PUBLIC HEALTH RESEARCH

A Study of Indoor Environmental Factors in University Offices on Malaysia's East Coast to Enhance Well-Being

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ABSTRACT

Introduction	This study investigates indoor environmental factors in several offices from one of the university at Malaysia's East Coast, focusing on enhancing occupational health and well-being among university staff by examining lighting quality and thermal comfort.
Methodology	Monitoring sampling were done based on hazard reports logged and data from three main offices or location were collected in this study.
Results	Utilizing Extech HD450 Heavy Duty Data Logging Light Meter to measure illuminance, the study found that most sampled points fell below the Occupational Safety and Health Guidelines' recommended range of 300-500 lux, indicating insufficient lighting that can cause visual discomfort and reduce productivity. Thermal comfort assessments, conducted with EVM-7 Indoor Air Quality 3M QUEST and AirPro Solution Models AP500, revealed acceptable temperature and humidity levels but often inadequate air velocity, particularly in the Science Officer's Office, leading to poor air circulation and potential health issues.
Conclusion	The study highlights the necessity of improving lighting solutions by installing additional fixtures or upgrading existing ones for sufficient and evenly distributed illumination and enhancing ventilation systems to ensure adequate air movement. Addressing these deficiencies is crucial for creating a conducive working environment, promoting employee satisfaction and productivity. This research focuses solely on monitoring and analyzing the collected data. No qualitative evaluation has been conducted as part of this study. This research advocates for a holistic approach to Indoor Environmental Quality (IEQ), involving regular assessment and targeted interventions to enhance the overall quality of university office environments, ultimately fostering a healthier and more productive workplace.
Keywords	Indoor Environmental Quality (IEQ), Occupational Health, Lighting Quality, Thermal Comfort, Industrial Hygiene

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INTRODUCTION

Indoor Environmental Quality (IEQ) is a crucial aspect of workplace design and management, significantly affecting the comfort, health, and productivity of employees. The multi-annual European roadmap for energy efficient buildings describes IEQ as an important area of investigation by 2020.[1] IEQ was introduced to produce an acceptable indoor environment that supports the occupant's health, well-being and comfort. The environmental factors of thermal comfort, visual comfort or lighting, acoustic and IAQ define indoor environment quality.[2] Among these factors, there are two elements focused in this study which are lighting quality and thermal comfort which play particularly pivotal roles in creating an optimal working environment.

The lighting quality is among the main considerations in IEQ measurement that should not be overlooked as it profoundly affects visual comfort, mood, and overall productivity. One of the common use measurements for lighting is illuminance. Illuminance is a term that describes the amount of light falling onto (illuminating) and splitting over the surface area.[3] Illuminance is defined as the luminous flux falling on the unit area of the surface that is under consideration. Illuminance levels and homogeneity that are at the optimum level increase visual perception, reducing tiredness symptoms including eye pain and headaches.[4] Lighting quality plays a vital role not only in illuminating spaces adequately for tasks but also in shaping mood and circadian rhythms.

Key considerations for optimal lighting include natural light exposure that has been linked to enhance mood and energy levels, promoting a healthier work environment. For instance, large windows and skylights are beneficial, but it is important to manage glare and excessive brightness. When the eye is continually forced to adapt to changing brightness, it suffers from eye strain and fatigue.[4] Other than that, artificial lighting that is too harsh or poorly distributed can cause discomfort and even disrupt sleep patterns. When natural light is insufficient, artificial lighting must fill the gap. LED lights are an excellent choice due to their energy efficiency, longevity, and quality of light.

Furthermore, the color temperature and spectral composition of light sources can influence occupants' perception of the space, affecting their comfort and well-being. Poor lighting can lead to reduced work efficiency, increased error rates, and negative impacts on mental health. On the other hand, illuminance levels that are well-maintained improve mood and alertness (decrease tiredness), which are key variables in improving occupants' performance.[4] Therefore, it is essential to design lighting solutions that provide a balance between natural and artificial light, cater to the specific tasks being performed, and accommodate individual preferences.

The standard of lighting measurement at the workplace used in Malaysia is known as the Guidelines on Occupational Safety and Health for Lighting at the Workplace 2018 by the Department of Occupational Safety and Health (DOSH).[5] These guidelines aim to offer guidance for creating visually comfortable environments tailored to the function of each interior space. Indoor lighting requirements differ based on the specific tasks performed, indicating the appropriate light levels for various areas within a building. Based on the DOSH standards, which specify an optimal lighting range of 300-500 lux for office environments. The illuminance from artificial lighting must meet the standards outlined to prevent negative impacts on occupants.

