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Indoor Air Quality Assessment in an Aging Educational Building: A Case Study of the ICRC Office, UTHM

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Abstract

Indoor air quality (IAQ) plays an important role in maintaining occupant health, comfort, and productivity, particularly in office environments. Aging buildings are often associated with ventilation limitations and deteriorated systems that may contribute to the accumulation of indoor pollutants. This study presents an IAQ assessment conducted at the Industry Community and Relations Centre (ICRC) Office, Universiti Tun Hussein Onn Malaysia (UTHM), an educational building established in 1999. The assessment involved a walkthrough inspection, physical measurements using sensor-based instruments, a subjective evaluation through an occupant questionnaire, and comparison with the Industry Code of Practice on Indoor Air Quality (ICOP IAQ 2010) guidelines and previous IAQ data. The subjective assessment focused on occupants' perceptions of indoor comfort and the occurrence of IAQ-related symptoms during working hours. Key physical parameters evaluated include air temperature, relative humidity, and air movement, while chemical parameters include carbon dioxide, carbon monoxide, ozone, formaldehyde, particulate matter, and total volatile organic compounds. Most parameters were within acceptable limits; however, particulate matter (PM_{10}) exceeded the ICOP IAQ 2010 limit of 0.15 mg/m^3, with concentrations of 0.328 mg/m^3 on Day 1 and 0.220 mg/m^3 on Day 2. Elevated PM_{10} levels are likely influenced by infrequent housekeeping activities and carpeted flooring. Correlation analysis indicated an association between increased particulate matter levels and reported symptoms such as fatigue and headaches, suggesting potential Sick Building Syndrome (SBS) conditions. The findings highlight the importance of continuous IAQ monitoring and proper maintenance of ventilation systems in aging educational buildings.

1. Introduction

Indoor air quality (IAQ) has become an important issue in recent years as people spend a large portion of their daily lives indoors, especially in offices, schools, and other institutional buildings (Mendell et al., 2024; WHO, 2021). The quality of indoor air directly affects occupants' health, comfort, and overall well-being (EPA, 2023). When indoor air quality is poor, occupants may experience discomfort, reduced work performance, and various health symptoms such as headaches, fatigue, eye irritation, and respiratory problems. These symptoms are often associated with Sick Building Syndrome (SBS) and have been widely reported in recent studies involving office and educational environments (Kim et al., 2025; Ullhaque, 2024). Therefore, maintaining acceptable IAQ is essential to ensure a healthy and productive indoor environment, particularly in administrative and educational buildings (ASHRAE, 2022).

Older buildings tend to face greater IAQ challenges due to aging ventilation systems, material deterioration, moisture problems, and limited maintenance practices (Sundell et al., 2021; Guarnieri et al., 2023). As ventilation efficiency decreases over time, indoor pollutants such as carbon dioxide (CO_2), particulate matter (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOCs), ozone (O_3), and formaldehyde can accumulate within enclosed spaces (Mendell et al., 2024; Yu et al., 2024). Prolonged exposure to these pollutants has been linked to increased reports of SBS symptoms, with recent studies highlighting strong associations between elevated particulate matter levels and complaints of fatigue, headaches, and respiratory discomfort among building occupants (Tamran et al., 2025; Ullhaque, 2025).

The Industry Community and Relations Centre (ICRC) at Universiti Tun Hussein Onn Malaysia (UTHM) is one of the university's older administrative buildings and is used daily by staff and visitors who spend extended periods indoors. Due to its age and continuous use, the building may be susceptible to IAQ problems that have not been thoroughly evaluated. Previous research has shown that administrative buildings with similar characteristics often experience declining indoor air quality when regular monitoring and proper maintenance are not consistently implemented (Guarnieri et al., 2023; ASHRAE, 2022).

This study aims to assess indoor air quality at the ICRC Office through physical measurements and visual inspections. The measured data are compared with the acceptable limits specified in the Industry Code of Practice on Indoor Air Quality (ICOP IAQ, 2010) to determine the current condition of the indoor environment. The findings of this study are expected to provide useful insights for improving IAQ management and enhancing occupant comfort in aging educational buildings.

2. Case Study

The study was conducted at the Industry Community and Relations Centre (ICRC) Office located on Level 1 of the A2 Academic Building at Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, Johor, as shown in Figure 1. The building was constructed in 1999 and has been in continuous operation for more than two decades, serving various administrative functions over the years. The office consists of a main working area, a meeting room, a pantry, and supporting spaces. The building is primarily ventilated using a mechanical air-conditioning system, with limited natural ventilation through operable windows, as well as ceiling and standing fans to assist air circulation. The office is staffed by approximately 10 employees, and normal operations run for about 8 hours per day.

