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Indoor Environment Quality and Occupants Satisfaction in Office Building

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ABSTRACT

An office building is a space where many occupants work and is also composed of an open space. The indoor environment is divided into a thermal comfort, acoustic quality, lighting environment, and an indoor air quality, and is also changed by various factors. In particular, energy use is an important factor for securing a comfort range of temperature and humidity. In the open space office, satisfaction with the acoustic environment may be reduced due to the conversation sound and phone ringing of the occupants. This study aims to examine the characteristics of indoor noise changes in the office building with low satisfaction with the sound environment and to discuss countermeasures.

Keywords : Indoor Environment Quality, Acoustic Comfort, Office Building

INTRODUCTION

In particular, the office, where research tasks are carried out, is an important factor in improving productivity. Indoor environmental factors can be broadly classified into four categories: indoor air quality, thermal environment, lighting environment, and acoustic environment. If the indoor environment is not favorable, occupants may complain of discomfort, and such discomfort can negatively impact work quality [1,2]. Interest in evaluating Indoor Environmental Quality (IEQ) comprehensively is increasing.

With the recent Russia-Ukraine war, energy costs have surged like never before. Building energy usage has a significant impact on indoor temperature and humidity control, and a certain level of energy consumption is necessary to maintain a comfortable thermal environment. Energy conservation has become even more crucial at this point. If energy usage is reduced to the point where indoor environmental conditions are unsatisfactory, occupants may experience discomfort during working hours, resulting in decreased work productivity. Energy usage and acoustic comfort may not have a direct correlation. Acoustic evaluation parameters in office spaces can include noise levels, reverberation time, sound absorption area, and speech transmission index. ISO 22955 [3] provides technical guidelines for planning, design, and layout to ensure acoustic quality in open office spaces.

ISO 3382-3 [4] is a standard that specifies the metrics and methods for measuring the acoustic characteristics of open-plan offices. It includes parameters for speech intelligibility, which ensures clear speech communication within the same office space, as well as indicators for speech privacy between office spaces. While many countries have established acoustic performance standards for offices, Republic of Korea currently does not have such standards in place.

Lee et al. [5] conducted a study analyzing the satisfaction with indoor environmental conditions and work productivity of occupants in a research building. Based on previous research findings, they confirmed that indoor lighting environment and office layout are related to administrator's work productivity, and indoor lighting environment, office layout, thermal comfort, and acoustic environment are related to researcher's work productivity.

It appears that in a previous study [6], general satisfaction with indoor environmental indicators (temperature, air quality, lighting, and noise) was investigated among occupants in the same building, and it was found that satisfaction with acoustic performance was lower compared to other environmental indicators. The previous study relied on self-reported survey results from occupants and did not involve physical measurements.

The objective of this study is to measure the actual physical noise levels in the research building where research work is conducted, in order to investigate the reasons for low satisfaction among occupants regarding the acoustic environment and to identify potential countermeasures. Based on the results of this study, identifying the issues related to the acoustic environment for occupants and deriving improvement measures could contribute to enhancing the acoustic environment of the research building and improving the satisfaction of the occupants.

METHODS

To investigate the reasons for low satisfaction with the acoustic environment, a three-week monitoring and analysis of noise levels was conducted at two indoor locations. The inside of the building plane was divided into two parts and two microphones (ch1 and ch2) were installed. Additionally, the impact of external traffic noise was examined by opening windows adjacent to the measurement point (ch2) to assess the level of noise ingress into the office space.

The office building in question is a 25-year-old building that does not have a mechanical ventilation system for introducing outdoor air. Therefore, in order to ventilate the space, windows adjacent to the exterior need to be manually opened. The process of opening the windows is not automated, and occupants located near the windows need to directly open them.

The building under measurement is rectangular in shape, with a length of 77 m and a width of 18.5 m. It is located parallel to a road, with a distance of approximately 50 m from the road. The road has a width of approximately 45 m with 8 lanes (4 lanes in each direction). There is an intersection in front of the building. The building has 5 floors, and the noise levels were measured at the 5th floor. The traffic volume on the road in front of the building is 4000 small vehicles per hour and 170 large vehicles per hour, with a vehicle speed of 60 km/h.

