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# The Role of Building Sector in Preserving Occupant Health for A Sustainable Development: A Review

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**Abstract.** There has been a dramatic rise in research on sustainable development but limited attention is given to human aspects such as their needs and requirements in a sustainable building. The majority of people spend their time mostly indoor, either for working, studying or living. Therefore, it is important to understand the health implications of building on occupants. The impact of indoor environment on occupant health has been largely disregarded. It should be part of the main agenda in progressing towards sustainable development. This paper aimed to discuss the interplay between indoor environment and occupant health and highlighted the role of building sector in preserving occupant health to ensure that buildings can be optimised for the benefit of occupants. A literature search on published works of indoor environment and occupant health has identified four indoor environment parameters that contribute to occupant health. These include indoor air quality, indoor lighting, indoor cleanliness and ergonomic. The impacts of each indoor environment parameter on occupant health were discussed in this paper. The findings will serve as reference for policy makers to preserve occupant health in buildings and as enhancement strategies for sustainable building development to fulfil the human requirements.

## 1. Introduction

In 1987, a report entitled “Our Common Future” was published by the World Commissioner for the Environment and Development [1]. In this report, sustainable development was introduced as a development that conformed to the present demands, without compromising the ability to help future generations to meet their own needs [2]. The concern about sustainable development was recognised in the United Nations Conference held in Rio in 1992 as well as World Summit in 2002. Environmental, social and economic are the three main pillars proposed within the context of sustainable development. Social dimension in sustainability development emphasises the key features of human life, including quality of life, environmental satisfaction, human well-being and health, to the global development agenda [3]. However, several studies reported that social sustainability has not obtained as much attention as compared to environmental and economic sustainability [4,5,6]. For instance, most decisions made during the conceptual design phase of a building were based on energy performance and economic condition, while end user requirement was not considered because there was no standard principle and lack of information about the requirements needed by building users [7]. Even in the context of smart buildings, the needs of building occupants are often ignored [8].

Other than energy, economic and environmental footprints, the building sector also has a significant impact on their occupants as the majority of people spend their time mostly in enclosed buildings [9]. According to the World Health Organisation (WHO), almost two thirds of the 12.6 million deaths were caused by the environment each year and by providing a healthier environment could help to



reduce nearly 23% of global deaths [10]. As the majority of individuals spend their time greatly indoors, buildings are obviously becoming one of the most essential drivers of human health. Moreover, with the outbreak of the novel corona virus, many people are required to stay at home, and carry on their daily activities, such as working and studying, in the same built environment for a long period [11]. In response to this circumstance, the building sector should flexibly adapt these situations without compromising the health of occupants in line with the sustainable development goals (SDG) to ensure healthy lives and promote well-being. Several progresses were made to meet the SDG No.3, particularly amongst building occupants. However, the actions taken were not advancing at the required scale to achieve the specific targets [12].

From a normative point of view, it is widely accepted that the building sector should positively contribute to occupant health. However, with the increasing rate of sick building syndrome (SBS) in recent years, occupant health has become one of the major issues in sustainable building [13,14]. The development of sustainable building has for many years been associated with energy performance without fully examining the impacts on occupant health, such as glare caused by large window areas, overheating, increased noise level due to unbalanced ventilation system and exposure to poor indoor air quality due to inadequate ventilation rates [15,16]. Parallel to the effects of building indoor condition on occupant health, indoor environmental quality has been emphasised as a key factor in sustainable building performance due to its impact on occupant comfort, health and productivity [17,18]. There are national and international laws made with regard to indoor environmental quality as a compulsory subject. For instance, The Directive (EU) 2018/844 highlights the need to improve indoor environment and occupant health besides energy performance of building. Similarly, most green building certification schemes have included specific indicators for indoor environmental assessment of buildings.

To understand the relation between indoor environment and occupant health is essential to enhance the formulation of requirements for architectural and building system design. Nevertheless, occupant health is subjected not to a single indoor environmental factor but multiple indoor environmental factors simultaneously [19]. Several studies reported that it was complicated to break down indoor environmental factors into categories or indicators and determine how these categories or indicators contribute to occupant health [20,21]. Therefore, to address these challenges, the present study aims to discuss the impact of indoor environment on occupant health and highlight the role of building sector in preserving occupant health.

