ORIENTAL JOURNAL OF CHEMISTRY
An International Open Access, Peer Reviewed Research Journal
www.orientjchem.org

ISSN: 0970-020 X
CODEN: OJCHEG
2025, Vol. 41, No.(4):
Pg. 1331-1340

Indoor Air Quality Assessment Based on Floor-Level Variations in a University Library

NORMAH AWANG[1]*, NUR KHALIDA JAMALUDIN[2], NURUL FARAHANA KAMALUDIN[1] and MUHAMMAD IKRAM A WAHAB[1]

[1]*Center for Toxicology and Health Risk Studies, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia.
[2]Environmental Health and Industrial Safety Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia.
*Corresponding author E-mail: norm@ukm.edu.my

http://dx.doi.org/10.13005/ojc/410431

(Received: June 19, 2025; Accepted: August 02, 2025)

ABSTRACT

Libraries are environments where students often spend extended periods due to their conducive and quiet atmosphere that supports focused learning. However, poor indoor air quality (IAQ) in such settings can negatively impact cognitive performance and pose health risks. This study aimed to assess the IAQ at Levels 1 and 3 of the Dr. Abdul Latiff Library, Universiti Kebangsaan Malaysia, by evaluating physical, chemical, and biological parameters, as well as ventilation performance indicators. Data were collected through walkthrough inspections, direct measurements, and questionnaires distributed to library staff and users. The results revealed that temperature readings at sampling points 4,5, and 6 exceeded the ICOP IAQ 2010 acceptable limits, while air movement across all sampling points fell below the recommended range. Other IAQ parameters remained within acceptable limits. Statistically significant differences ($p<0.05$) were observed in CO_2 and PM_{10} levels on Level 1 and in temperature and PM_{10} levels on Level 3. Although overall IAQ was acceptable, elevated temperatures and inadequate air movement were identified as concerns.

Keywords: Indoor air quality, Library, Thermal comfort, Mechanical ventilation and air conditioning.

INTRODUCTION

Indoor air pollution has emerged as a growing concern due to its substantial impact on human health, particularly in enclosed environments where individuals spend approximately 90% of their time (Corlan *et al.,* 2021). Indoor air quality (IAQ) refers to the condition of the air within and around buildings, influencing the comfort, health, and well-being of occupants (Seng *et al.,* 2023). Libraries, being enclosed and often densely occupied by students and staff, fall into this category and therefore require systematic IAQ monitoring and management.

Poor IAQ is associated with both short- and long-term health effects, including headaches, fatigue, respiratory and eye irritation, dizziness, and nausea (Kumar *et al.,* 2023). Prolonged exposure may lead to conditions such as Sick Building Syndrome (SBS) or Building-Related Illness (BRI), which can significantly affect productivity and well-being. In academic settings, such as libraries, maintaining optimal IAQ is not only essential for protecting occupant health but also for enhancing cognitive performance, concentration, and learning outcomes.

Various environmental factors influence IAQ, including volatile organic compounds (VOCs), particulate matter, humidity, ventilation efficiency, and microbial contaminants. In public and academic buildings like the Dr. Abdul Latiff Library, ensuring that IAQ meets established standards is crucial for promoting a healthy and conducive learning environment (Hassan *et al.,*) 2021. Good air quality supports not only user comfort but also institutional goals related to academic excellence.

This study investigates IAQ conditions at Levels 1 and 3 of the Dr. Abdul Latiff Library by measuring physical, chemical, biological, and ventilation-related parameters. A distinctive feature of this research is its focus on floor-level variations in IAQ, an aspect rarely explored in previous studies. By comparing findings across different floors and sampling points, this study aims to uncover localized differences that may affect user experience and to evaluate compliance with the ICOP IAQ 2010 guidelines. The results will help identify potential pollutant sources and inform targeted strategies for improving indoor environmental quality in academic spaces.