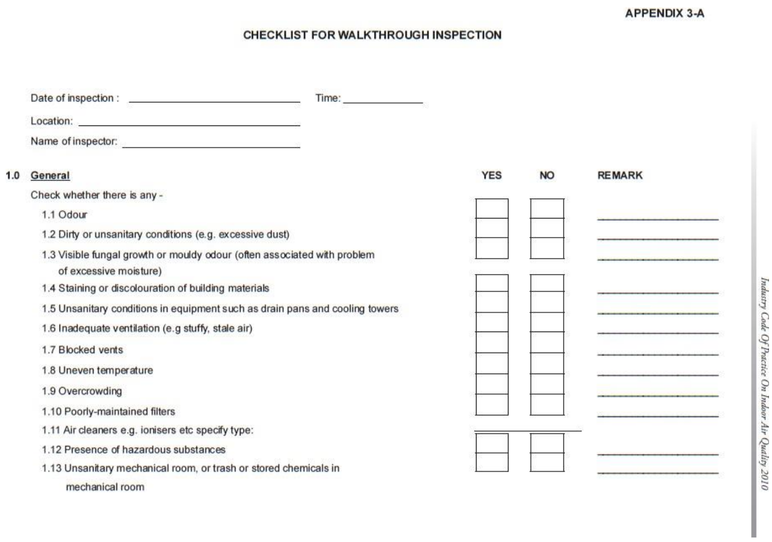
Fig. 1 *ICRC Office, UTHM*

2.1 Method of Study

The methodology of this study was structured into several phases to ensure a systematic and comprehensive assessment of indoor air quality at the ICRC Office, UTHM. In general, the study method was divided into three main phases: walkthrough inspection, physical measurement, and subjective measurement. The walkthrough inspection was conducted to observe the building condition and identify potential factors affecting indoor air quality. This was followed by physical measurements to obtain quantitative data on selected IAQ parameters using appropriate instruments. Lastly, subjective measurements were conducted to gather occupants' perceptions and feedback on the indoor environment. The combination of these phases provided a holistic evaluation of the indoor air quality conditions at the study location.

2.2 Walkthrough Inspection

A walkthrough inspection was conducted at the ICRC Office, UTHM, prior to instrument-based measurements to identify potential factors affecting indoor air quality. The inspection covered both external and internal areas of the building in accordance with ICOP IAQ 2010. External observations focused on potential outdoor pollution sources, such as vehicle traffic, waste disposal areas, smoking zones, and nearby dusty activities, that could influence indoor conditions through air infiltration. Internally, office spaces, meeting rooms, pantry, and storage areas were inspected for visible indicators of poor IAQ, including dust accumulation, dampness, mold growth, and unpleasant odors. The condition and operation of ventilation systems, including air-conditioning units, ceiling fans, and operable windows, were also reviewed to assess airflow effectiveness. In addition, potential indoor pollution sources such as cleaning agents, office equipment, and old furniture were identified. A standardized ICOP IAQ 2010 checklist as shown in Figure 2 was used to ensure a systematic and consistent inspection process.


APPENDIX 3-A

CHECKLIST FOR WALKTHROUGH INSPECTION

Date of inspection : ______________ Time: ________

Location: ______________

Name of inspector: ______________

1.0 General	YES	NO	REMARK
Check whether there is any -			
1.1 Odour			
1.2 Dirty or unsanitary conditions (e.g. excessive dust)			
1.3 Visible fungal growth or mouldy odour (often associated with problem of excessive moisture)			
1.4 Staining or discolouration of building materials			
1.5 Unsanitary conditions in equipment such as drain pans and cooling towers			
1.6 Inadequate ventilation (e.g stuffy, stale air)			
1.7 Blocked vents			
1.8 Uneven temperature			
1.9 Overcrowding			
1.10 Poorly-maintained filters			
1.11 Air cleaners e.g. ionisers etc specify type:			
1.12 Presence of hazardous substances			
1.13 Unsanitary mechanical room, or trash or stored chemicals in mechanical room			

Industry Code Of Practice On Indoor Air Quality 2010

Fig. 2 *Checklist for Walkthrough Inspection*

2.3 Physical Measurement

Three sampling points were selected for each space at the ICRC, UTHM, as shown in Figure 3, following ICOP (2010) guidelines as shown in Table 1. Sampling locations were at least 0.5 m from corners, walls, windows, partitions, or vertical surfaces, away from air supply diffusers, heaters, floor fans, or occupants' exhaled breath, not under direct sunlight, and at least 1 m from printers or photocopiers. Sampler inlets were positioned 75 to 120 cm above the floor, ideally at 110 cm. Sampling was conducted during office hours (8:00 AM–5:00 PM) over 2 days using calibrated instruments. For the questionnaire survey, 10 responses were collected from all staff working at the office.

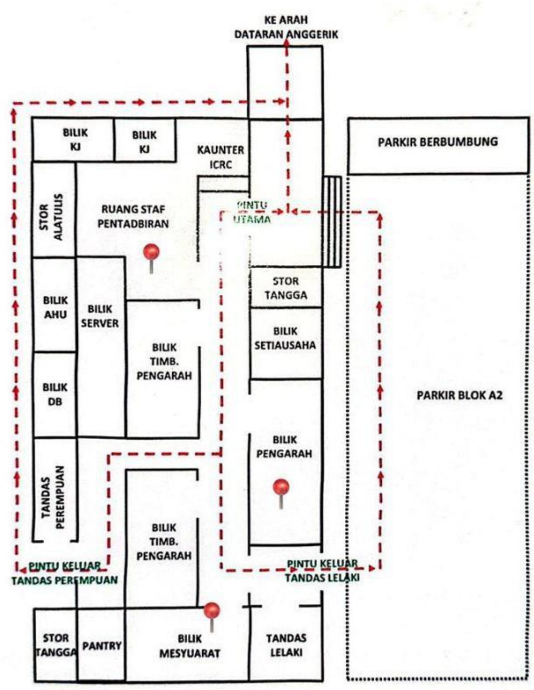


Fig. 3 *Layout sampling point*

Table 1 *Minimum number of sampling points recommended (ICOP IAQ, 2010)*

Total floor area (served by MVAC system) (m^2)	Minimum number of sampling points
< 3,000	1 per $\mathbf{500}\boldsymbol{m^2}$
3,000 - < 5,000	2
5,000 - < 10,000	12
10,000 - < 15,000	15
15,000 - < 20,000	18
20,000 - < 30,000	21
≥ 30,000	1 per $\mathbf{1{,}200}\boldsymbol{m^2}$

The measured indoor air quality (IAQ) data were analysed by comparing the obtained values with the acceptable limits specified in the Industry Code of Practice on Indoor Air Quality (ICOP IAQ 2010) as shown in Table 2 and 3. The analysis focused on identifying parameters that exceeded the recommended standards and evaluating possible contributing factors, including ventilation performance, building age, and occupant-related activities. Where applicable, current measurements were also compared with previous monitoring data to assess changes in indoor air quality over time.