## **2. Building indoor environment**

The quality of indoor environment is becoming increasingly important to guarantee a healthy environment for the occupants because most of the world's population has prolonged exposure to environments that are enclosed with various indoor pollutants, such as carbon monoxide, particulate matter, formaldehyde and volatile organic compounds [22]. One of the environmental impacts caused by high emission of pollutants in the building life cycle is occupant health. The World Health Organisation [23] defined health as the absence of disease and infirmity, whereby a person should have normal condition of physical, mental and well-being. A study by Meijer et al. [24] indicated that huge amounts of pollutants are released, especially during the operational phase of building life cycle. The potential of adverse health effects from indoor pollutant exposures in buildings includes but not limited to lung cancer [25], asthma [26] and risk of premature death [27]. However, the indoor environment in buildings has potential to provide health benefits for the occupants by mitigating the negative impacts on people while optimising the indoor environment features for occupant health [28]. The issue of indoor environment has become a matter of concern in global sustainability. Fisk [29] stated that most energy efficiency retrofitting in buildings has significant impact on multiple indoor environmental parameters, specifically indoor air pollutant, temperature, humidity, extent of moisture and mould. Previous studies have acknowledged the short-term and long-term effects of indoor environment on occupants. For example, short-term exposure to poor quality of indoor conditions can affect occupant comfort, health and productivity [30]. Meanwhile, prolong exposure to poor indoor conditions is associated with various building-related illnesses, such as cancer, skin disease and

respiratory problems [31]. Therefore, understanding the sources of indoor environmental discomfort is crucial to prevent negative impacts of indoor environment on occupant health.

A healthy indoor environment is critical for sustainable building because it results not only in resource conservation but also increase in productivity and occupant health. Wierzbicka et al. [22] reported that occupant health is associated with a multitude of factors and a wide range of possible interactions with numerous indoor environmental features. For example, energy saving efforts in building is related to increase in levels of moisture and indoor airborne pollutants as well as decrease in ventilation rate, which in turn are likely to cause negative health effects. Moreover, existing studies that focused on single causes of certain health symptoms did not show adequate explanatory potential for general implementation [32]. Therefore, it is challenging to identify the proportion of health benefits attributed by indoor environment of buildings and the interface between ranges of indoor environment factors and health outcomes. Acknowledging the absence of holistic perspectives on the interplay between indoor environment and occupant health, the present study aims to highlight the role of the building sector in preserving occupant health while operating at its optimal level.

### **3. Research methodology**

A wide range of literature is reviewed to establish a holistic understanding of the interface between indoor environment and occupant health. The search for relevant literature was performed on two search engines (Web of Science and Scopus) via a keyword search on indoor environment and occupant health. The main objective of the literature review was to document and analyse crucial literature and acknowledge the state-of-art in indoor environmental quality in regard to occupant health. Relevant literature, including journals and conference papers, was reviewed and compiled. Based on the detailed review of published research articles, four indoor environment parameters that could have significant impact on occupant health were identified. These included indoor air quality, indoor lighting, indoor cleanliness and ergonomic. Discussion on the identified indoor environment parameters is presented in the following sections.

### **4. Indoor air quality (IAQ)**

One of the indoor environment parameters that constitute health concern for its occupant is indoor air quality. Global observations have found that indoor air pollution was accountable for more than 1.6 million deaths and had become 2.8% of the world's burden of diseases [33]. Prolonged exposure to indoor air pollution can create a public health threat to the occupants such as heart diseases, asthma and lung cancer [34]. There is strong evidence in literature that acknowledged the association between poor indoor air quality and negative health outcomes. For instance, high concentration of indoor air pollutants in buildings can induce adverse health effects to occupants, such as infections, allergies, toxic illnesses and asthma [35]. Besides, bacterial and fungal growth in indoor environment also contribute to poor indoor air quality and cause serious health effects on occupants. The health effects experienced by occupants can be mild as respiratory irritation or extreme such as toxic effects, systemic infections, skin diseases and asthma [36].

In general, poor indoor air quality is frequently aggravated by insufficient ventilation, absence of air filtration, and lack of fresh air in enclosed spaces [37,38,39]. Indoor air quality in buildings can be enhanced in three ways, including air cleaning, designing ventilation systems, and source controlling [40,41]. Ventilation rate is an effectual parameter of IAQ in a building, whereby higher ventilation rates produce better indoor air quality for occupants. This is because the concentration of contaminants in the indoor air will build up and increase the risk of infection if there is insufficient and inefficient ventilation in the indoor environment. To meet the need of fresh air in buildings, there are several implementations of ventilation system in buildings, namely naturally ventilated system, hybrid system and mechanically ventilated system. Mujan et al. [42], suggested that health aspect in building is best met by the hybrid system, consisting of natural and mechanical ventilation. However, the selection of ventilation system in buildings should be made by following the climate factors, depending on the types of building and occupant activities conducted in the building [43].

## 5. Indoor lighting

The condition of indoor lighting is crucial in determining health and visual comfort amongst building occupants. As stated by Lewy et al. [44], indoor lighting has a fundamental role for the circadian clock through melatonin suppression and cortisol release in humans. Daylight in indoor environments is frequently not adequate; hence, artificial lighting is often required in buildings [45]. Designing a proper lighting system for indoor environment is a process that requires an appropriate prior study because the primary goals of indoor lighting for many years were to aid the visual task by providing accurate illuminance level and colour temperature of emitted light [46]. The lighting system in buildings usually depends on various aspects, such as intensity, distribution of light, glare, daylight availability, colour rendition and dynamics [47].