Thermal comfort is another critical element of IEQ and refers to the condition in which an individual feels neither too hot nor too cold, which can otherwise lead to discomfort, decreased productivity, as well as various problems such as dryness, health, morality, and a well-known sick body syndrome.[6] The word comfort is defined as a mental state of satisfaction with the thermal environment and is influenced by various factors, including physical conditions, physiological responses, and psychological states.[7] According to Kaushik et al.[7], thermal comfort is significantly influenced by factors such as age, gender, metabolism, local climate, clothing, physical activity, location, posture, and mood.

Thermal comfort relates to the physical environmental factors in naturally ventilated and conditioned environments. It is expressed as "the condition of mind in which satisfaction is expressed with the thermal environment".[1] Thermal comfort conditions consist of factors, such as, air temperature, humidity levels and air movements. The most obvious factor, where both excessively high and low temperatures can cause discomfort and affect productivity, while high humidity can make the air feel warmer than it actually is, and low humidity can cause dryness and discomfort. Adequate air circulation also can help in achieving thermal comfort by preventing stagnant air and distributing heat evenly throughout the room. An insufficient ventilation of the spaces can cause symptoms such as headaches or excessive fatigue.[8]

Inadequate thermal conditions can lead to various problems, including decreased concentration, increased stress, and a higher risk of heat-related illnesses or hypothermia. Proper management of heating, ventilation, and air conditioning (HVAC) systems is essential to maintain a pleasant indoor atmosphere. Implementing smart HVAC systems that can adjust based on real-time data and individual preferences can significantly enhance thermal comfort.

Simultaneously, considerations of air temperature, humidity levels and airflow distribution contribute to overall thermal satisfaction. Thus, maintaining satisfactory thermal comfort and IEQ conditions is one of the major challenges in existing buildings which are aimed to achieve nearly zero-energy building (nZEB) standards in The European Union (EU) member states.[1] Therefore, it is imperative to establish an optimal environment for workers within buildings to enhance their quality of life.

Maintaining a comfortable temperature in office environments is essential for well-being and productivity, ideally between 20-26°C. In Malaysia, air-conditioning systems are used to achieve this, but temperature variations can occur due to direct sunlight or air-conditioning vents. To avoid excessive heat during hot weather, windows, skylights, or glass partitions should be managed properly. The recommended relative humidity range is 40-60%, with low humidity potentially causing dryness of the eyes, nose, and throat, and high humidity (above 80%) leading to fatigue and a sense of stuffiness. Air movement should be between 0.1 and 0.2 meters per second to prevent stuffiness and draughts, respectively. These guidelines are based on the Guidelines on Occupational Safety and Health in the Office by the Department of Occupational Safety and Health, Ministry of Human Resources, Malaysia.[9] This study was conducted to assess the indoor environment of the selected locations, as these offices had reported poor indoor conditions affecting the comfort and well-being of the occupants. The objective of this study is to investigate indoor environmental quality (IEQ) factors, specifically lighting quality and thermal comfort, in selected office environments on one of the university at Malaysia's East Coast.

METHODS

IEQ Parameter 1: Lighting Quality

Illuminance measurements were conducted at the Center for Co-curricular Office at one of the university Campus in east coast for the purpose of determining lighting or illuminance level for tasks and activities involved in the related work area. This location was selected due to the hazard report logged by the administration office. Illuminance is measured using Extech HD450 Heavy Duty Data Logging Light Meter which is a handy instrument equipped with a sensor for light detection. The measured illuminance is directly displayed in lux (lx). Lux (lx) is the SI unit of illuminance and luminous emittance, measuring luminous flux per unit area (DOSH 2018). The average illuminance is compared to the recommended illuminance of Occupational Safety and Health Guidelines for Workplace Lighting 2018 by DOSH[5] of 300-500 lux for office environments to determine the adequacy of lighting in the work area. This workspace carries out office activities such as writing, typing, reading, and processing data.