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Table 2 *Acceptable range for specific physical parameters*

Item	Parameter	Acceptable Range
1	Air Temperature	23-26 °C
2	Relative Humidity	40-70%
3	Air Movement	0.15-0.50m/s

Table 3 *List of Indoor air contaminants and the acceptable limit*

Indoor Air Contaminants	Acceptable limits		
	ppm	mg/m^3	cfu/m^3
Chemical contaminants:			
(a) Carbon monoxide	10	-	-
(b) Formaldehyde	0.1	-	-
(c) Ozone	0.005	-	-
(d) Respirable particulates	-	0.15	-
(e) TVOC	3	-	-
Biological contaminants:			
(a) Total bacterial counts	-	-	500*
(b) Total fungal counts	-	-	1000*
Ventilation performance indicator:			
(a) Carbon dioxide	C1000	-	-

2.4 Subjective Measurement

Subjective measurement was conducted using a structured questionnaire to obtain occupants' perceptions of indoor air quality at the ICRC Office, UTHM. The questionnaire was designed to complement the physical measurements by capturing occupants' experiences and comfort levels while working in the office environment. The survey questionnaire was divided into three main sections. The first section focused on respondent background information, including gender, age, and duration of time spent in the office. The second section evaluated occupants' perceptions of the indoor environment, covering aspects such as thermal comfort, air movement, air freshness, and the presence of dust or odour. The third section assessed health-related symptoms commonly associated with indoor air quality issues, such as headaches, eye irritation, fatigue, and respiratory discomfort experienced during working hours. The questionnaire was distributed to all occupants working at the ICRC Office. A total of 10 respondents participated in the survey, representing all staff working in the office. The responses obtained were analysed to identify common perceptions and symptoms related to indoor air quality, and the findings were used to support and interpret the results of the physical IAQ measurements.

2.5 Correlation Method Between Persistent Symptoms and IAQ Data

A correlation analysis was conducted to examine the relationship between reported persistent symptoms among occupants and the measured indoor air quality (IAQ) parameters. Data on occupant symptoms were collected via a structured questionnaire, and IAQ parameters were measured with portable instruments during the assessment period. The correlation between symptom occurrence and IAQ parameters was calculated using Microsoft Excel as shown in Figure 4, to identify potential associations between indoor environmental conditions and occupant discomfort. This approach was applied to support the evaluation of how variations in IAQ may influence occupant health and well-being.

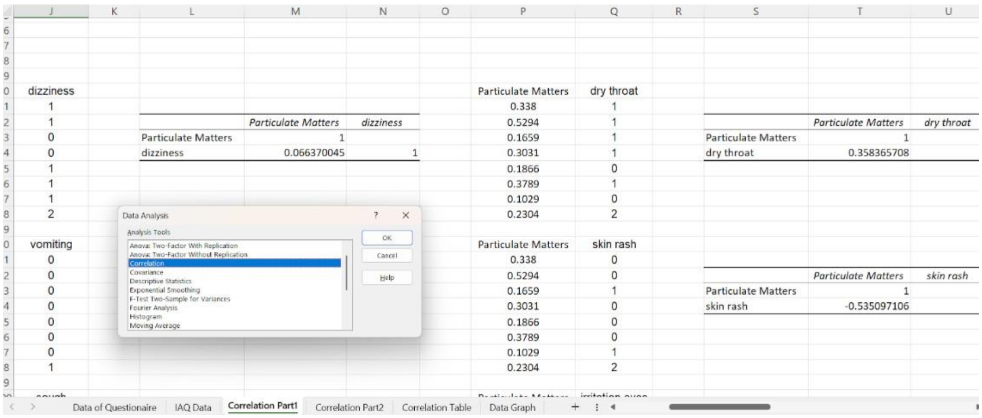

Fig. 4 *Data analysis using correlation function*

3. Results and Discussion

The results of this study focus on evaluating measured indoor air quality (IAQ) parameters and identifying those that exceed recommended standards. Measurements were conducted during normal office operating hours, with readings taken at 5-minute intervals to ensure stable and representative values. The collected data were analysed against the acceptable limits specified in ICOP IAQ 2010 to determine overall IAQ performance. Parameters exceeding the recommended limits were identified and discussed in relation to ventilation effectiveness and occupant activities, with particular attention given to particulate matter levels.

