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Investigation of Indoor Environment Conditions in Low-Rise Condominiums in Bangkok

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ABSTRACT

Indoor Environmental Quality is critical for ensuring residents' comfort and health, particularly in residential buildings. However, currently there is a significant research gap in IEQ studies for low-rise urban condos, which are likely to suffer from worse conditions due to external pollution and the urban heat island effect than high rise condos. This study seeks to address this lack by performing field assessments and deploying questionnaires to ascertain the state of IEQ and its impact on the inhabitants. The results reveal that the external pollution sources, along with concerns for safety and insects, influence behaviors such as keeping windows closed. This behavior has a detrimental effect on indoor air quality. Measurements of noise and CO2 levels within these buildings frequently surpassed acceptable thresholds, corroborating the findings from occupant satisfaction surveys. While other IEQ parameters like room temperature, relative humidity, and lighting largely met established standards and garnered satisfaction.

1. Introduction

Bangkok's urban landscape is currently undergoing an extensive transformation, particularly in the housing market. The growing number of condominiums has significantly altered the city's skyline[1]. Currently, individuals spend more time indoors [2], which has led to an increased focus on Indoor Environmental Quality (IEQ). IEQ considers factors such as Indoor Air Quality (IAQ), Thermal Comfort, Visual Quality, and Acoustic Quality [3], and is becoming an increasingly vital concern for residents. It is essential for residents to be mindful of IEQ's impact on their health[4], [5], [6], [7], productivity [8], [9], and overall comfort[10], [11], [12]. Unfortunately, maintaining an excellent IEQ in Bangkok's condominiums is a formidable challenge. Many of these buildings were developed by real estate companies, which often do not prioritize indoor living conditions. Consequently, residents are often left with limited space and minimal renovation options to improve their indoor environment.

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Low-rise condominiums, characterized by a height of less than 23 meters [13], are particularly susceptible to the urban heat island effect. This phenomenon, which causes urban areas to experience higher temperatures than surrounding rural areas due to the density of buildings and asphalt, air and noise pollution [14], can be exacerbated by their close proximity to pollution sources at the street level and their low altitude. Consequently, the management of air quality and temperature within these structures has become a topic of increased concern.

Recent research has primarily focused on high-rise condominiums and houses[10], [15], [16], [17], [18], [19], [20], [21], while the investigations of low-rise condominiums are comparatively limited. This study aims to comprehensively examine the indoor environment of low-rise condominiums in Bangkok, with the goal of understanding their current state and the impact they have on people living in them. By identifying the specific challenges faced by low-rise residences in urban areas, this study seeks to bridge the gap in the existing literature and provide a foundation for future improvements in the design and regulation of low-rise condominiums.

2. Methodology

This research project utilized a combination of survey-based investigations and physical measurements to attain a comprehensive understanding of indoor environmental quality (IEQ). All data were collected during the summer season in Thailand between March 21 and March 30, 2023. The study's timeline fell after the COVID-19 pandemic, which may have influenced the participants' behaviors and opinions. The quantitative portion of the study involved distributing questionnaires to five low-rise condominiums situated in different areas of Bangkok, including Silom, Prakanong, Bangkhen, and Rama9. The questionnaire design featured both closed-ended and open-ended queries covering topics such as occupancy duration, use of air conditioning, participants' levels of satisfaction with IEQ, its effects on health and productivity.

This study advanced to its on-site field measurement phase, which comprised the examination of two representative residential units occupied by middle-income individuals, a studio apartment and a single-bedroom unit. The physical evaluation was based on the capabilities of the monitoring devices outlined in Table 1 and included continuous monitoring for a period of one week. To replicate a typical breathing zone, monitoring tools were strategically positioned in each unit's living room and bedroom at a height of 1.1 meters. Continuous operating devices were set up to collect data every 10 minutes, enabling the tracking of changes and recurring trends in the environment. The data collection process was conducted in a manner that did not disrupt residents' daily activities or surroundings, with the aim of accurately portraying their genuine living circumstances. Detailed information about the selected residential units and residents, including the floor plan, details of residential units, and the residents' details, is presented in Figure 1, Table 2, and Table 3.