There are two types of lighting measurement that can be conducted to measure lighting levels using a Extech HD450 Heavy Duty Data Logging Light Meter, which are general lighting at a general area and specific task or activity at workstation area assessment. In this study, general lighting measurements were conducted to assess lighting levels. General lighting provides uniform illumination for the entire work area, such as offices or storage spaces, to ensure adequate lighting for various activities. The room index was calculated to determine the number of measurement points in a particular work area after measuring the length and width of the room, and height of lighting above the working plane.

The following formula was used to calculated Room Index based on the Guidelines on Occupational Safety and Health for Lighting at the Workplace 2018 by DOSH[5]:

$$Room\ Index\ = \frac{L\ \times W}{Hm\ (L +\ W)}$$

where,
L : Length of room (m)
W : Wide of room (m)
H_m : Height of lighting above the working plane (m)

Room Index calculation:

$$Room\ Index\ = \frac{8\,m\ \times\ 3.4\,m}{1.9\,m\,(8\ +\ 3.4)m}$$

$$Room\ Index\ = \frac{27.2\ m}{21.7\ m}$$

$$Room\ Index\ =\ 1.3\ m$$

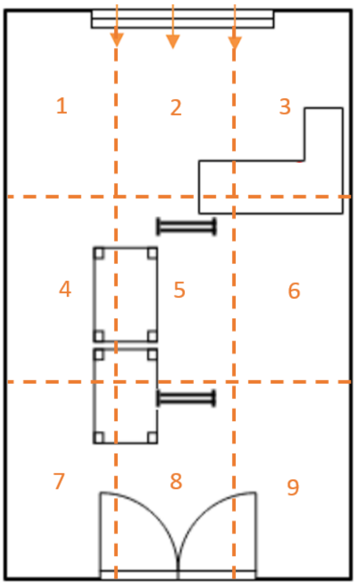
Table 1 below refers to the number of measurement points required based on the room index calculation. The number of measurement points given is the minimum requirement. Based on the table below, nine measurement points need to be taken during the lighting monitoring at the Center for Co-curricular Office.

Table 1 Minimum number of measurement points for measuring average illuminance in rooms of different proportions

Room Index	Number of measurement points
Below 1	4
1 and below 2	9
2 and below 3	16
Above 3	25

Source: Guidelines on Occupational Safety and Health for Lighting at the Workplace 2018 by the Department of Occupational Safety and Health (DOSH)[5]

Figure 1 The numbers represent the measurement points taken at the Center for Co-curricular Office.



After setting the small squares based on the room layout as in Figure 1, the illuminance was measured at the center of each square using a lux meter. Multiple readings were collected across the area to ensure an even distribution of measurements. The lowest measurement range of the lux meter was selected as appropriate to give more precise reading. It is important to note that the monitoring was carried out with all lamps switched on and the blinds closed to ensure the assessment focused exclusively on the artificial lighting within the room.

IEQ Parameter 2: Thermal Comfort

Thermal measurements were conducted in the office of the Science Officer and Elysian Spa by using EVM-7 Indoor Air Quality 3M QUEST. Same as for lighting monitoring taken, these locations were selected due to the hazard reports logged by the administration office. The EVM-7 Indoor Air Quality 3M QUEST monitoring device was capable of measuring both thermal and IAQ parameters. This durable and simple model provides simultaneous worksite area monitoring of temperature, relative humidity, Carbon Dioxide (CO_2), Nitrogen Dioxide (NO_2), Particulate Matter 10 (PM_{10}), and Total Volatile Organic Compounds (TVOCs) in the workplace at the same time. This evaluation necessitates the measurement of several thermal parameters, including temperature and relative humidity. Additionally, air velocity measurements were taken at the science officer and Elysian Spa using the AirPro device.

To conduct thermal monitoring using the EVM-7 Indoor Air Quality 3M QUEST, the data stored in the instrument memory should first be cleared to ensure a fresh start for the study. The monitoring purpose and objectives, including the study duration and parameters of interest, are then defined. Once the study setup is complete, the Run/Stop key is pressed to initiate the monitoring process. During the study, each sensor and parameter is adjusted to the correct values. Results are displayed on the instrument or transferred to the Data Management Software (DMS) for further analysis. To conclude the study, the Run/Stop key is pressed again to stop data acquisition. This process ensures accurate and reliable air quality data is obtained for analysis.

