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Improving indoor environmental quality (IEQ) for occupant health and well-being: A case study of Swedish office building

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Abstract. Indoor environmental quality (IEQ) is a major domain of building conditions relating to occupant comfort, health and well-being. Especially in the office environment, IEQ can influence work productivity positively. Within the 17 UN Sustainable Development Goals (SDGs), goal 3 good health and well-being, and goal 8 decent work and economic growth are the two areas where IEQ can significantly contribute. To better design sustainable office buildings in line with the agenda 2030, the study aims to examine occupant satisfaction, health and work in a newly renovated office building which is labelled by the BREEAM certification scheme Silver. Occupant preferences of IEQ comparing to the current conditions were also explored to provide advice for future design. The results show that occupant satisfaction with IEQ has not well achieved and in the office environment occupants prefer warmer temperature, more fresh air, less noise, and more daylight. We also find that perceived IEQ is extensively related to occupant health and work productivity. It concludes that in such a newly renovated office building as a high-performance building, there are still many problems from the indoor environments. Therefore, improvements are needed to gain occupant satisfaction and positively influence occupant health, well-being and work productivity.

Keywords. Indoor environmental quality; Occupant survey; Health symptom; Work productivity

1. Introduction

Indoor environmental quality (IEQ) is a major domain of building conditions relating to occupant comfort, health and well-being [1]. Especially in the office environment, IEQ can significantly effect on employees' performance and work productivity. The consequence of bad indoor environments can lead to low work productivity and more sick leaves. Within the 17 UN Sustainable Development Goals (SDGs), goal 3 good health and well-being, and goal 8 decent work and economic growth are the two areas where IEQ can



significantly contribute. Traditionally, IEQ includes the main four aspects of thermal environment, air quality, acoustic comfort and lighting and daylight. Research showed that different factors of IEQ impact human comfort and health [2-4]. The influence of IEQ on work productivity have been also being revealed especially in green buildings [5]. These factors are also required in many international building certificates, for example LEED, BREEAM, HQE, DGNB/SGNI. To achieve the Paris agreement's goal of limiting global warming to below 2°C, 50% or more energy saving potential of the building sector is needed in 2050. Therefore, mutual success on energy performance and indoor environmental quality are aimed to contribute to social, environmental and economic sustainability.

However, in green buildings, we can still see new buildings or newly renovated building which are complained about by the occupants, especially for indoor environmental conditions [6]. The gaps between the design and the actual condition and occupant real satisfaction exist. Therefore, the paper studied the newly renovated office building located in Sweden which has been labelled by the BREEAM certification scheme as Silver rating. Post-occupant surveys were designed and conducted to holistically reveal the perceived IEQ conditions and actual occupant satisfaction in office environment, to explore the existing problems and occupant demand. The perceived IEQ is further linked to self-reported health and work productivity to further provide experience for an evidence-based building design.

2. Methods

A large-scale office building with a floor area of about 4000 m² and occupied by hundreds of employees located in the western part of Sweden was studied by the qualitative method of occupant surveys. The building was newly renovated to be low-energy demand and good indoor comfort. It was certified by the international scheme of BREEAM as Silver rating. The study was conducted during the first week of September 2019. During the study period, questionnaires were filled in by the employees in the office. The design of the questionnaire addressed detailed questions on occupant comfort, health and self-reported work productivity. This paper collected the responses of perceived IEQ from the occupants, with regard to the main aspects of thermal environment, air quality, acoustic and lighting and daylight. In total, 160 employees participated in the survey study and provided effective response samples. The ratio of female participants and male participants is 1.3:1.

The survey holistically studied IEQ at the workplace in the office. The method to observe occupant perceptions includes the questions of occupant satisfaction, perceived stress and occupant preferences for IEQ. Occupant satisfaction is asked as “how are you satisfied with the different IEQ factors in your work area”; perceived stress is asked as “how have you been bothered by the IEQ factors in your work area”; and occupant preference is asked as “which condition you would like to work in”. Moreover, office-related health symptoms were surveyed by a series of questions, e.g. fatigue, headache, difficulty concentrating, irritations. In the paper, fatigue and difficulty concentrating were analysed. Occupant self-reported work productivity was also studied concerning the feedback from the leaders and supervisors and also self-expectation on the tasks.