3.1 Walkthrough inspection

A walkthrough inspection was conducted at the ICRC Office, UTHM, prior to data collection to observe the indoor environment and identify factors that may influence indoor air quality. The inspection covered the air-conditioning and mechanical ventilation systems, the cleanliness of indoor surfaces, work area layout, and potential sources of indoor pollutants. Dust accumulation was observed on the air-conditioning vents and surrounding ceiling areas, as shown in Figure 5. Discoloration and dust were also noted on some ceiling tiles and upper wall areas above office doors, as shown in Figure 6. The office is served by a centralized air-conditioning system and is occupied by staff for approximately 8 hours per day. The main working area, shown in Figure 7, is carpeted and consists of open workstations and enclosed offices. Office equipment, such as computers, photocopiers, and laser printers, was available during normal working hours.

Fig 5 *Dust buildup on the air-conditioning vent and ceiling surface*

Fig 6 *Dirty and slightly stained ceiling and wall area above the office door*

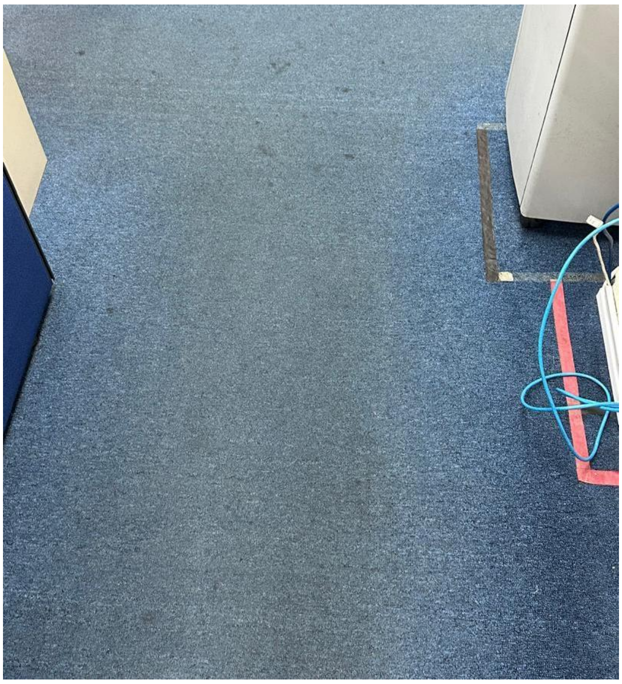

Fig. 7 *Carpet floor working area*

3.2 Physical Measurement

A 2-hour morning and 2-hour evening session assessment was carried out in the UTHM ICRC Office during normal working hours. The parameters measured included air temperature, air movement, relative humidity, carbon monoxide, carbon dioxide, ozone, total volatile organic compounds, formaldehyde, and particulate matter. Measurements were taken at a height of 110 cm, which corresponds to the typical working level of office staff. Three sampling points are shown in Fig. 8, Fig. 9, and Fig. 10. Each parameter was recorded at two-minute intervals. The data collected for the qualitative assessment is shown in Table 4.

Fig. 8 *Sampling point 1 for data measurement*

Fig. 9 *Sampling point 2 for data measurement*

Fig. 10 *Sampling point 3 for data measurement*

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Table 4 *Data measurement for IAQ parameters at ICRC UTHM*

	Day 1	Day 2	status
Air Temperature, T (°C) Day 1 Day 2 Mean			
Acceptable limits/ range: 23–26 °C (ICOP IAQ 2010)			
Maximum	24.5	24.2	
Minimum	22.9	22.5	Within acceptable limit
Average	23.8	23.3	
mean	24.35	22.7	
Air Movement, V (m/s)			
Acceptable limits/ range: 0.15–0.5 m/s (ICOP IAQ 2010)			
Maximum	0.76	0.81	
Minimum	0.02	0.00	Within acceptable limit
Average	0.22	0.17	
mean	0.79	0.01	
Relative Humidity, RH (%)			
Acceptable limits/ range: 40–70% (ICOP IAQ 2010)			
Maximum	70.50	68.90	Within acceptable limit
Minimum	66.90	66.00	
Average	68.27	67.86	
mean	69.70	66.45	
CO (ppm)			
Acceptable limits/ range: 10 ppm (ICOP IAQ 2010)			
Maximum	0	0	
Minimum	0	0	Within acceptable limit
Average	0	0	
mean	0	0	
Formaldehyde			
Acceptable limits/ range: 0.1 ppm (ICOP IAQ 2010)			
Maximum	0	0	
Minimum	0	0	Within acceptable limit
Average	0	0	
mean	0	0	
Ozone (ppm)			
Acceptable limits/ range: 0.05 ppm (ICOP IAQ 2010)			
Maximum	0.014	0.012	
Minimum	0.000	0.002	Within acceptable limit
Average	0.006	0.007	
mean	0.013	0.001	
PM10 (mg/m³)			
Acceptable limits/ range: 0.15 mg/m3 (ICOP IAQ 2010)			
Maximum	0.994	0.684	
Minimum	0.050	0.010	Exceeding Range
Average	0.328	0.220	
mean	0.839	0.030	
Total Volatile Organic Compound (ppm)			
Acceptable limits/ range: 3 ppm (ICOP IAQ 2010)			
Maximum	0	0	
Minimum	0	0	Within acceptable limit
Average	0	0	
Mean	0	0	
CO_2 (ppm)			
Acceptable limits/ range: 1000 ppm (ICOP IAQ 2010)			
Maximum	666.00	538.00	
Minimum	321.00	377.00	Within acceptable limit
Average	501.81	433.16	
mean	602.00	349.00	

The environmental monitoring at the ICRC Office identifies Particulate Matter (PM10) as the primary parameter of concern, with average concentrations of 0.328 mg/m^3 on Day 1 and 0.220 mg/m^3 on Day 2 as shown in Fig. 11. These levels significantly exceed the 0.15 mg/m^3 limit set by the ICOP IAQ 2010, and this data aligns directly with the health symptoms reported by the occupants. The high prevalence of fatigue, drowsiness, and headaches among staff is a typical manifestation of Sick Building Syndrome (SBS) triggered by such elevated dust levels. These symptoms are likely exacerbated by the office's physical conditions; specifically, the aging centralized air-conditioning system showed visible dust buildup on vents, suggesting that particulates are being recirculated rather than filtered. Furthermore, the presence of carpeted flooring, which is vacuumed only twice a month, acts as a dust reservoir that is constantly re-suspended into the breathing zone by daily movement. This combination of high particulate load and stagnant air creates a "stuffy" environment that directly contributes to the lethargy and headaches reported by most of the workforce.