AirPro Solution Models AP500 are available with the support of a mobile application to further extend the use and functionality of the instruments. These mobile applications enable one to connect to the instrument using Bluetooth. To begin using the app, it must be downloaded from the App Store or Google Play Store. The AirPro® instrument should then be powered on, and Bluetooth must be enabled on the mobile phone. A seamless connection between the device and the AirPro® instrument is achieved by following the steps provided in the app. Once connected, various settings can be configured through the app, including the preferred measurement units and data logging settings, which are more conveniently adjusted via the app than through the instrument's settings. The app provides real-time monitoring of the air velocity data and the measurement can be done on smart mobile devices and it makes it easier to conduct intensive and precise IAQ assessments.

The floor plans in Figure 2 and 3 shows where the EVM 7 devices are placed to monitor thermal conditions in key areas at the office of the science officer and Elysian Spa.

Figure 2 Floor plan of the science officer's office, Faculty of Veterinary Medicine.

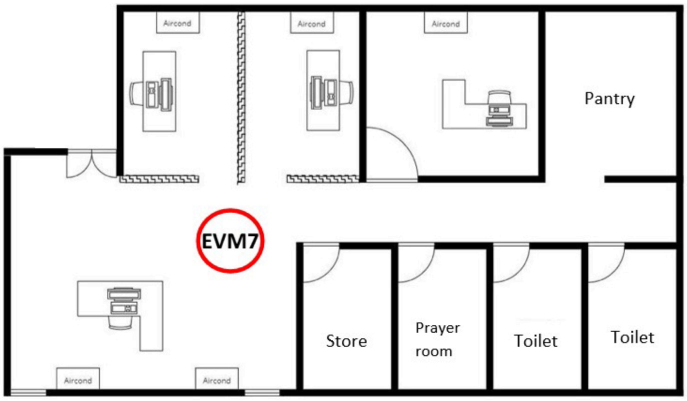
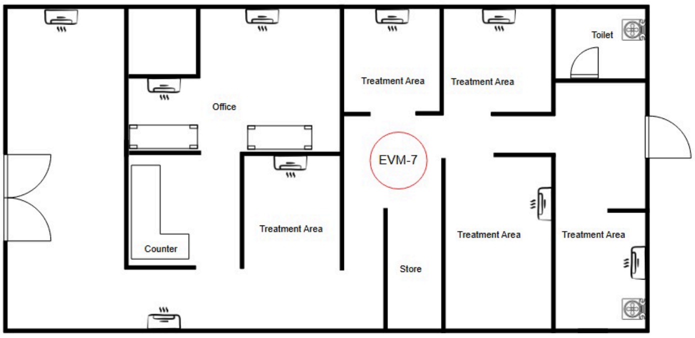


Figure 3 Floor plan of the Elysian Spa.



RESULTS & DISCUSSION

Lighting is a crucial element in the built environment, significantly impacting occupants in various ways. Beyond its well-known role in facilitating vision, lighting also influences physiological and psychological functioning, affecting occupants' well-being and overall experience.[10] The illuminance monitoring in the Officer's Room aimed to assess the adequacy and consistency of lighting conditions based on the Occupational Safety and Health Guidelines for Workplace Lighting 2018, which specify an optimal lighting range of 300-500 lux for office environments. The monitoring was conducted with all lamps turned on and the blinds closed to ensure that the assessment focused solely on the artificial lighting provided within the room.

Based on Table 2 for lighting measurement results, the lux readings for all sampling points falling below the DOSH recommended range. This indicates a significant deficiency in the current lighting setup, potentially impacting the occupants' visual comfort and productivity. A lack of lighting in the workplace is the primary cause of visual discomfort as well as physiological and psychological strain among workers.[4] The main issue appears to be that the lamps in use have been operating for an extended period, leading to diminished lighting efficiency and the number or placement of light fixtures were inadequate to provide the necessary illumination levels throughout the room. Poor illumination can result in visual fatigue due to excessive strain on the eyes and can also cause indirect effects such as adopting awkward postures to compensate for inadequate lighting, which may lead to discomfort or back pain. These conditions can lead to anxiety and fatigue as well as migraines and nausea, backache, neck pain, shoulder pain, poor concentration, and daytime sleepiness.[11]