Methodology

This study was conducted at the Dr. Abdul Latiff Library, Universiti Kebangsaan Malaysia, Kuala Lumpur Campus, focusing on two specific floors: Level 1 and Level 3. A total of seven indoor sampling locations were selected: three at Level 1-Ruang Buku (S1), Ruang Akhbar (S2), and Bilik Buku Kebelakangan (S3); and four at Level 3-Ruang Bacaan 1 (S4), Ruang Bacaan 2 (S5), Bilik Koleksi Rujukan (S6), and Ruang Serbaguna (S7).

Ethical approval for this study was obtained from the Universiti Kebangsaan Malaysia Research Ethics Committee (Ref. No: JEP-2024-868). Written informed consent was obtained from all participants, with consent forms and questionnaires provided in English.

Walkthrough Inspection and Questionnaire Survey

An initial qualitative walkthrough inspection was conducted using a checklist adapted from the Department of Occupational Safety and Health's Industry Code of Practice on Indoor Air Quality (ICOP IAQ, 2010). This inspection provided observational data on the physical conditions of the library and identified potential risk factors affecting IAQ.

Subsequently, a quantitative survey was administered using a structured questionnaire, also adapted from ICOP IAQ (2010). The questionnaire was distributed to library staff to gather information regarding IAQ-related symptoms and potential indoor pollutant sources.

Sampling Strategy

Air quality measurements were conducted during four time slots aligned with the library's operational hours: 8:00–10:00 AM, 10:00 AM–12:00 PM, 1:00–3:00 PM, and 3:00–5:00 PM. Each sampling session lasted for two hours. All sampling points across both floors were assessed using the same set of instruments to ensure consistency and accuracy in measurements.

Measurement of IAQ Parameters

Physical, Chemical, and Ventilation Parameters:

Measurements of temperature, relative humidity, air movement, carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde, and particulate matter (PM_{10}) were conducted using a TSI IAQ-Calc Indoor Air Quality Meter (Model 7545) and GrayWolf AdvancedSense Pro multi-parameter probe. All instruments were calibrated prior to data collection. For each sampling point, three readings were recorded per time slot, each taken over a 15-min interval to compute average values.

Biological Parameters

Microbial sampling was performed using a portable BioStage single-stage impactor attached to a calibrated air sampling pump (SKC AirCheck XR5000), operating at a flow rate of 60 L/min for five minutes, following the NIOSH Manual of Analytical Methods (NMAM) 0800. Trypticase Soy Agar (TSA) was used for culturing bacteria and Sabouraud Dextrose Agar (SDA) for fungi. TSA plates were incubated at 37°C for 24 h, while SDA plates were incubated at 25°C for 72 hours. Colony counts were used to calculate microbial concentrations, expressed in colony-forming units per cubic meter (cfu/m³), using the method described by Er *et al.,* (2015).

Data Analysis

All data were analyzed using IBM SPSS Statistics version 27. Descriptive statistics were used to summarize IAQ parameters, occupant-reported symptoms, and potential pollutant sources. One-way Analysis of Variance (ANOVA) was employed to examine statistically significant differences between sampling points on each floor. All measured values were compared against the acceptable limits outlined in ICOP IAQ (2010).

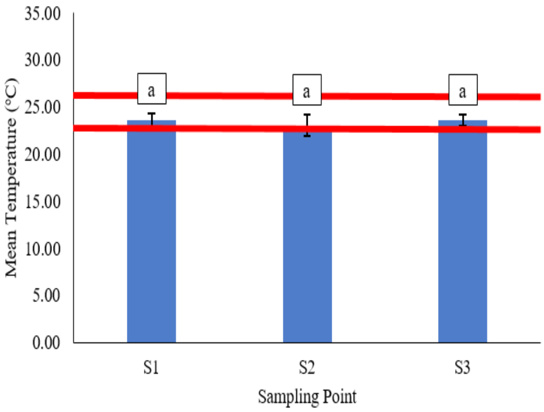
RESULTS AND DISCUSSION

Walkthrough inspection and questionnaire survey

The walkthrough inspection revealed that both Level 1 and Level 3 of the library are equipped with centralized air conditioning systems. However, signs of poor indoor maintenance were observed, including visible fungal growth on walls and ceilings, which may indicate persistent moisture or ventilation issues. Stains on the carpet further suggest potential water damage or infrequent cleaning practices. Additionally, the presence of multiple electronic devices used by students and staff was noted, which could contribute to internal heat and pollutant emissions.