3. Results

3.1 Occupant satisfaction with IEQ

The results of occupant satisfaction with IEQ in the office environment are shown in detail in figure 1. Most satisfied parts lie on the factors of lighting, daylight, air quality and relative humidity. In contrast, the condition of room temperature and noise are inclined to be dissatisfied. The results show the satisfaction

with IEQ in descending order with the highest satisfaction on light and the lowest satisfaction on room temperature.

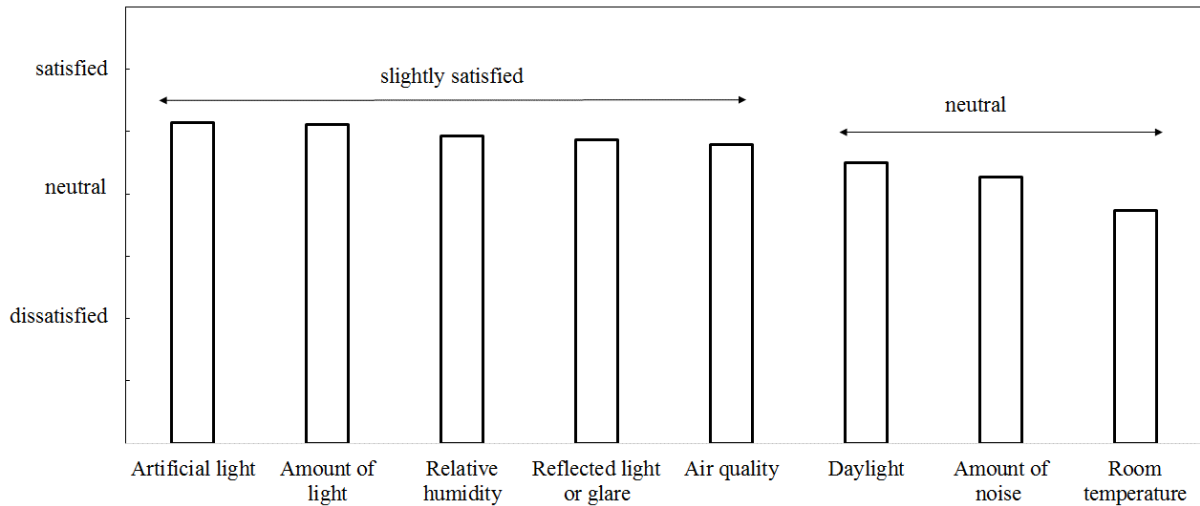


Figure 1. Occupant satisfaction with IEQ in the office environment

3.2 Occupant perceived stress with IEQ

The perceived stress from the indoor environment is further explored. Figure 2 shows the results of the stress level in ascending order. Among different factors, most perceived stress is caused by cold room temperature and too much room noise. The frequency is at least once a week. Other factors, such as air draught, dry air, dust and stuffy air are perceived as less stressful.

