spread on the COVID-19 virus. According to previous investigations into SARS (Booth etal, 2005), spread through aerosolization remains a potential secondary transmission method, especially within the interior spaces. These aereosols are released naturally and through mechanical ventilation methods. These natural and artificial methods highlight on the importance of assessing the parameters of air, water and light of the WELL Building Standard® within the housing built environment.

Inadequate attention has been given to the spread of the virus under indoor microclimatic parameters of air, water and light. As literature stated that the effect of microclimate of an interior is very relevant to the propagation of droplets, where dispersion is enhanced by indoor and outdoor microclimatic profiles (Guerrero, 2020). As an example, current research depicts that respiratory particles exhaled after a sneeze can be dispersed by turbulent wind more than three times further than the physical distancing measures recommend. Thus, the microclimatic parameters of air, water and light is of vital importance when designing pandemic resilient housing interiors.

The aforementioned assessment system by WELL Building Standard® can be considered for design standards, and can be used to assess current housing and to prioritize interventions. This paper provides contributions based on the framework in the assessment system by WELL Building Standard® of the the microclimatic concepts of air, water and light of interiors as a foundation to re-think the current safety measures and to re-imagine the housing spaces to assure human well-being amidst the ongoing COVID-19 pandemic.

II. METHODOLOGY

The features that impact the spread of COVID-19 in the built environment (these built environments vary from hospitals to other public spaces) is examined upon and it is translated in terms of effective planning of housing environments. Firstly, through a qualitative systematic review the features reported by researchers as impacting the spread of the coronavirus were recorded and organized into three domains, i.e. - the concepts of the three domains of the WELL Building Standard® which form the structure of the framework.

The research papers for the systematic literature review were searched on, Emerald Insight, Scopus, ScienceDirect and PubMed. They were selected because of their different main subject areas, which could provide a thorough overview of the topic. The titles and the abstracts the papers were examined to determine if they were suitable for the research purpose.

The literature review led to the outline structure of the framework of mitigating the spread of COVID-19 in housing units in which the most

recurring determinants of housing quality were reported. The structure of the framework is based on the checklist proposed by the WELL Building Standard®. It brings together the major concerns to consider when assessing the suitability of dwellings to the needs of housing during a pandemic situation. The framework has therefore been structured into three domains as follows- air, water and light.

III. RESULTS AND DISCUSSION

Table 1 indicates the results of the systematic review with the three selected domains.

Table 1. Classification of referemces sccording to paper number

Domain	Reference Paper Number
Air, water	4, 5, 8, 10, 3,9, 13,6, 2,12,1
Light	7, 1, 15, 16

Source: Author

When the concepts of air and water are considered, the microclimatic conditions of the interiors of residential units is of paramount importance, this includes air temperature, humidity and air quality. The air within the interiors is of natural and artificial sources. With the installation of HVAC systems in the modern context, the risk of COVID-19 spreading is relatively high within interiors.

The prevention and mitigation of transmission of viruses through the built environment relies of inline filtration mediums (Chan etal 2020, Chang etal 2020). The mechanical systems of residential housing units generally need a minimum efficiency reporting value (MERV) of 8, as with this efficiency rate 70 to 85% of particles ranging from 3 to 10µm can be captured. The housing units of condominiums usually are installed with package thermal air conditioners (PTAC). A majority of viruses, including CoVs, have a size range between 0.004 to 1.0 µm (Goldsmith etal, 2004). It is proven that SARS-CoV-2 virus lies in aerosol particles in a spectrum of sizes from 0.25 to 0.5 µm(Liu etal, 2020). This aspect highlights on the need for filtration mechanisms with a high efficiency to reduce the transmission of these virus particles. Residential buildings require MERV-5- MERV-11 whilst hospitals and other health care settings utilize a MERV-13 or higher (Goldsmith etal, 2004).

Research as indicated that viruses including CoVs struggle to survive in typical indoor air temperatures and relative humidity above the range of 40% (Kim etal 2007, Biospace 2020, Noti etal 2013). Moreover, the changes in humidity levels effect on the susceptibility of an individual to viruses (Eccles, 2002). Humidity levels of interiors also impact on how far the virus gets deposited along the respiratory tract(Marr etal, 2019). However, humidity levels of interiors should not exceed 80% as high levels induce mold growth which have negative effects on human health (Block, 1953). According to ASHARE 170-2017, the current ventilation standards highlight on a RH range between 20% to 60%, however, with the above findings from literature, a relative humidity range between 40%-60% can aid in limiting the spread of the SARS-CoV-2 within housing interiors. This will help maintain thermally comfortable interiors in the long-run for occupant comfort (ASHARE 2017, Noti etal 2013).