Indoor lighting is an undeniable issue in sustainable building because the absence of an adequate level of indoor lighting has a significant impact on human health. Inappropriate indoor lighting contributes to glare problems, visual discomfort, work performance and human health issues. Boyce et al. [48] found that high intensity of lighting increased core body temperature of occupants than low intensity of lighting in buildings. Similarly, Xu et al. [49] demonstrated that colour temperature of indoor lighting had significant effects on occupant's heart rate and blood pressure, whereby high colour temperature of indoor lighting increased the heart rate and blood pressure of occupants. In addition, poor distribution of light sources in building could cause vision problems on occupants, such as eye strain, blurry vision and eye injuries [50].

To analyse the quality of lighting system in buildings is essential to ensure that the visual performance of occupants is not compromised by the energy saving effort. In recent years, designers, engineers, and researchers have shown a growing interest in intelligent and sustainable lighting systems in buildings to achieve energy efficiency and indoor visual comfort. Due to the quick technological developments, the lighting system in buildings has provided occupants with more control over indoor lighting. It was found that such strategy is crucial to enhance the performance of lighting system and occupants' visual comfort [51].

## 6. Indoor cleanliness

Indoor cleanliness has been recognised as one of key issues in developing a sustainable building. Traditionally, cleanliness refers to the removal of dirt, absence of dust, stains, unpleasant odour and paramount importance aspect for human health [52]. On the other hand, the concept of indoor cleanliness is associated with the protection of human health through avoidance of disease. In recent years, requirements for more effective cleaning activities in buildings is increasing as exposure to contaminated spaces can result in severe and chronic health effects, especially respiratory illness [53]. Cleanliness factor in buildings is essential as a comprehensive infection prevention strategy. Donskey [54] stated that improved indoor cleanliness could reduce building-related infections amongst occupants because contaminated surfaces in buildings could cause transmission of viral pathogens. Infectious disease transmission is also influenced by sharing of equipment such as phones, copy machines, desks and computer keyboards [55].

Many research studies were carried out on the impact of indoor cleanliness of occupant health in buildings. For example, adequate containment of dust in indoor environment can reduce the potential of respiratory problems amongst building occupants [56]. Belachew et al. [57] also reported that the prevalence of building-related diseases such as headache, asthma, fatigue and dizziness was higher amongst occupants who lived in an unhygienic building as compared to those who lived in a clean building. Therefore, the maintenance of cleanliness in buildings should be a major focus as it directly and indirectly impacts the health of building occupants. The development of control procedures which limits the acquisition of pathogens in building is essential to prevent and reduce the risk of infections amongst building occupants.

## 7. Ergonomic

Ergonomic needs to be considered as a fundamental aspect in the design of sustainable buildings. Integrating ergonomics into sustainable buildings improves occupant performance, health and well-being, while it supports sustainability at the occupant and system settings [58]. The concept of

ergonomics can be tailored to how a building is designed, to reduce the potential risk of injury to occupants. The issues of musculoskeletal disorder are commonly related to occupants who have a short-term or long-term impact on human health. Wells [59] mentioned that ergonomically designed user-friendly appliances and indoor environment play a crucial role in preserving a healthy occupant. Previous studies have acknowledged the effect of ergonomic approaches in buildings on occupant health. For example, the implementation of ergonomic workstation contributes to better physical health condition by mitigating the impact of long stretches of sitting, which frequently happen amongst office employees [60]. According to Pyke et al. [61], the implementation of ergonomics in green building design has contributed to lower injury rates amongst occupants. Indeed, the World Health Organisation (WHO) strongly recommends the implementation of ergonomic standards within any occupational health and safety practices in buildings [33]. Therefore, ergonomics considerations should be an integral part of the planning procedure when developing a sustainable building.

## 8. Conclusion

This paper proposed a holistic understanding of the indoor environmental effect on occupant health and highlighted the role of the building sector in preserving occupant health. A review of published literature yielded four indoor environment parameters that were significantly related with occupant health: indoor air quality, indoor lighting, indoor cleanliness and ergonomic. The impact of each indoor environment parameter on occupant health was discussed in this paper. By identifying the consequences of indoor environment on occupant health, this paper demonstrated that building design and systems have the potential to cause adverse health effects on occupants. Theoretically, the collective effort will continue to be a feature in recent building systems. However, studies have largely ignored the potential effects of indoor environment design on occupant health. A multiple disciplinary approach is imperative for the architects, building engineers, building scientists, health professionals and facility managers to provide better understanding on how buildings can be designed to support human health and well-being. In summary, evidence from this paper provided insights into enhancement strategies for sustainable building to maximise occupant health in buildings and further research should consider about testing the significance of identified indoor environment parameters in a specific context, such as hospitals and classrooms.

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