Table 1
List of measurement devices

Parameter	Device	Range	Accuracy	Measurement Period
Temperature	T&D TR-74 Ui	0 to 55 ° C	±0.5°C	One-week
Humidity	T&D TR-74 Ui	10 to 95 %	±5% RH at 25°C, 50% RH	One-week
Light	T&D TR-74 Ui	0 lx to 130 kl	±5 % at 25°C, 50 %RH	One-week
CO2	T&D TR-76 Ui	CO2: 0 to 9999ppm	±(50 ppm + 5% of reading) at 5,000 ppm or less (*3)	One-week
Globe temperature	T&D TR-52i	-60 to 155 ° C	Avg. ± 0.3 ° C at -20 to 80 ° C	One-week
Air velocity	Testo 425	0-20 m/s	±(0.03 m/s + 5 % of mv)	One-time
Sound level	Lutron SL-4023SD	30 to 130 dB	±1.5dB	One-time

Table 2
Information about residential units

Room code	Area (sqm)	Directions	Floor level	Room Type	Partition	Location
A	23.25	North	5	Studio	Sliding Glass	Prawet
B	41	East	5	One-bedroom	Concrete wall	Bangkhen

Table 3
Information about the residents

Room code	Occupancy gender	Age	BMI
A	female	31	26
B	male	35	27.4

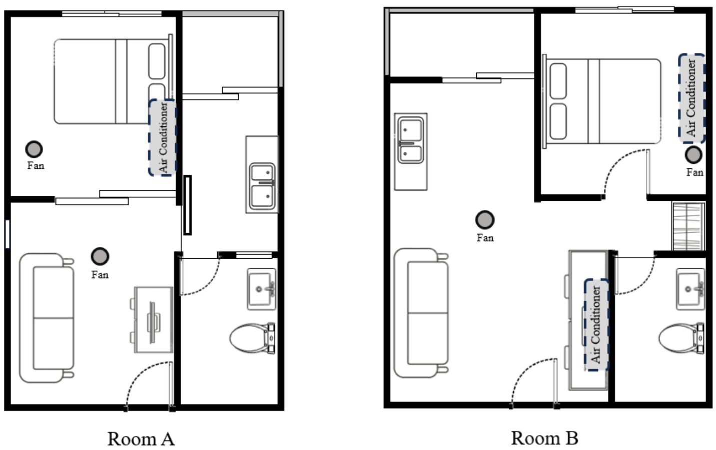

Fig. 1. Room floor plans

3. Results

3.1 Result of survey-based investigation

Regarding the data obtained from a questionnaire survey of residents in five condominiums, the participants comprised 50 respondents, evenly divided by sex, with 50% male and 50% female participants. All respondents resided in residential units equipped with split-type air conditioning systems. The largest demographic age group among the respondents was between 20 and 30, accounting for 57% of the total number of respondents. This was followed by those aged 31-40 at 26%, 51- 60 at 11%, and 41 to 50 at 7% with 37% of the respondents were working from home. Their living spaces varied in size from 26 to 56 square meters, and were located on floors 2 through 8.

3.1.1 Usage Pattern

The analyzed data as shown in Figure 2 and 3 reveal that individuals typically dedicate a considerable portion of their time to their bedrooms, spending 8 to 15 hours between 9 pm and 10 am. Bedroom usage patterns on weekends were consistent with those on weekdays. In contrast, people tend to spend more time in the living room on weekends, with a usage duration of 9 am to midnight. Furthermore, the patterns of air conditioning use in both the bedroom and living room align with the amount of time residents spend in these areas. Most of the participants indicated in an open-ended question that they kept their air conditioning units at all times in their residential units to counteract high outdoor temperatures.