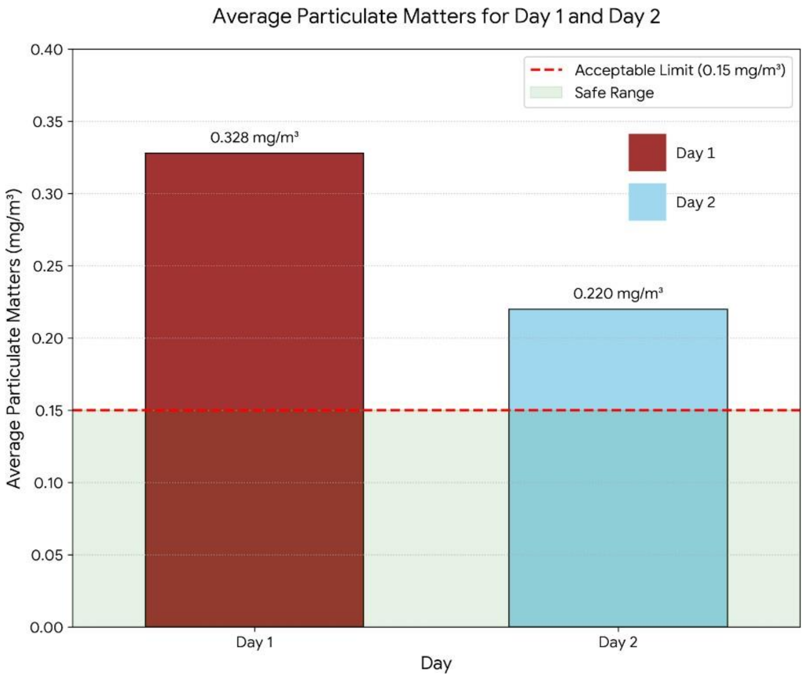

Fig. 11 *Average particulate matters*

3.3 Subjective Measurement

The survey results regarding environmental dissatisfaction are illustrated in Figure 12. The disturbance factors identified by occupants included inconsistent room temperatures, stagnant or "stuffy" air, and visible dust accumulation. These findings were corroborated by the walkthrough inspection, which revealed dust buildup on HVAC diffusers and evidence of dirt or mold growth on ceiling tiles and door frames, likely due to high humidity and aging infrastructure.

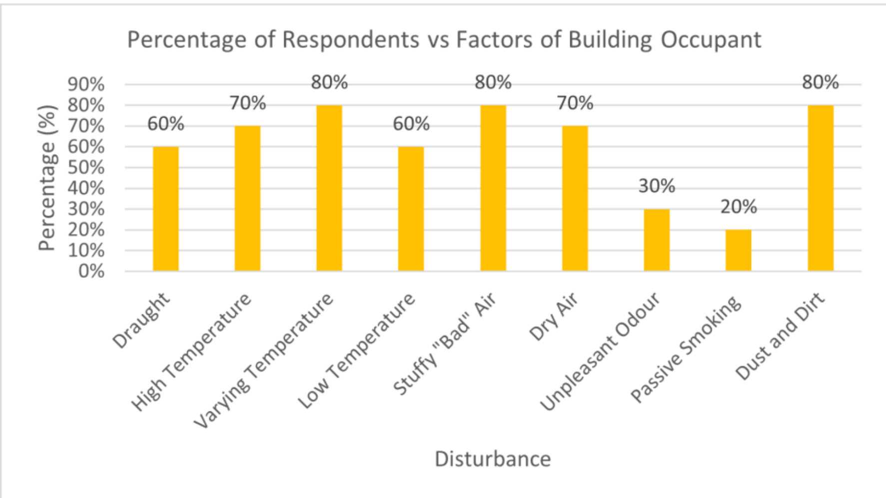

Fig. 12 *Percentage of respondents vs factor of building occupant*

In addition to environmental factors, the prevalence of health symptoms was recorded, as shown in Figure 13. A significant number of respondents reported experiencing fatigue, drowsiness, and headaches during working hours. These symptoms are characteristic of Sick Building Syndrome (SBS) and suggest that the current ventilation rates may be insufficient to maintain a healthy indoor environment. The correlation between the observed physical conditions and the reported health issues emphasizes the need for improved maintenance and ventilation strategies in the ICRC office. The survey results indicate a clear alignment between the physical environment of the ICRC office and the symptoms reported by its occupants. Specifically, the high prevalence of respiratory discomfort and "dusty" sensations reported by staff directly corresponds with the elevated PM10 levels recorded during the monitoring period. Both Day 1 (0.328 mg/m^3) and Day 2 (0.328 mg/m^3) exceeded the ICOP IAQ 2010 limit of 0.15 mg/m^3. This correlation is further justified by the walkthrough inspection, which noted significant dust accumulation on AC vents and the presence of old carpeting. Since these carpets are only vacuumed twice a month, they likely act as a reservoir for particulates that are re-suspended into the air by daily foot traffic, leading to the symptoms reported.