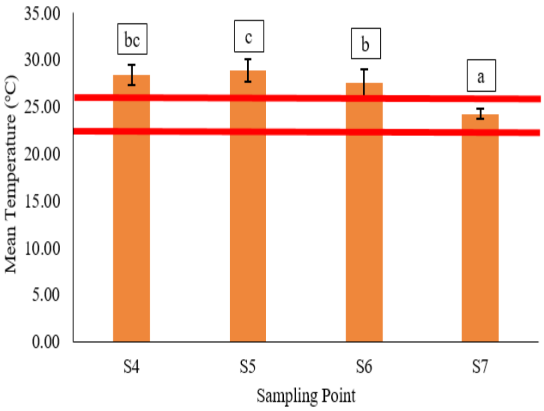
Findings from the questionnaire survey indicated that occupants frequently experienced discomfort related to dust and dry air. Commonly reported symptoms included headaches, fatigue, and coughing-ailments often associated with suboptimal indoor air quality. These subjective complaints support the need for objective IAQ evaluation.

Physical parameters



Acceptable limit range: 23–26°C
*The same letter indicates no significant difference in temperature between sampling points

Fig. 1. Mean of temperature at sampling points Level 1

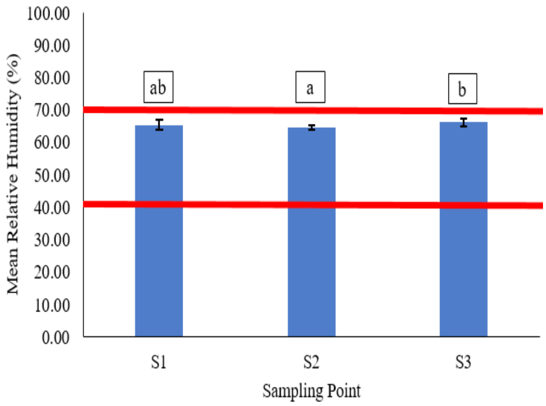


Acceptable limit range: 23–26°C
*Different letters indicate significant differences in temperature between sampling points

Fig. 2. Mean of temperature at sampling points Level 3

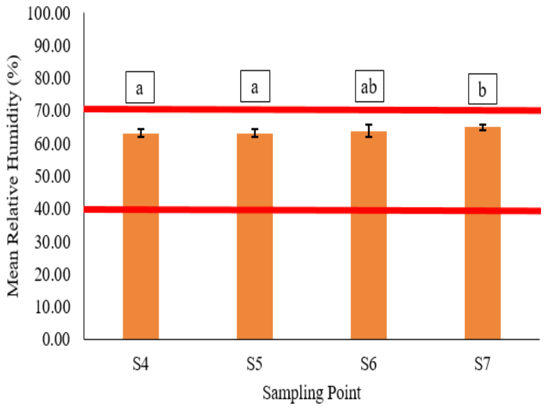
Figure 3 and Fig. 4 present relative humidity results at Level 1 and Level 3, respectively. The average reading recorded ranged from 64.64% to 66.10% at Level 1 with Sampling Point 2 having the lowest (64.64±0.61%) and Sampling Point 3 having the highest (66.10±1.32%). Meanwhile, relative humidity ranged from 63.00% to 64.86% at Level 3, with Sampling Point 5 recording the lowest (63.00±1.12%), while Sampling Point 7 recorded the highest (64.86±0.81%). Fig. 1 and Fig. 2 also show that all sampling points at both levels are within the acceptable limit range (40% to 70%) as stated in ICOP IAQ (2010). Besides that, one-way ANOVA shows the reading has no significant differences ($p>0.05$) between Sampling Point 1 as compared to others at Level 1. Level 3 also showed no significant differences ($p>0.05$) between Sampling Point 6 as compared to others. Decreasing library users during sampling activity influences the average reading recorded for relative humidity. This aligns with a statement from past research which suggests that factors such as number of users, the type of activity, characteristics of the space, personal factors, and temperature (Özdamar and Umaroğullari 2018).