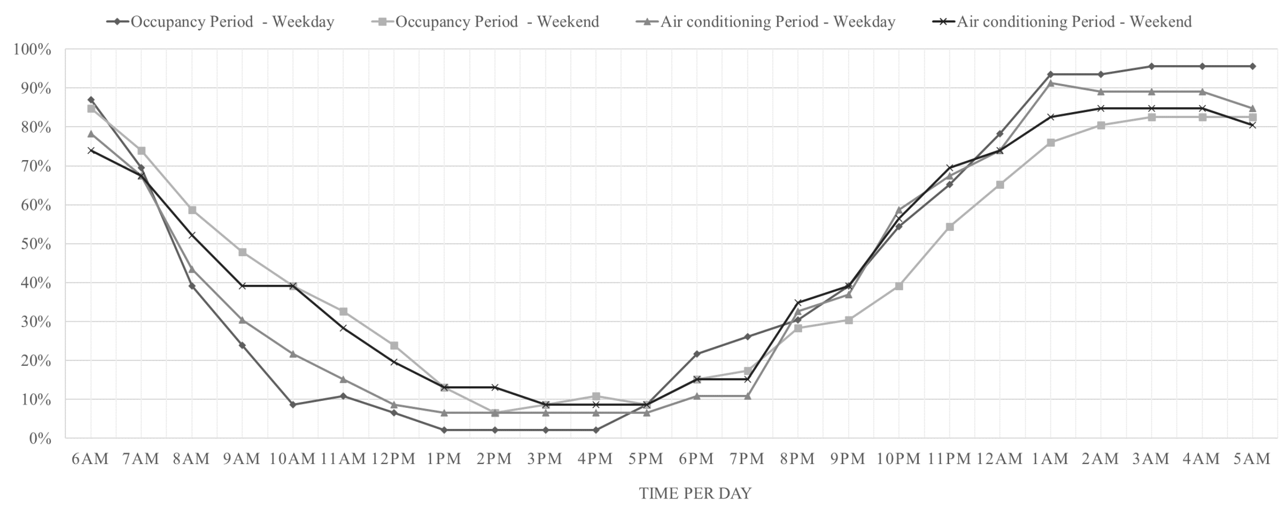

Fig. 2. the percentage of occupied period and air conditioning usage in the bedroom

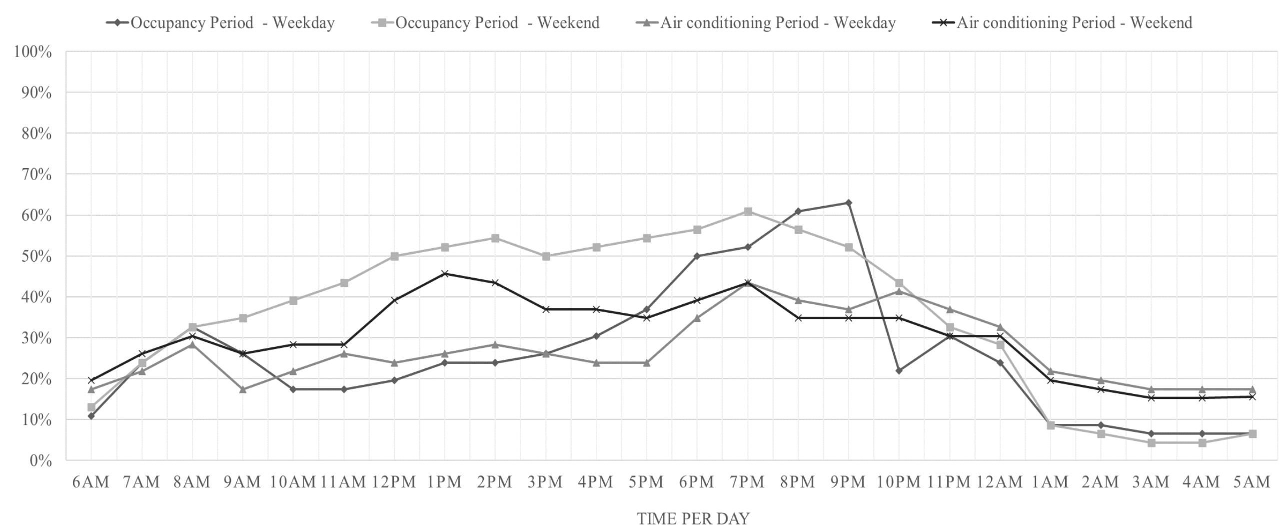

Fig. 3. the percentage of occupied period and air conditioning usage in the living room

3.1.2 Occupant satisfaction

This study assessed the satisfaction levels of multiple aspects of the indoor environment, including temperature, humidity, airflow, ventilation, indoor air pollution, lighting, and noise (Figure 4). Indoor air pollution and noise have emerged as primary areas of concern. According to the ASHRAE standards, which stipulate that occupant comfort is deemed acceptable when 80% of individuals report neutral to satisfactory conditions, the findings indicate a problem, as 25% of the respondents expressed dissatisfaction with indoor air quality, while 40% reported noise dissatisfaction. Open-ended responses from the survey revealed that rooms with windows on only one side failed to provide adequate natural light and ventilation, which negatively influenced tenant comfort. Furthermore, the participants highlighted significant disturbances from traffic noise and sounds originating from neighboring rooms. However, for other parameters, the results indicate that over 80% of the residents were neutral, satisfied, or very satisfied, as they could directly control elements such as temperature using fans or air conditioners, wind flow with fans, and lighting by simply turning artificial lights on or off.