Along with the noise level, indoor temperature and humidity were measured at the same time to confirm changes in the thermal environment.

RESULTS

Noise Pressure Level

Figure 1 illustrates the changes in noise levels throughout the entire measurement periods. As shown in the graph, the noise exhibits a periodic pattern with consistent variations. Multiple noise events occur daily, and there are slight differences in noise patterns depending on the day of the week. On the last two days of the measurement periods, indoor noise was measured with the external window open, or external noise levels were measured by installing a microphone outside the window.

During business hours (9:00-18:00), the noise levels exhibited a pattern of initially increasing and then decreasing, with high noise levels generated in a short period of time due to office activities such as talking, phone calls, and operation of office equipment.

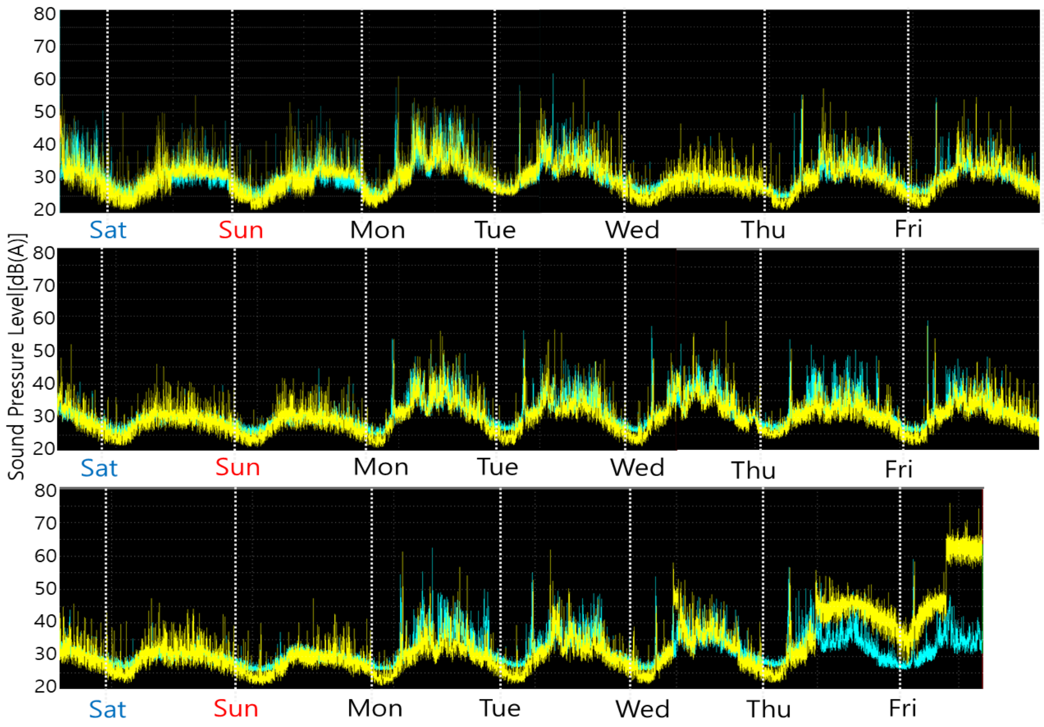

Figure 1. Change in noise level during the measurement periods

Figure 2 shows the daily (24-hour) Leq24h calculated during the measurement period, with the minimum and maximum noise levels indicated on the graph. The shaded area represents weekends (Saturday to Sunday). The daily Leq fluctuated within the range of 30-40 dB(A), and a cycle of decreasing noise levels during weekends with no business activities is observed. The daily variation in noise levels was not significant.

Based on the data, the 24-hour Leq was below 40 dB(A), which is lower than the WHO's night-time noise guideline of 40 dB(A). However, it is noted that there were instances where the noise levels exceeded 80 dB(A) due to certain activities causing high noise emissions. The noise levels in the office were not consistently high, but there were occasional spikes in maximum noise levels due to specific noise emitting activities occurring for short durations.

The duration of the measurement period during which the 24-hour Leq did not show significant changes was observed. It is necessary to consider the appropriate measurement period to determine the indoor noise characteristics of the target building. In this study, the changes in noise levels were examined over a period of approximately 3 weeks, and the frequency characteristics of Leq for each day were compared with those of Leq over a 7-day period, as shown in the following graph.