Additionally, poor lighting can negatively impact mood and energy levels, leading to decreased productivity and morale among employees, and increasing the likelihood of errors and accidents in tasks that require precision and attention to detail. Science firmly supports the notion that unsuitable lights can reduce employee productivity while also making people feel unhappy and agitated[4]. Moreover, problems with external or natural light entering the workspace were noted, particularly from midday to evening as the sun changes position. Daylight changes can have a significant impact on the eyesight and behavior of human resources. It is therefore possible for employees to feel drowsy and lethargic if the workplace lighting is not able to accurately replicate natural light.[4] Employees may get disengaged in their work because of this issue, which may impair their performance.[12]

Several measures can be undertaken to preserve visual comfort and increase visual performance. These include installing additional lighting fixtures or upgrading existing ones to ensure sufficient illumination, implementing a routine maintenance schedule to clean and replace bulbs regularly, and reassessing the lighting layout for even distribution of light. It is critical not only to provide the appropriate quantity of light, but also to ensure that the light is evenly distributed across the work area. Daylight penetration in the workplace is highly advisable to support “Green Technology". To reduce energy consumption and costs while maintaining visual comfort and work performance, lighting installations should be designed with energy efficiency in mind.[4] Addressing these deficiencies is crucial to enhance the visual comfort, health, and productivity of the room's occupants. By upgrading fixtures, optimizing the lighting layout, and maintaining a regular schedule of bulb replacement and cleaning, the room can achieve the required lighting standards and provide a more conducive working environment to occupants.

Thermal comfort conditions consist of factors, such as, temperature, relative humidity and air velocity named as environmental parameters. Achieving thermal comfort is crucial for maintaining productivity, well-being, and health in indoor environments.[13] Based on results tabulated in Table 3, the temperature measurements showed that in the Science Officer's office, the temperature ranged from a minimum of 20.8°C to a maximum of 26.1°C, with an average of 23.6°C. In contrast, the Elysian Spa had temperatures ranging from 25.0°C to 26.8°C, with an average of 25.7°C. Most temperature readings from both locations fall within the acceptable range of 23°C to 26°C, indicating a generally stable and suitable environment. However, it is notable that the reading of 20.8°C recorded at the Elysian Spa falls below the acceptable lower limit. The indoor air temperature of a building significantly impacts the body's heat production and dissipation processes, which are essential for maintaining thermal comfort and overall well-being.[14] This suggests a potential issue with temperature control in that specific area, which should be addressed to ensure consistent comfort and adherence to indoor air quality standards.

Table 2 Lighting measurement results

Sampling Station	Equipment	Measurement Points	Lux Reading (lux)	Notes	DOSH Standards
Officer’s Room	Lux Meter	1	39.8	The monitoring was done while the lamp is on and the blinds are closed.	300-500 lux
		2	59.5		
		3	55.5		
		4	68.9		
		5	92.7		
		6	66.2		
		7	61.8		
		8	87.5		
		9	63.3		

Table 3 Thermal measurement results

Parameters	Equipment	Science Officer's Office, Faculty of Veterinary Medicine			Elysian Spa			Acceptable limits of Quality Industry Indoor Air 2010
		Max	Min	Ave	Max	Min	Ave	
Temperature (°C)	EVM-7 Indoor Air Quality 3M QUEST	26.1	20.8	23.6	26.8	25.0	25.7	23 - 26
Relative Humidity (%)	EVM-7 Indoor Air Quality 3M QUEST	67.6	53.4	61.5	61.3	43.7	49.4	40 - 70
Air Velocity (m/s)	AirPro Solution Models AP500	0.13	0.05	0.09	0.22	0.13	0.15	0.15 - 0.50

Relative humidity readings, also taken with the EVM-7 Indoor Air Quality 3M QUEST, were within acceptable limits in both locations. The Science Officer's Office had a relative humidity range from 53.4% to 67.6%, averaging 61.5%, while the Elysian Spa ranged from 43.7% to 61.3%, with an average of 49.4%. The acceptable range for relative humidity is 40% to 70%. These results indicate that both locations maintain suitable humidity levels for comfort and material preservation.

Air velocity measurements, obtained using the AirPro Solution Models AP500, revealed that the Science Officer's Office had air velocities ranging from 0.05 m/s to 0.13 m/s, with an average of 0.09 m/s. The Elysian Spa's air velocity ranged from 0.13 m/s to 0.22 m/s, averaging 0.15 m/s. The acceptable range for air velocity is 0.15 m/s to 0.50 m/s. The Science Officer's Office consistently fell below this range, indicating insufficient air movement and potentially poor air circulation. In contrast, the Elysian Spa met the minimum acceptable air velocity, suggesting a more effective ventilation system. Improvements in air velocity at the Science Officer's Office could significantly enhance indoor air quality and occupant comfort.