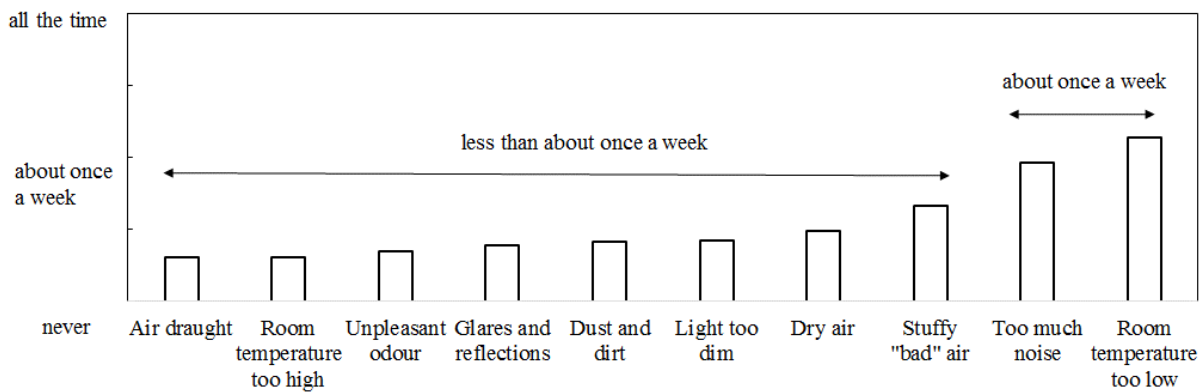


Figure 2. Occupant perceived stress from IEQ in office environment

3.3 Occupant preferences for IEQ

With investigating occupant satisfaction and perceived stress with indoor environmental conditions, it is also interesting to understand how occupants prefer to work in indoor environments. The bar chart in table 3 presents the percentages of occupant preferences on different IEQ factors. More than 55% percent of the occupants prefer a warmer temperature in the office and more than 30% percentage of the occupants need the environment to be quieter with less noise. The preference for the factors of temperature and noise are also indirectly reflected from the results of occupant dissatisfaction and perceived stress shown in figure 1 and figure 2. There are other factors which have not been reported significantly to be dissatisfied or stressful but still been reported as more than 20% percent of the occupants to be improved, including more fresh air and more daylight. Less than 20% percentage of the occupants prefer to have less glare, fewer odours and higher relative humidity. Only less than 5% percentage of the occupants indicate no change with the current indoor environment.