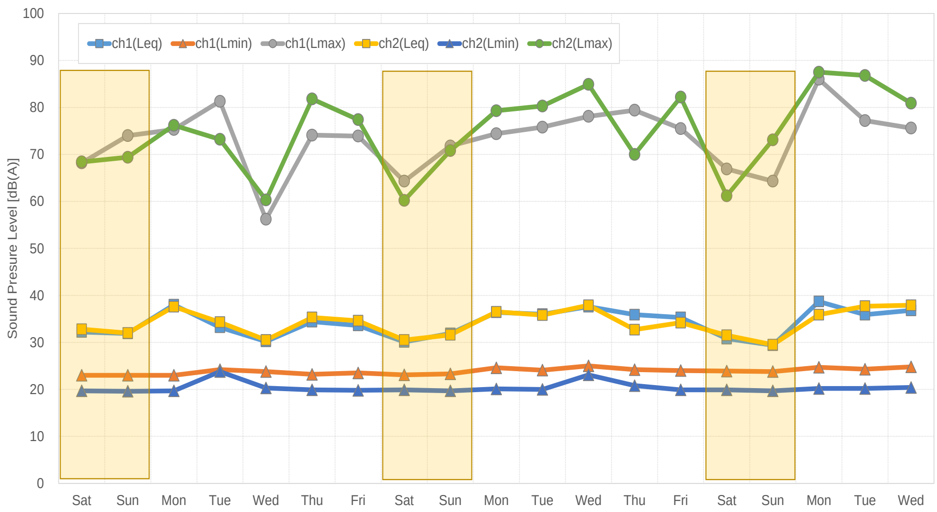

Figure 2. The noise level over a 24-hour period

In some cases, the 1-day Leq and 7-day Leq may show similar levels, and there were instances where the noise levels decreased on certain days. It is expected that even in spaces with minimal changes in noise levels, the characteristics of noise levels can be determined with a shortened measurement period. As shown in Figure 3, although there may be differences in noise levels, the frequency characteristics are mostly consistent.

If noise measurements cannot be continuously measured for a long time, it is also worth considering reducing the measurement period. In Korea, when measuring road traffic noise, the results measured three times at 5 minutes Leq during the daytime are considered as the representative noise level by arithmetic average.

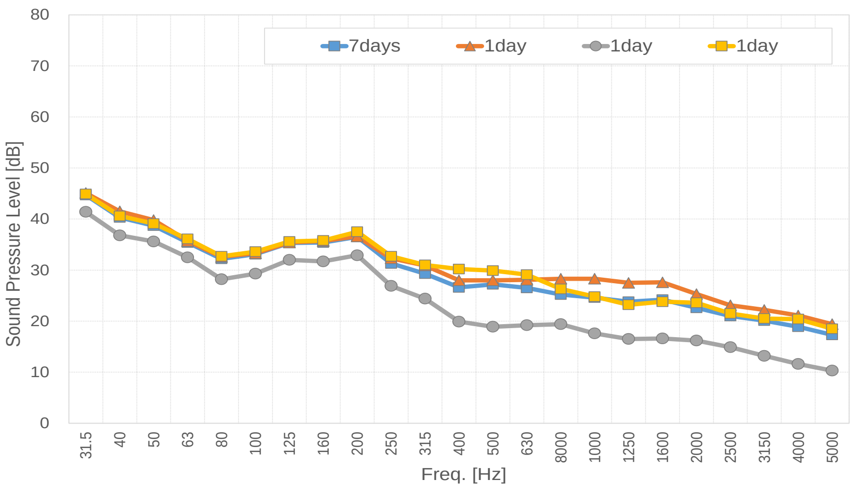

Figure 3. Frequency characteristics according to the average period

Figure 4 shows the frequency characteristics of window opening and external noise levels. When the window adjacent to the microphone location was opened, the noise level increased by approximately 9 dB(A), and the external noise level outside the window was measured at 63.7 dB(A). Based on the measurement results, the sound insulation performance of the window was estimated to be approximately 28 dB. Due to the 9 dB increase in noise level through window opening, occupants near the window may experience discomfort due to the increased noise.