Regarding the high frequency of headaches, fatigue, and drowsiness among the staff, these can be attributed to the overall decline in air freshness within the aging building infrastructure. While CO_2 and CO levels were within the allowable range, the combination of high particulate matter and poor air movement creates a stagnant environment, often referred to as "stuffy air." In such conditions, the body's thermal comfort is compromised, and the lack of effective air circulation can lead to lethargy and a drop in concentration levels. The fact that many respondents identified these specific symptoms suggests that the office is experiencing a degree of Sick Building Syndrome (SBS), likely caused by the centralized AC system's inability to adequately filter fine dust or provide sufficient fresh air intake.

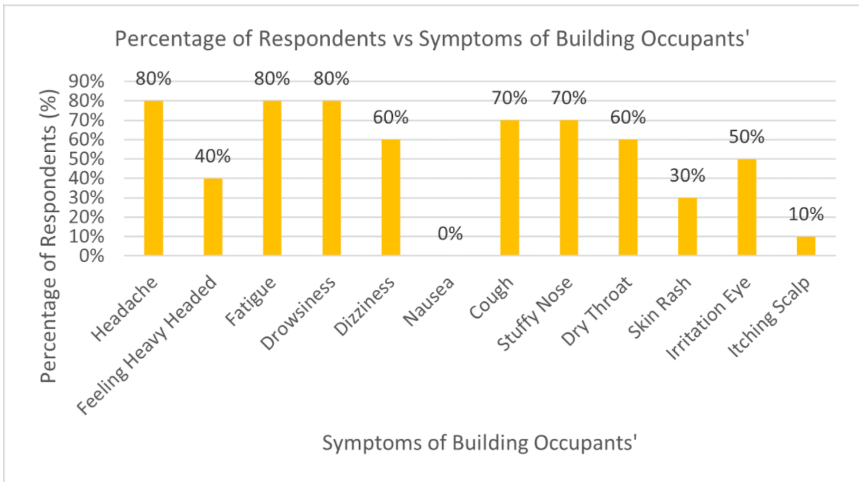

Fig. 13 *Percentage of respondents vs symptoms of building occupants*

3.4 Comparison of IAQ Results Between Current Assessment and Previous Data

In this section, the findings from the current assessment are compared against the previous indoor air quality data for the ICRC UTHM office. The primary objective of this comparison is to track changes in the indoor environment over time and to evaluate whether the building's ventilation and maintenance systems continue to perform effectively. Since the two sets of data were collected at different times, the focus of this analysis is not just on the raw numbers, but on whether the parameters consistently meet the safety standards set by the Industry Code of Practice (ICOP). By looking at the "Previous" vs. "Current" results side by side, it becomes easier to spot where air quality has improved and where it has unfortunately degraded. Table 5 summarizes these values, providing a clear overview of the office's environmental performance across both assessment periods.

Table 5 *Comparative analysis of Indoor Air Quality (IAQ) parameters between previous data and current assessment*

IAQ Parameter	Previous Data (Morning/Evening)	Current Assessment (Morning/Evening)	Status
Temperature	25.23 / 25.43	23.67 / 23.43	Within Range
Relative Humidity	68.4 / 68.4	68.4 / 68.4	Within Range
Air Velocity	0.14 / 0.14	0.19 / 0.17	Improved
Carbon Dioxide	921 / 780	510 / 425	Within Range
Ozone	0.003 / 0.009	0.006 / 0.009	Within Range
Particulate Matter	0.004 / 0.029	0.352 / 0.196	Exceeded

When looking at the thermal conditions, there was a clear downward shift in the office temperature. The previous records showed the office was kept between 25.23°C and 25.43°C, whereas the current measurements found it to be cooler, ranging from 23.67°C to 23.43°C. Although the temperature dropped by about 2°C, it is important to note that both sets of data are still within the official 23°C to 26°C comfort bracket. This suggests that while the air conditioning settings might have been adjusted recently, the office still maintains a stable thermal environment that meets standard requirements.

Interestingly, the relative humidity readings were identical across both the old and new assessments, holding steady at 68.4%. From an engineering standpoint, this level of consistency is quite rare and suggests that the building's moisture-control system is operating in a highly consistent manner. While this value is technically under the 70% maximum limit, it is leaning toward the higher side. It's a "safe" zone for now, but being this close to the limit means the office can feel a bit humid, so it should be monitored to prevent future dampness issues.

Air movement in the office has actually improved since the last check (Figure 14). The previous data showed a velocity of 0.14 m/s, just under the minimum requirement of 0.15 m/s, suggesting the air was likely feeling a bit "stuffy" or stagnant back then. The current assessment recorded higher speeds of 0.17 m/s to 0.19 m/s as shown in Fig. 15. Based on the findings, the ICRC office has undergone upgrades to the air conditioning system following the acquisition of previous data. These enhancements have resulted in more efficient airflow throughout the office, ensuring that the air movement now meets the required standards for a healthier and more comfortable indoor environment. This improvement in air velocity, coupled with a notable reduction in CO_2 levels, confirms that the upgraded ventilation system is functioning effectively in circulating fresh air.