Based on the monitoring at Elysian Spa, it was observed that the airflow is poor at five stations, and the situation worsens during peak times when 30 students, lecturers, and staff are present. During peak times, the accumulation of heat and carbon dioxide from occupants can make the environment stuffy and unpleasant, increasing discomfort.[6] This highlights a significant issue with the existing localized ventilation system, which is used for each of the five workstations. Without proper ventilation inlets and outlets, the air becomes stagnant and stuffy, exacerbating discomfort and potentially leading to health issues.

The current system lacks the capability to bring in fresh air and expel stale air, which results in insufficient air circulation and poor air quality. The low air velocity at the spa, combined with the absence of windows and exhaust fans, indicates inadequate air movement and poor air circulation. To improve air quality and comfort at Elysian Spa, it is recommended to install air humidifiers and expand the space for better airflow. Humidifiers will add moisture to the air, alleviating dryness and reducing dust and allergens. By making the space larger and more open, overcrowding can be reduced, enhancing air circulation. Adding ventilation solutions like exhaust fans and windows will ensure fresh air comes in and stale air goes out, making the environment more pleasant and healthy for everyone.

In the Science Officer's Office at the Faculty of Veterinary Medicine, even though temperature and humidity levels are within acceptable ranges, the air velocity is relatively low. Poor air circulation due to low air velocity can create stagnant air pockets where moisture accumulates, which can lead to mold development in an office due to several factors. Hidden moisture in absorbent materials such as carpets, curtains, and upholstered furniture, as well as behind walls, in ceilings, or under floors, can also lead to mold growth. According to guidelines for office safety and health, ventilation should be sufficient, aiming for at least 10 liters of fresh air per second per person in general office areas, or 10 liters per second for every 10 square meters of floor space. This can be achieved through natural ventilation like opening windows or doors or artificial methods such as mechanical ventilation or air-conditioning systems. Therefore, ensuring good ventilation and regular maintenance is essential to prevent mold and maintain a healthy office environment.

Addressing the mold issue in the Science Officer's Office at the Faculty of Veterinary Medicine requires immediate and long-term actions. Begin by replacing and removing ceiling sections affected by severe mold to eliminate the current infestation. Implement regular monitoring and cleaning of mold-prone areas to control mold before it spreads. Ensure prompt replacement of any ceiling with moisture or leakage to prevent mold growth. Regular maintenance and monitoring of humidity levels and moisture sources are crucial to maintaining a healthy office environment and preventing mold growth.

Thermal comfort is closely interconnected with ventilation systems in indoor environments. Adequate building ventilation helps regulate indoor temperature and enhances thermal comfort by ensuring sufficient air exchange rates and maintaining a balance between incoming and outgoing air streams. Air movement inside the enclosed space depends on the location of the inlet and outlet of the air, size and location of the window, climatic condition, type and intensity of activities, number of people, and the efficiency of the ventilation system. However, ventilation has a significant impact on energy use in buildings[15]. Thus, managing air flow and temperature also contribute to maintaining a balanced humidity level that enhances thermal comfort.

CONCLUSION

This study successfully achieved its objective by assessing the indoor environmental quality of the selected locations, identifying deficiencies in lighting and thermal comfort, and providing recommendations for improvements to enhance occupational health and well-being. The daylight illumination and thermal comfort plays an important role on employee health and thereby adversely affects the work productivity. Addressing these issues through improved lighting fixtures, regular maintenance, and enhanced ventilation systems is crucial for creating a conducive work environment. By prioritizing indoor environmental quality (IEQ) improvements, organizations can foster healthier, more comfortable workplaces that support employee satisfaction, and overall well-being. Investing in high-quality thermal and lighting solutions is not merely a cost but a strategic move towards fostering a thriving work environment. This holistic approach to IEQ contributes to the overall success and efficiency of the organization. The findings from this research provide valuable insights for future initiatives aimed at optimizing IEQ in university office settings, thereby contributing to the broader goals of creating sustainable and supportive work environments.

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