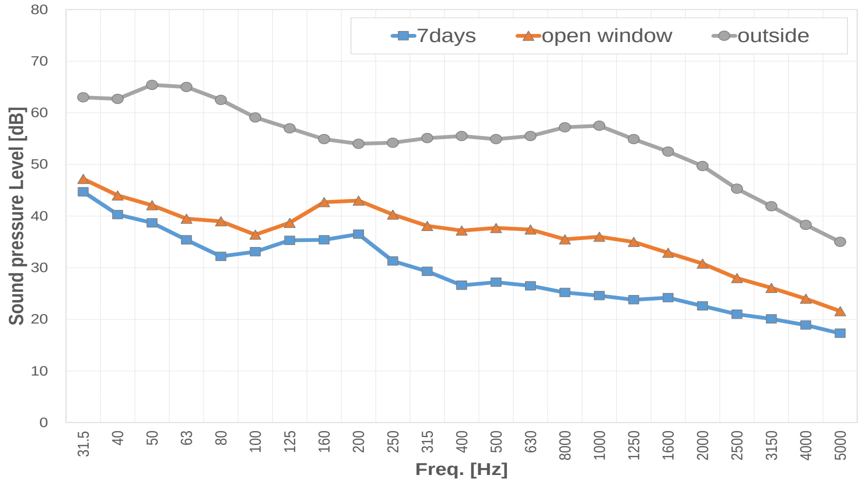

Figure 4. Frequency characteristics according to the locations

Temperature, Relative Humidity and Carbon dioxide (CO_2)

The thermal environment measurement was conducted from late February to early March, which is the time when the season changes from winter to spring. Figures 5 to 7 show the changes in temperature, relative humidity, and CO_2. The shaded areas in the figures represent Saturday and Sunday. It was observed that the indoor temperature decreased over the weekends and rapidly increased with the start of work on Monday, with a pattern of gradually decreasing temperatures after noon that repeated daily. The temperature difference within a day sometimes reached up to 6 degrees Celsius. The patterns of change were almost similar every day.

The changes in humidity were difficult to observe periodic patterns, unlike the temperature changes. It sometimes increased and sometimes decreased over a few days. It was determined that the indoor environmental conditions were influenced by the humidity conditions of the outdoor air. The maximum humidity was also observed to be as low as 43%, which is lower than the recommended indoor humidity level of 30~50%, indicating a need for management of indoor humidity to maintain optimal indoor conditions.

The CO_2 concentration was maintained at around 420 ppm during weekends when there were no occupants, but it increased up to 1 000 ppm with the start of work on Monday. During weekdays, it showed a relatively consistent pattern of change, and it was determined that the concentration varied depending on the number of occupants. It was also noted that the CO_2 concentration did not exceed the indoor CO_2 standard of 1000 ppm, which is the guideline for indoor air quality in Korea.