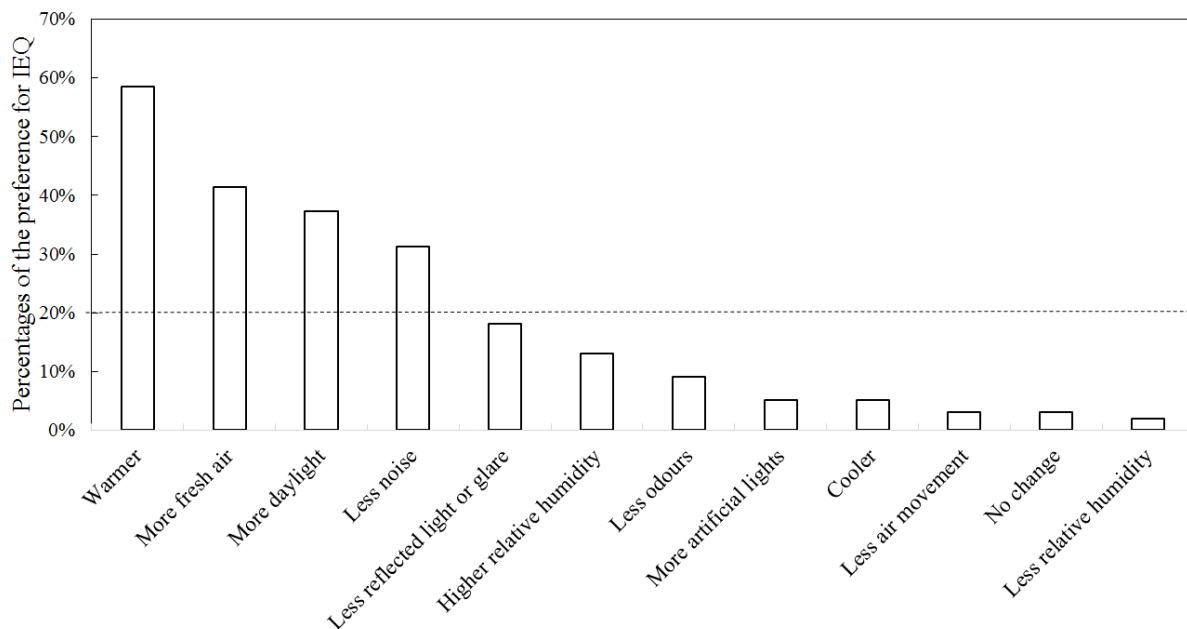


Figure 3. The percentages of occupant preference for IEQ in office environment

3.4 The associations between perceived IEQ and self-reported health symptoms

The correlation coefficients between the health symptom of fatigue and perceived IEQ including occupant satisfaction and perceived stress were analysed and are shown in figure 4. The higher the absolute value of the correlation coefficient, the larger the association. Regarding occupant satisfaction with the indoor environment, the factors of air quality, relative humidity and noise are found to be significantly correlated with the symptom of fatigue. They show a small association with fatigue. When checking the correlation coefficient between perceived stress and fatigue, we found more factors show significant correlations, such as room temperature and air draught. Among the factors, unpleasant odours show a medium association and all the other factors show a small association. The significant level is hereinafter referred to as $p < 0.05$.

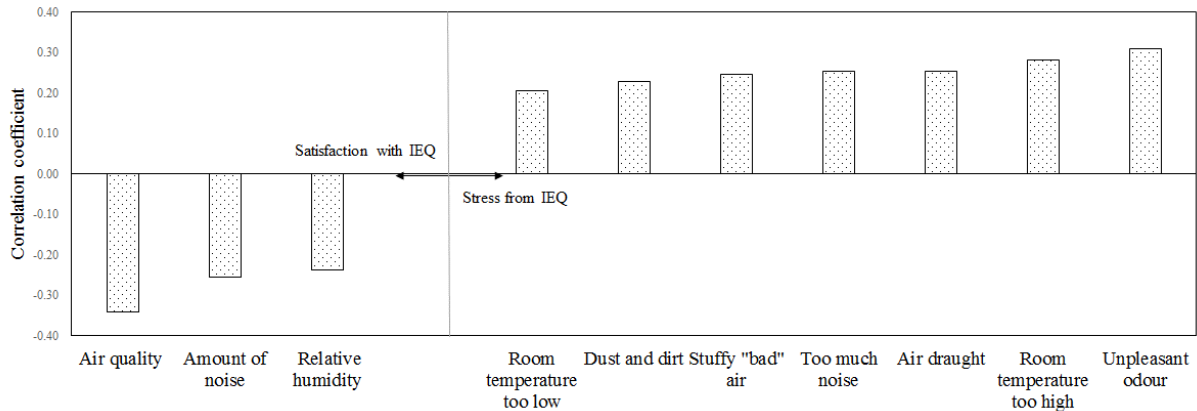


Figure 4. The correlation coefficients between the health symptom of fatigue and occupant satisfaction and perceived stress from IEQ

The correlation coefficients between perceived difficulty concentrating and perceived IEQ are shown in figure 5. Regarding occupant satisfaction with the indoor environment, the factors of noise, air quality, relative humidity and air movement are found to be significantly correlated with the symptom of difficulty concentrating. Among the factors, satisfaction with noise shows a medium association with the difficulty concentrating; satisfactions with relative humidity and air movement show a small association. When checking the correlation coefficient between perceived stress and difficulty concentrating, we found more factors showing significant correlations, such as too dim light and air draught. Comparing to the satisfaction with noise, the perceived stress from noise shows a significantly large association with difficulty concentrating. The stress from air quality, e.g. stuffy air and unpleasant odour show the same medium association. However, we did not get the significant association for room temperature which is the most complained factor by the occupants.