3.1.3 Adaptive Behavior

Regarding adaptive behavior (Figure 4), in terms of temperature and humidity, air conditioning systems are the most preferred solution, followed by fans and windows. However, when in terms of air velocity, ventilation and, air pollutant control, more respondents reported using fans and exhaust vents in bathrooms than opening windows. For lighting comfort, the survey indicates that the majority of the respondents preferred the use of artificial light sources, such as light bulbs, to adjust brightness levels at 80% more than using blinds and curtains. As for noise pollution, residents are yet to find an effective solution,

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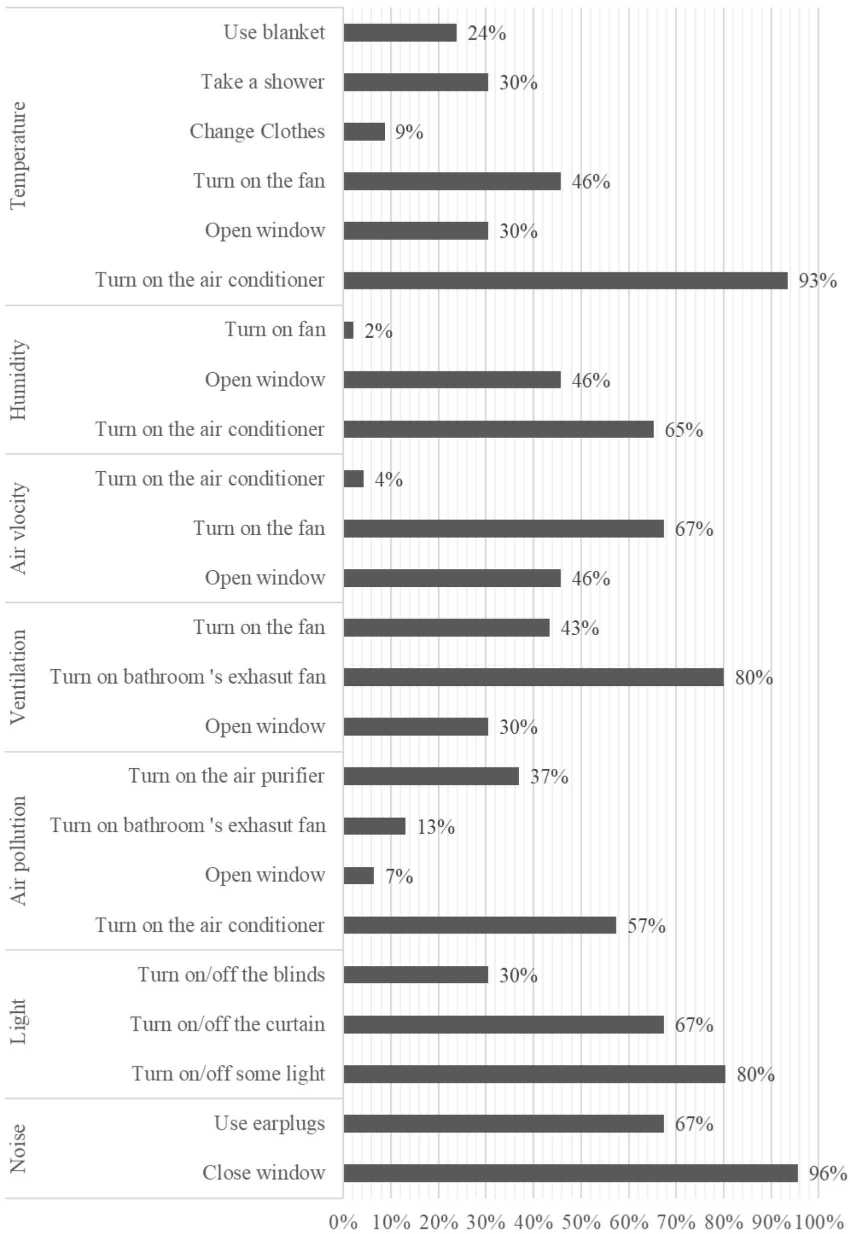

Fig. 4. the percent of adaptive behavior for each IEQ parameter.