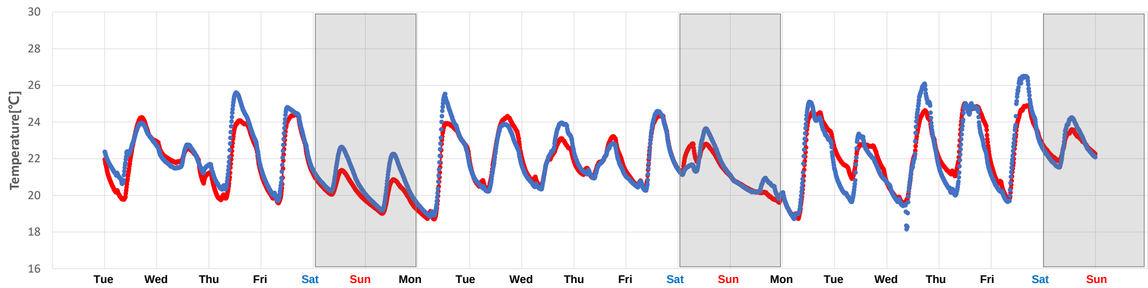

Figure 5. Change in temperature during the measurement periods

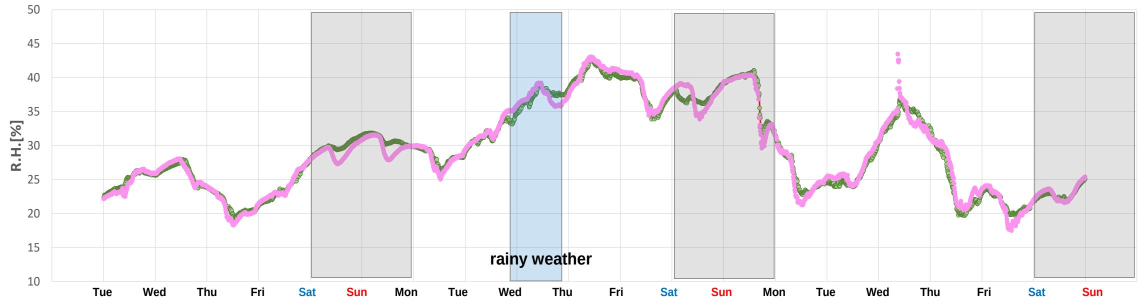

Figure 6. Change in relative humidity during the measurement periods

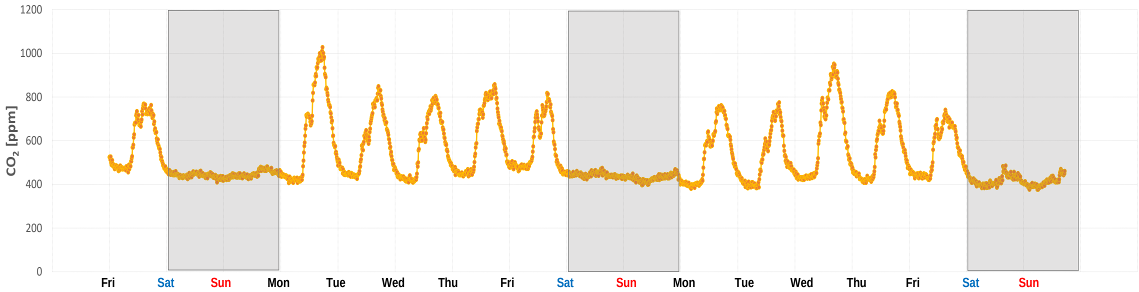

Figure 7. Change in CO_2 during the measurement periods

Measures to increase satisfaction with noise environment

The noise level in the office is around 40 dB(A), which is not considered high. However, the satisfaction with the acoustic environment among the occupants was found to be low compared to other indoor environmental indicators. There could be several possible reasons for the low satisfaction with the acoustic environment, including:

The first reason for the low satisfaction with the acoustic environment could be the occasional noise events despite the overall noise level not being high. Noises from neighboring spaces such as phone conversations, meetings, and office equipment can sharply increase the noise level compared to the background noise level in a quiet indoor environment, leading to decreased satisfaction.

The second reason is that conversations can be heard clearly from neighboring spaces during phone calls or meetings. This can lead to higher dissatisfaction with the conversation noise level, as office occupants may find it intrusive or distracting.

The last reason is that the lack of consideration for consistent layout and noise reduction measures in the office space, where researchers reside in the same area at regular intervals. This may have resulted in inadequate measures to address noise issues, leading to lower satisfaction among office occupants.

In order to increase satisfaction with the acoustic environment, a noisy place and a quiet place should be separately arranged, or a noise barrier device should be installed in a space where noise is expected. It is also considered to install sound proof panels or noise absorbing materials inside the office. Creating a physical internal environment and taking necessary measures by collecting inconveniences from the participants will be a way to increase satisfaction with the acoustic environment.

CONCLUSION

A review was conducted on the sound and thermal environments of the open office where research work was carried out. The noise level generated indoors was not high around 40 dB(A), but there was an event where the noise level increased intermittently. Intermittent noise occurrence is considered as a factor to be taken into account for improving indoor occupants' satisfaction with the acoustic environment.
Temperature changes showed a consistent pattern with no significant fluctuations, while humidity appeared to be influenced by outdoor conditions, indicating the need for measures to control indoor humidity. CO_2 also showed a certain pattern of change, and rarely exceeded 1 000 ppm.
Even if the noise level is low, the intermittent loud noise affects the person's satisfaction with the acoustic environment, so appropriate measures such as separation of noise sources and installation of sound absorption materials are needed.

Acknowledgements

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