The carbon dioxide levels showed a very positive trend, dropping significantly from the previous assessment. Earlier records showed levels as high as 921 ppm, but the current readings were much lower, between 425 ppm and 510 ppm. Since the acceptable limit is 1000 ppm, the office is in good shape. This drop of nearly 400 ppm is a strong indicator that the ventilation system is doing a good job of bringing in fresh outdoor air, or it could simply mean there were fewer people in the room during my testing. Either way, the air is well-oxygenated.

Ozone is often a concern in offices with lots of photocopiers, but here it remains a non-issue. The levels I recorded (0.006 to 0.009 ppm) are almost identical to the previous data and are well below the 0.05 ppm safety limit. Since the numbers are so low, it's clear that there aren't any machines or air cleaners in the ICRC office producing harmful levels of ozone. It is a very safe result that hasn't changed much over time.

The most concerning discovery in this study is the massive jump in particulate matter. In the past, the office was well within the 0.15 mg/m³ limit, but my current results show levels reaching 0.352 mg/m³, more than double the allowed limit, as shown in Figure 15. After a walkthrough inspection and speaking with the staff, the reason became clear: the office uses carpeted flooring but is vacuumed only twice a month. This infrequent cleaning allows dust to accumulate deep within the carpet fibers. In the morning, as staff walk around, they disturb this trapped dust, kicking it back into the air (a process called re-entrainment). This explains why the morning dust levels are so much higher than the evening and represents a major failure in current maintenance protocols.

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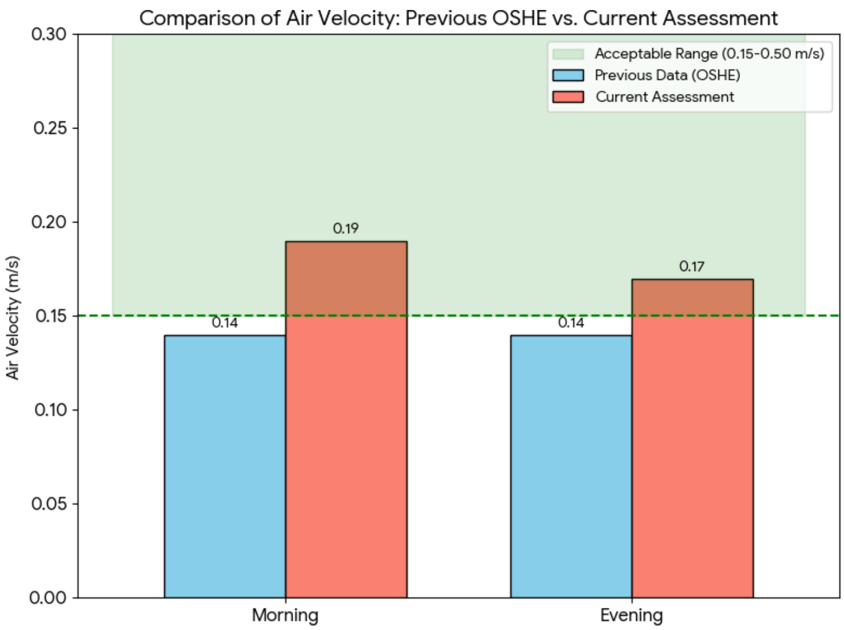

Fig. 14 *Comparison of air velocity*

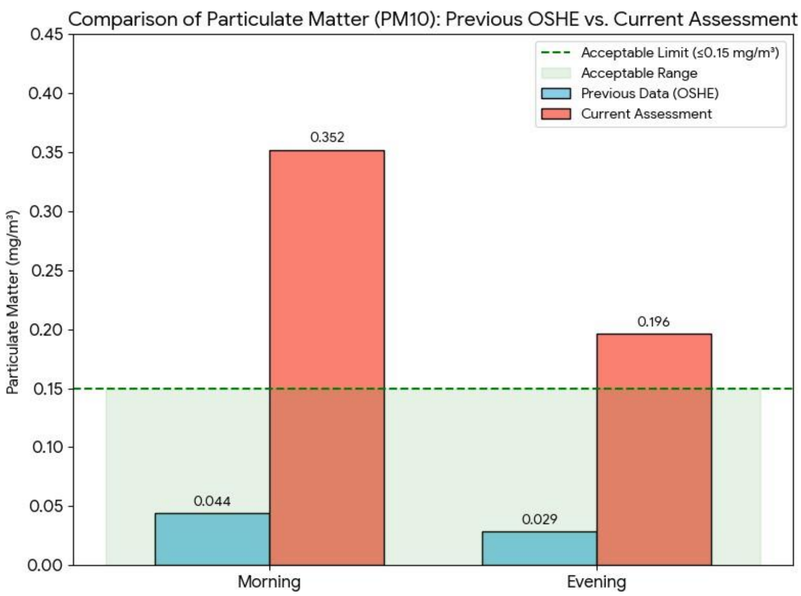

Fig. 15 *Comparison of particulate matter (PM10)*

3.5 Correlations Between Symptoms of Building Occupants and Indoor Air Quality Parameters

When evaluating how indoor air quality relates to symptoms experienced by building occupants, various environmental factors are considered for their influence on comfort and health. Key parameters include air temperature, air velocity, relative humidity, carbon dioxide, ozone, and particulate matter, all of which contribute to indoor environmental conditions. By analysing patterns in these air quality indicators together with feedback from occupants, potential relationships between environmental conditions and reported symptoms can be identified. This information is valuable for guiding strategies aimed at improving indoor air quality and promoting occupant health and comfort. Fig. 16 presents the correlation between occupants' symptoms and indoor air quality parameters.