To confirm this new trend, the survey asked residents, "When you turn off the air conditioner, do you open the window?" The results indicate that approximately 70% of the participants always closed the windows even when the air conditioning was turned off. The primary reason for this behavior is safety concerns (8%), in addition to unfavorable external conditions such as high PM2.5 pollutants (64%), high temperature (11%), noise (8%), and pests (8%). Residents on the lower floors were particularly concerned about these issues.

3.1.4 Impacts on health and work productivity

Upon examining the health consequences depicted in Figure 5, it is evident that an overwhelming majority of the survey participants did not attribute any immediate physical or psychological health effects to the IEQ. Air pollution was the most significant element affecting IEQ, affecting the nasal system (22%), eyes (14%), and skin (30%). More than half of the respondents indicated that their sleep quality was hindered by external noise, noise from neighbors, external street lighting, air pollution, and insects. In terms of productivity, 54% of the respondents reported that their residential units' IEQ influenced their concentration and work performance. Poor IEQ conditions, including noise, extreme temperatures, inadequate lighting, and pollution, have been reported to cause discomfort while remote working.

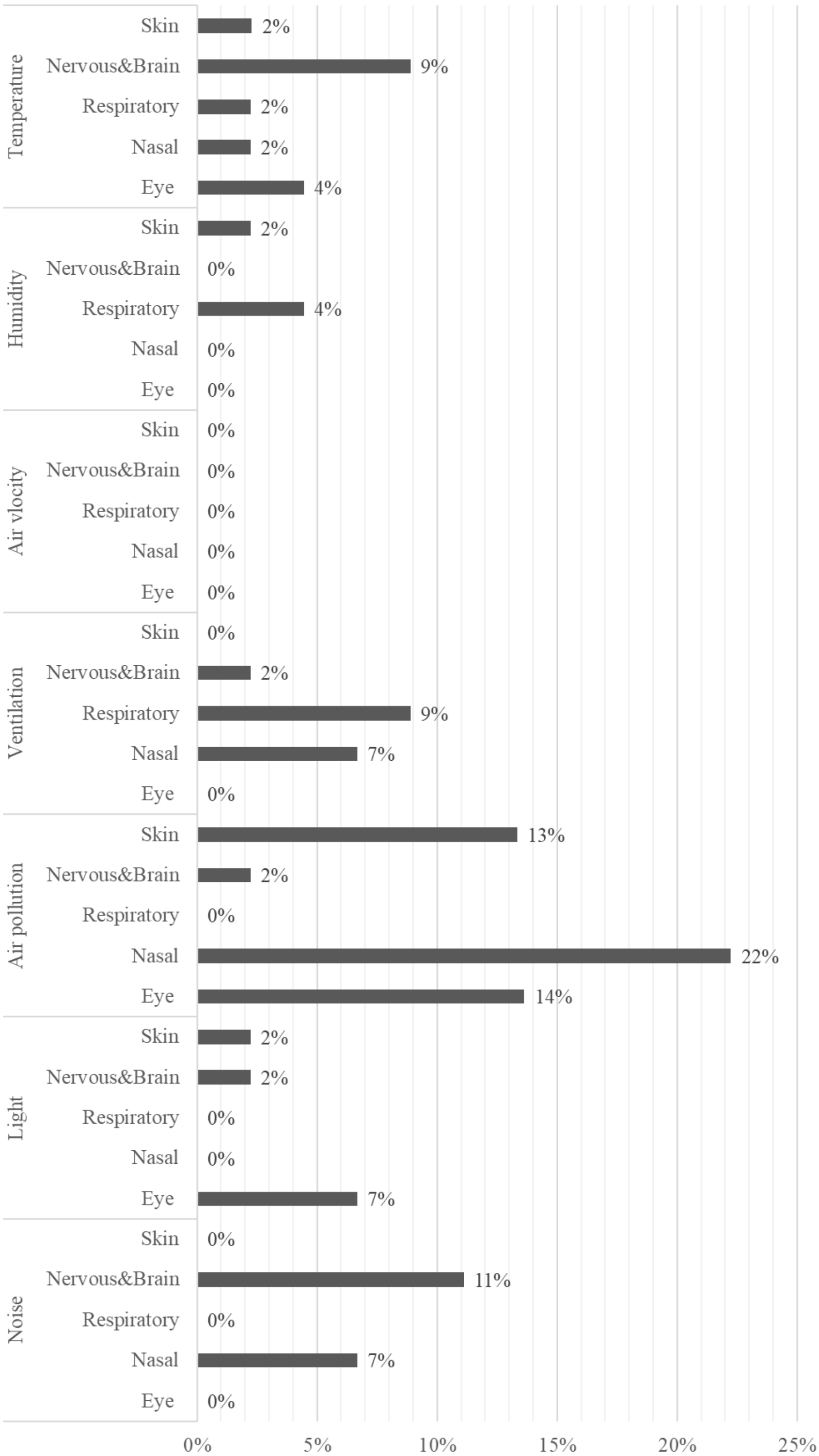

Fig. 5. the percentage of IEQ impacts on health

3.2 Results from on-site measurement

The analysis outcomes were classified based on the conditions present in both the bedroom and living room, and were further segmented into daytime (6:00 am to 6:00 pm) and nighttime periods (6:00 pm to 6:00 am). The findings were then evaluated in comparison to established standards and regulations for well-being building.

3.2.1 Wind velocity and acoustic environment

The results are presented in Table 4. Regarding wind velocity, when the window was closed and the air condition was used, the wind speed ranged between 0.02-0.08 m/s and between 0.02-0.18 m/s when the door is opened. According to the WELL certification standards, the air velocity should not exceed 0.2 m/s, measured 1.7 m above the floor [22]. Therefore, the room units complied with this standard. For the decibel levels in the rooms, the values of both rooms were comparable, regardless of whether the window was