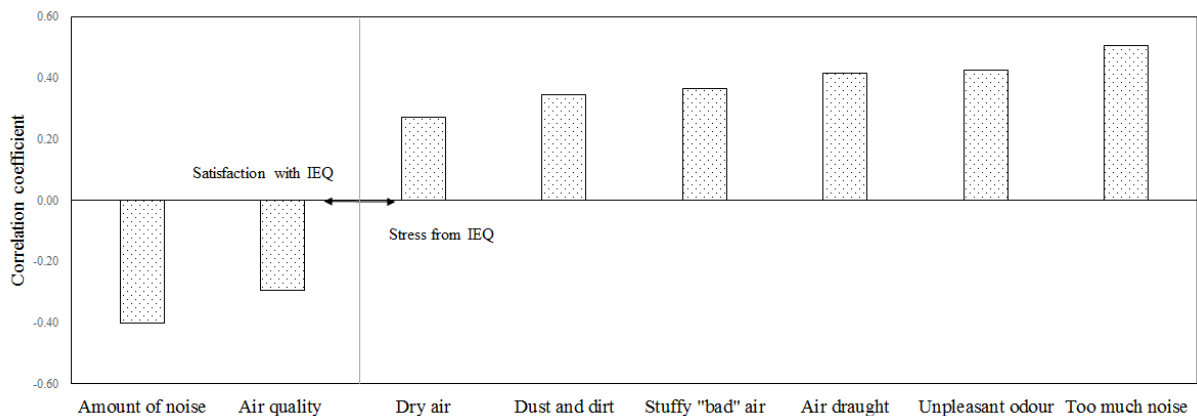


Figure 5. The correlation coefficients between the health symptom of difficulty concentrating and occupant satisfaction and perceived stress from IEQ

3.5 The associations between perceived IEQ and self-reported work productivity

Furthermore, the association between self-reported work productivity and perceived IEQ are examined by the correlation coefficients. Figure 6 shows that occupant satisfaction of the quality of lights in terms of reflected light and glare has a significantly small association with the positive feedback of work from the leader and supervisor. It shows that more factors regarding the perceived stress from noise and air quality are related to self-reported work productivity with a small association.

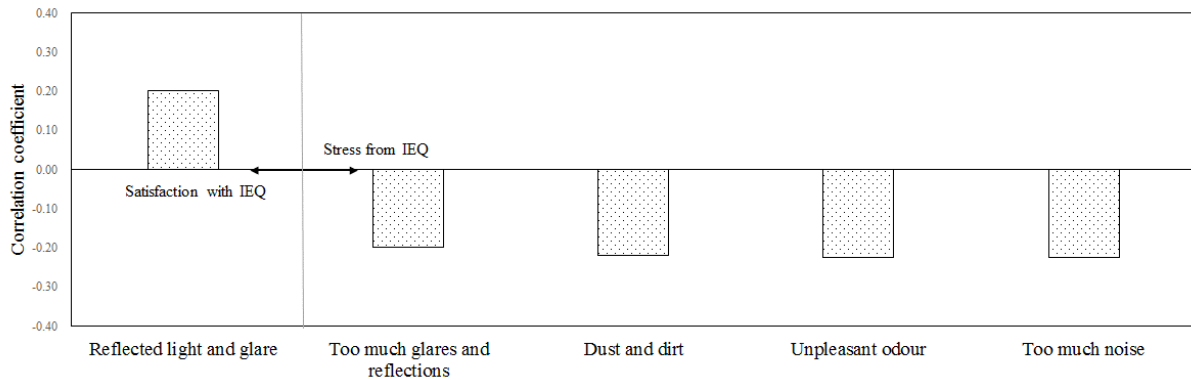


Figure 6. The correlation coefficients between self-reported work performance of “feedback from leader and supervisor on my work” and occupant satisfaction and perceived stress from IEQ

The correlation coefficients between the self-reported work performance of “doing all the tasks as I expected” and perceived IEQ are shown in figure 7. Occupant satisfaction with the reflected light and glare, artificial light and noise level show a significantly small association. Occupant perceived stress from unpleasant odour shows a medium association. The associated factors are different between satisfaction and perceived stress.