The next part of this paper indicates about a strategy which is used in hospitals to prevent the risk of pathogens spreading from room to room. These aspects can be incorporated when designing the air systems of housing units. For example, in hospitals, high risk patients are stationed in rooms known as the protective environment (PE) rooms. This is to limit the exterior airborne infectious particles from entering the interior of the rooms. For this to be achieved, these rooms require a negatively pressurised HEPA air supply relative to the corridor space and adjacent other rooms (ASHARE 170-2017). This pressure difference between the corridor space and PE rooms will prevent the air from circulating from one source to another. Thus, the spread of the pathogens can be minimised. This similar strategy can be adopted into the housing context with regard to the pressure difference by the mechanical ventilation systems. However, in the medical context, the most effective method to prevent and limit the spread of pathogens from room to room is to design a buffer between common areas and high risk spaces, these are called anterooms. In the housing scenario, powder rooms cater this

similar function or a buffer room can be designed to limit the pathogens from spreading.

The third concept of light also help in the control of the existence of infections particles indoors. Daylight is an element of paramount importance in architecture as it has been proven that bacteria particles inside households to become less associated with human interaction than in darker spaces (Fahimpour etal, 2018). In buildings the spectrum of the sun is been filtered through windows, especially glass. The resuting UV rays are been absorbed with finishes indoors while preventing the reflection of the UV rays into the surrounding spaces.

The effect of daylight on indoor viruses and SARS-CoV-2 is still not examined, the use of UV rays has been explored. As electric lighting is already used as engineering controls for disinfecting the indoor spaces. UV rays are of short wavelengths and these are germicidal and these are successfully used in clinical spaces to deactivate viruses and also reduce the survival rate of viruses (Rutala etal, 2017)

Most UV light rays are eliminated in the atmosphere, while much of the UV rays is eliminated through building glass layers. Airborne viruses that contain single-stranded RNA (ssRNA) are reduced by 90% with a low dose of UV light, and the UV dose requirement increases for ssRNA viruses found on surfaces (Tseng 2007, Lytle 2005). Thus, in terms of the concept of light these startegies of using UV light can be used in housing units to limit the spreading of viruses.

IV. CONCLUSION

It can be proven from history that pandemic situations have led to new designing startegies for housing. For example the Great Fire and Great Plaque in England during the industrial revolution. The same scenario needs to looked upon within the prevailing COVID-19 sitaution. The WELL Building Standard® , was the first standard for healthy buildings and the world's first people-oriented building certification standard focused on living conditions. The WELL Building Standard® is a performance-based assessment system that measures, certifies, and monitors the characteristics of the built environment that affect human health and wellbeing, such as air, water, nourishment, light, fitness, comfort, and mind. The performance parameters of air, water and light were examined closely in this paper through a systematic literature review. Inadequate attention has been given to the spread of the virus under indoor microclimatologic parameters of air, water and light.

When mass housing in taken into context with the pandemic situation further research needs to be done. As the different types of mass housings such as flats, high risers, row houses etc…need to be examined with the pandemic situation. These are of paramount importance for further research within the housing context. This research paper is a steeping stone for further studies. As the paper presents set of adaptive guidelines which have been have been derived through a systematic literature review. These can be applied in designing mass housing and also in managing Built Environment in similar pandemic situations.

The conclusions derived from the detailed analyses and discussions are as follows-

The installation of HVAC systems in the modern context, the risk of COVID-19 spreading is relatively high within interiors.

The mechanical systems of residential housing units generally need a minimum efficiency reporting value (MERV) of 8, as with this efficiency rate 70 to 85% of particles ranging from 3 to 10μm can be captured.

It is proven that SARS-CoV-2 virus lies in aerosol particles in a spectrum of sizes from 0.25 to 0.5 μm.

This aspect highlights on the need for filtration mechanisms with a high efficiency to reduce the transmission of these virus particles.

Residential buildings require MERV-5- MERV-11.

Viruses including CoVs struggle to survive in typical indoor air temperatures and relative humidity above the range of 40%.

Humidity levels of interiors also impact on how far the virus gets deposited along the respiratory tract.

Humidity levels of interiors should not exceed 80% as high levels induce mold growth which have negative effects on human health.

A relative humidity range between 40%-60% can aid in limiting the spread of the SARS-CoV-2 within housing interiors. This will help maintain thermally comfortable interiors in the long-run for occupant comfort

A strategy which is used in hospitals to prevent the risk of pathogens spreading from room to room can be implemented in housing designs.

The high risk rooms in hospitals require a negatively pressurised HEPA air supply relative to the corridor space and adjacent other rooms.

This pressure difference between the corridor space and PE rooms will prevent the air from circulating from one source to another. Thus, the spread of the pathogens can be minimised.

This similar strategy can be adopted into the housing context with regard to the pressure difference by the mechanical ventilation systems.

The most effective method to prevent and limit the spread of pathogens from room to room is to design a buffer between common areas and high risk spaces, these are called anterooms.

In the housing scenario, powder rooms cater this similar function or a buffer room can be designed to limit the pathogens from spreading.

It has been proven that bacteria particles inside households to become less associated with human interaction than in darker spaces.

In buildings the spectrum of the sun is been filtered through windows, especially glass.

The resuting UV rays are been absorbed with finishes indoors while preventing the reflection of the UV rays into the surrounding spaces.

Airborne viruses that contain single-stranded RNA (ssRNA) are reduced by 90% with a low dose of UV light, and the UV dose requirement increases for ssRNA viruses found on surfaces

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