open or closed, owing to their location away from major roads. However, the noise levels within these residential units, based on the Thai SOOK certification (well-being building standards of Thailand,) and WELL certification (well-being building standards of the United States), were higher than the recommended maximums of 36-65.5 dBA. External noise and noise from mechanical systems should not exceed 40 and 45 dBA[23], respectively, and the average background noise in the bedroom should not exceed 35 dBA [22]. These standards were not met in tge residential units, which highlights the need for improvement.

Table 4. presents the results of the wind velocity and sound level measurements.

IEQ parameter	Building code	Close window (Turn on air condition)		Open window	
		Bed room	Living room	Bed room	Living room
Air velocity	A	0.08 m/s	0.07 m/s	0.18 m/s	0.25 m/s
	B	0.08 m/s	0.03 m/s	0.02 m/s	0.05 m/s
Sound level	A	44-51 dBA	37-41 dBA	42-65 dBA	45-54 dBA
	B	40-56.70 dBA	36-40.40	41-65.50 dBA	43-53.60 dBA

3.2.2 Hygrothermal Environment

The survey data as shown in Figure 6 indicates that occupants typically set their air conditioning between 24.0-26.0 °C. The bedroom of unit A and the living room of unit B, where air conditioning is used consistently, generally have temperatures ranging from 24.0 to 29.0 ° C. On the contrary, in Unit A's living room, where only a fan is used and natural ventilation is allowed, temperatures mostly fall within 29.0 and 32.0 ° C. Unit B's bedroom, which uses a mixture of air conditioning and natural ventilation, has temperatures predominantly between 23.0-33.0° C. The WELL certification suggests that comfort temperatures are within the range of 21.0 to 25.0 ° C [15]. However, this can be difficult to achieve in hot and humid climates such as Thailand. Rangsiraksa's (2006) [10] research indicated that Thai occupants prefer around 25 ° C in air-conditioned (A/C) spaces and 28 ° C in naturally ventilated (NV) spaces. In terms of relative humidity as shown in Figure 7, the findings from Unit B's living room were excluded because of water leakage. In Unit A, the relative humidity fluctuates between 44-64% during the day and 42-61% at night. The WELL standard recommends maintaining 30%-60% relative humidity levels for 98% of the occupied hours [22]. This standard was met for 100% and 99% of the occupied hours in Unit A's living room and bedroom, respectively.