Correlation Coefficients	SBS Symptoms	Air Temperature	Air Movement	Relative Humidity	Carbon Dioxide	Ozone	Particulate Matters
Pearson's Correlation	Headache	-0.008	0.432	-0.175	-0.183	0.309	-0.144
	Feeling Heavy Headed	0.653	-0.052	0.694	0.401	-0.392	0.036
	Fatigue	0.435	0.403	0.290	0.343	-0.312	0.022
	Drowsiness	0.004	0.597	-0.267	0.110	0.106	0.126
	Dizziness	0.081	0.672	-0.229	0.203	-0.164	0.066
	Nausea	-0.088	0.432	-0.179	-0.183	0.309	-0.144
	Cough	-0.314	0.311	-0.321	-0.370	0.343	-0.199
	Nose Irritation	0.034	0.494	-0.123	0.013	-0.098	-0.142
	Dry Throat	0.226	-0.059	0.251	0.117	0.115	0.358
	Skin Irritation	-0.171	0.106	-0.083	-0.417	0.437	-0.535
	Eye Irritation	0.1	0.124	0.136	-0.109	0.215	-0.193
	Itching Scalp	-0.088	0.432	-0.175	-0.183	0.309	-0.144

Fig. 16 *Correlation between occupants' symptoms and IAQ parameter*

Based on Fig. 16, the Pearson's correlation coefficients show how different Sick Building Syndrome (SBS) symptoms are related to indoor air quality parameters such as air temperature, air movement, relative humidity, carbon dioxide, ozone, and particulate matter. These correlations help to understand whether changes in environmental conditions may be associated with the symptoms reported by building occupants. A positive correlation means that as the value of an environmental factor increases, the likelihood or severity of the symptom also increases. Conversely, a negative correlation indicates that as the environmental factor increases, the symptom tends to decrease. For example, feeling heavy-headed has a moderate positive correlation with both air temperature and relative humidity, indicating that occupants may be more likely to experience this symptom when indoor conditions are warmer and more humid. Dizziness and drowsiness also show moderate positive correlations with air movement, suggesting that air circulation may influence these symptoms. In addition, fatigue shows moderate correlations with air temperature, air movement, and carbon dioxide levels, suggesting that both thermal comfort and ventilation conditions contribute.

Other symptoms show weaker or mixed relationships with indoor air quality parameters. Cough displays moderate negative correlations with air temperature, relative humidity, and carbon dioxide, while showing a moderate positive correlation with ozone. This suggests that certain pollutants may be more strongly related to respiratory symptoms than general thermal conditions. Skin irritation stands out as it shows a moderate positive correlation with ozone and moderate negative correlations with carbon dioxide and particulate matter, indicating sensitivity to specific air pollutants.

However, many symptoms, such as eye irritation, nose irritation, and dry throat, show only weak correlations across most parameters. This suggests that these symptoms may be influenced by factors beyond the measured indoor air quality conditions.

Overall, although some SBS symptoms show moderate relationships with specific environmental factors, most correlations are weak and inconsistent. This indicates that indoor air quality parameters alone may not fully explain the occurrence of SBS symptoms, and that a combination of environmental and individual factors is likely involved.

4. Conclusion

This study successfully evaluated the indoor air quality at the ICRC Office, UTHM, using walkthrough inspection and physical measurements in accordance with ICOP IAQ 2010 guidelines (DOSH, 2010). The findings show that most physical and chemical parameters were within acceptable limits, indicating generally satisfactory indoor environmental conditions. However, particulate matter concentrations exceeded the recommended standard, suggesting potential shortcomings in pollutant control and ventilation effectiveness. Similar findings have been reported in previous studies on aging and poorly maintained buildings, where particulate accumulation was linked to insufficient filtration and outdoor pollutant infiltration (Guarnieri et al., 2023). The results emphasize the need for continuous IAQ monitoring, routine maintenance of ventilation systems, and the implementation of appropriate mitigation measures such as improved filtration and housekeeping practices (ASHRAE, 2022). Overall, this study provides useful baseline information for enhancing indoor air quality management at UTHM and contributes to a better understanding of IAQ challenges in aging educational buildings. Based on the findings and the limitations of this assessment, several areas are suggested for future research.

Firstly, it is highly recommended to include lighting and illumination measurements in the next study. Lighting is a critical environmental factor that was not covered in this scope, yet poor lighting, whether too dim or causing glare is a primary cause of eye strain, headaches, and drowsiness in office settings. Investigating lighting quality would help determine whether the reported fatigue is purely an air-quality issue or a combination of environmental stressors. Additionally, future studies should prioritize the biological assessment (bacterial and fungal counts) that was delayed in this study, as mold growth in aging ventilation systems can be a hidden contributor to occupant ill-health. Extending the monitoring period to different seasons would also provide a more comprehensive understanding of how the building performs throughout the year.

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Conflict of Interest

The author declares no conflict of interest regarding the publication of this paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design**: Che Muhammad Naqeb Bin Che Baharum1, Azian Hariri; **data collection**: Che Muhammad Naqeb Bin Che Baharum; **analysis and interpretation of results**: Che Muhammad Naqeb Bin Che Baharum; **draft manuscript preparation**: Che Muhammad Naqeb Bin Che Baharum1, Azian Hariri. All authors reviewed the results and approved the final version of the manuscript.*

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