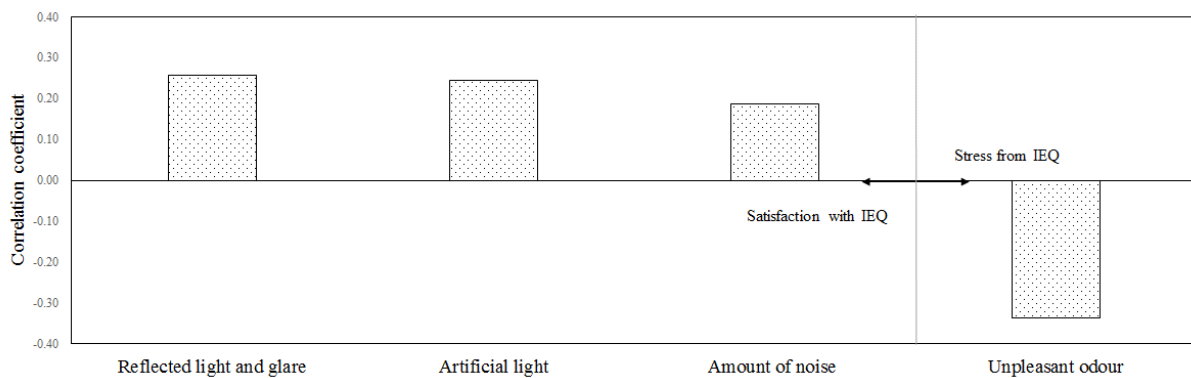


Figure 7. The correlation coefficients between self-reported work performance of “doing all the tasks as expected” and occupant satisfaction and perceived stress from IEQ

4. Discussion

The study shows the results of a large-scale office building based on 125 effective samples collected from the employees. The results reflect the quality of the indoor environment in the case study office building by

holistically analysing occupant satisfaction, perceived stress and preference. The associations between health symptoms and work productivity and perceived IEQ are further explored by the correlation coefficients. We have detected the problems of IEQ which are not perceived as satisfied, and which are preferred to be improved. Comparing to the other studies, we conducted more in-depth observation concerning different aspects with detailed factors. We find that the methods of studying perceived IEQ using satisfaction, stress and preference index can reveal the real performance of the building indoor environment and occupants' demand. However, the limited sample of building and occupants could not provide a common trend for the office building. To scale up, more samples of new office buildings with a similar typology and also certified by the international system need to be further studied and compared with the case study by using the same methodology to observe occupant perceived IEQ.

5. Conclusion

From the case study, we can conclude that in the newly renovated building labelled with BREEAM silver occupant satisfaction and well-being have not well achieved yet regarding the designed high-performance of IEQ. Occupants prefer the current indoor environment to be improved and better meet their real demands. There are still many problems from indoor environments. Therefore, improvements are needed to gain occupant satisfaction and positively influence occupant health, well-being and work productivity.

To better achieve the 17 UN Sustainable Development Goals (SDGs), goal 8 decent work and economic growth, the study shows detailed findings that can shed a light on the future design in terms of the IEQ aspects. Occupant health and work productivity show significant associations with the perceived IEQ at different levels. Regarding health symptoms, the most associated perceived IEQ factors are occupant satisfaction and perceived stress from air quality, acoustic and thermal environment including unpleasant odour, stuffy air, dust, room temperature, air draught and relative humidity. However, regarding self-reported work productivity, the most associated factors lie on the quality of lights, acoustic and air quality, including reflection and glare, artificial light, noise, unpleasant odour and dust. To better achieve the 17 UN Sustainable Development Goals (SDGs), goal 3 good health and well-being, the study designed a holistic method of occupant survey to examine the actual IEQ performance in new buildings with a high-performance certification, and explore the existing problems. The main dissatisfactions are caused by the factors of room temperature and noise. In contrast, occupant perceived stress from the indoor environment is not significant. Thus, it indicates that no stress perceived does not mean occupant is satisfied with the indoor environment. Furthermore, a significant percentage of the occupants prefer the current indoor environment to be improved. The main factors need to be concerned include room temperature, air freshness, daylight and noise. In summary, regarding the case study building rated in BREEAM silver, occupant dissatisfaction exists from the thermal environment, acoustic and the quality of lights. Acoustic and thermal environment are the leading aspects to cause perceived stress.

The study examined the potential problems of IEQ existing in the high-performance and newly renovated building and provides lessons learned and evidence for future sustainable office building design regarding what needs to be improved for IEQ concerning occupants' health and well-being when working in the office environment. Regarding the legislation perspective, it lacks the observation and involvement of occupant perceptions to the indoor environment which needs to be further implemented in future guideline, standard and building certification schemes.

Acknowledgement

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