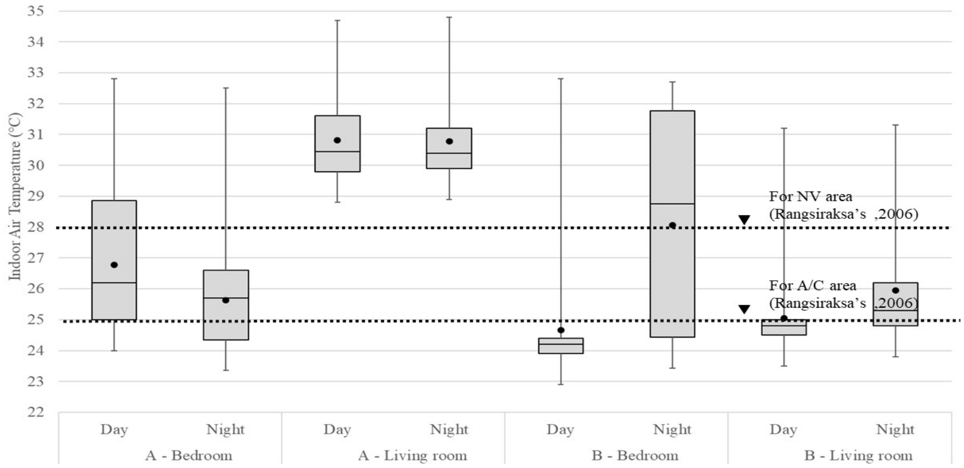

Fig. 6. Indoor air temperature during the day and night

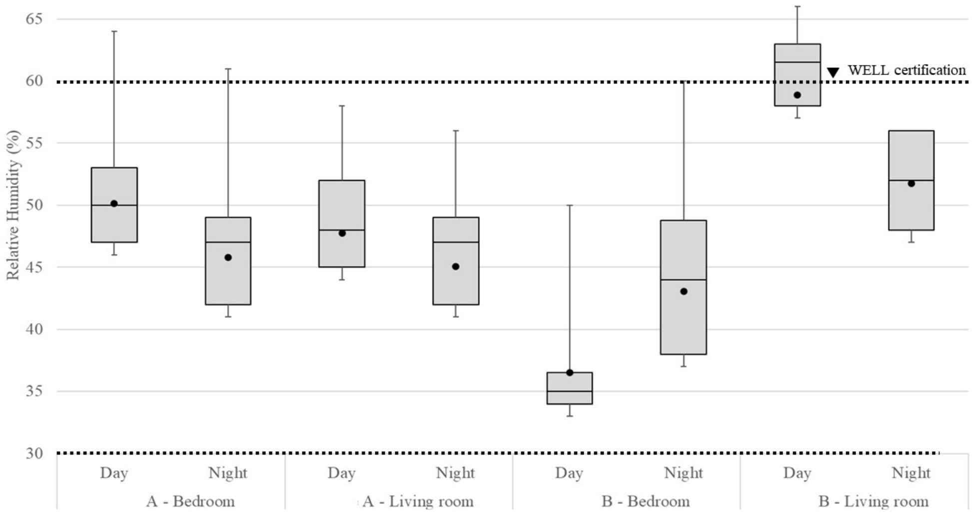

Fig. 7. relative humidity during the day and night

3.2.3 Indoor air quality

The main source of CO2 emissions in the Thai condominium units is human respiration. According to the WELL certification [22], the maximum CO2 level must not exceed 900 ppm, while the SOOK certification [23] prescribes a higher limit of 1100 ppm. However, in the studied bedrooms, the CO2 levels exceeded these standards, ranging from 459 to 1855 ppm during the day and from 421 to 1489 ppm at night. Living rooms showed similar trends with CO2 levels ranging from 505 to 1595 ppm during the day and from 428 to 1756 ppm at night as shown in Figure 8. The average CO2 concentration regularly exceeded the standard, both during the day and night. Excessive CO2 levels were observed during 37% of the hours occupied in the bedrooms and 11% in the living rooms per day.

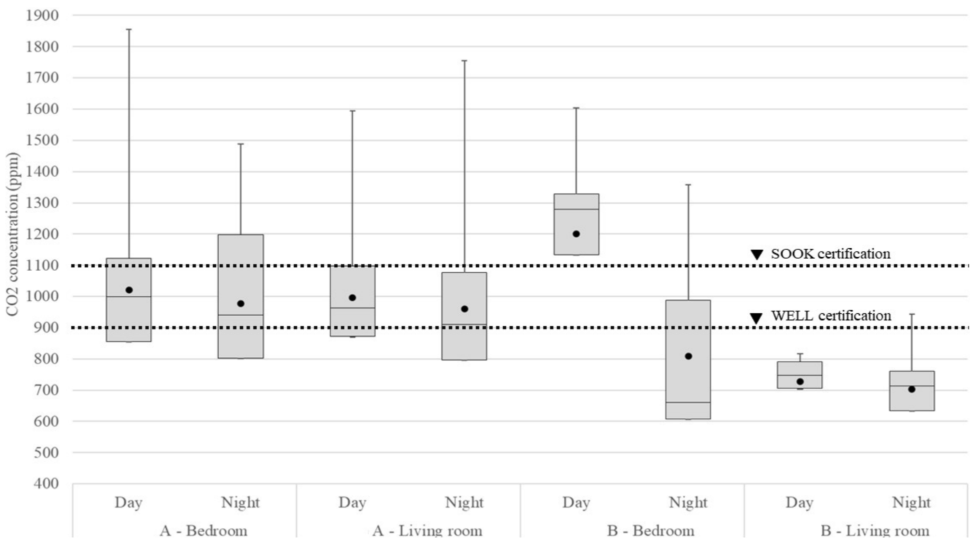

Fig. 8. CO2 concentration during the day and night

3.2.4 Lighting Comfort

In terms of lighting comfort, the Illuminating Engineering Society (IES) [24], which is recommended by WELL certification, suggests 30 lux for the living room and 50 lux for the bedroom. According to the norms laid out by the Bangkok Building Control Act (B.E. 2001) [25], residential units should ideally have a horizontal illuminance of 100 lux. Given the complexity of distinguishing between different activities and lighting periods, the data analysis in this research mainly focused on the peak lighting design values during the night. The lux level depended on the specific light fittings in each room. The study findings (see Figure 9) for bedrooms demonstrate a maximum lighting of 73 lux in Room A and 24 lux in Room B. For the living rooms, the peak lighting was 60 lux for Room A and 40 lux for Room B. However, the bedroom in unit A consistently failed to meet the standards.

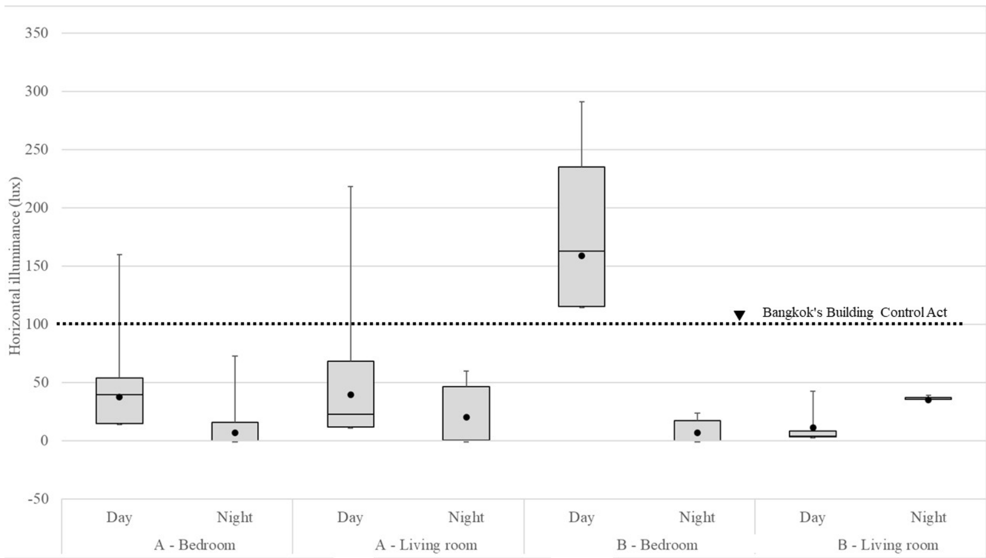

Fig. 9. visual comfort during the day and night

4. Conclusions

This research focused on Indoor Environmental Quality in Bangkok's low-rise condominiums, undertaking field assessments and questionnaires to evaluate IEQ and its effects on inhabitants. The results shed light on a significant issue: although temperature, humidity, and lighting adhere to acceptable standards because of operating air conditioning and artificial light, noise and air quality fall short. The crux of this problem lies in the proximity of these buildings to outdoor air and noise pollution, coupled with the tendency of residents to keep windows closed because of outdoor air quality concerns and safety, resulting in increased CO2 concentrations inside their homes. However, 80% of the respondents reported no direct health issues from IEQ factors, and approximately 50% noted disturbances in sleep patterns. Sleep disruption is a potential risk factor of long-term health problems. This study underscores the necessity for bespoke regulations or standards tailored to the distinct needs of low-rise residential buildings and ground-level condominiums. These buildings face unique challenges stemming from urbanization and their proximity to varying outdoor environmental conditions for healthier and more comfortable living environments.

5. Acknowledgement

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