Extreme relative humidity could impact occupants' health and the building's environment. This is supported by Hou *et al.,* (2021), which state that high relative humidity can increase the percentage of air humidity and is also a significant risk factor for sick building syndrome (SBS).



Acceptable limit range: 40-70%
*Different letters indicate significant differences in relative humidity between sampling points

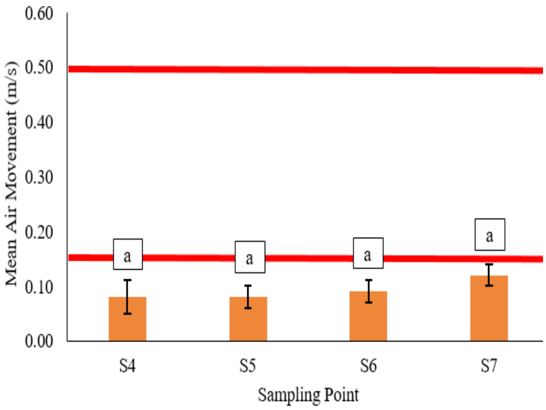
Fig. 3. Mean of relative humidity at sampling points Level 1



Acceptable limit range: 40%-70%
*Different letters indicate significant differences in relative humidity between sampling points

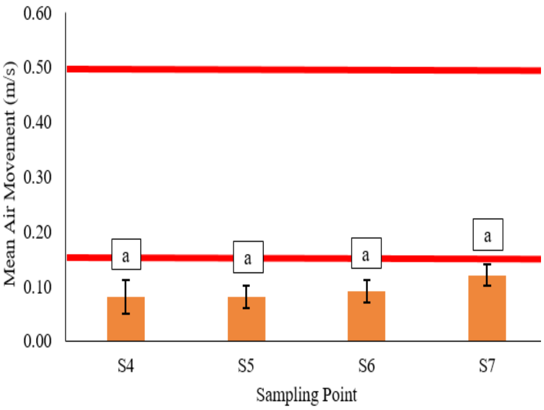
Fig. 4. Mean of relative humidity at sampling points Level 3

Figure 5 and Fig. 6 show air movement results at Level 1 and Level 3, respectively. At Level 1, the reading ranged from 0.05 m/s to 0.10 m/s, with Sampling Point 3 having the lowest (0.05±0.02 m/s) and Sampling Point 2 having the highest (0.10±0.02 m/s). Meanwhile, at Level 3, the range of the reading recorded was from 0.08 m/s to 0.12 m/s, with Sampling Point 5 and Sampling Point 4 being the lowest (0.08±0.02 m/s and 0.08±0.03 m/s) respectively and Sampling Point 7 having the highest (0.12±0.02 m/s). Fig. 5 and Fig. 6 show all sampling points at Levels 1 and 3 are way below the acceptable limit range (0.15 m/s to 0.5 m/s) as stated in ICOP IAQ (2010). In addition, statistical analysis using one-way ANOVA shows no significant differences (p>0.05) between Sampling Point 1 as compared to others at Level 1, while no significant differences (p>0.05) between all sampling points at Level 3. This is due to malfunctioning ventilation systems such as exhaust fans not functioning properly. The absence of centralized air conditioning and wall fans that are far apart from each other is also one of the causes of air movement on both levels becoming very slow, thus violating the specified range limit. As evidence, changes in fan speed have a direct impact on air movement and the absence of fans causes air movement to slow down (Raftery *et al.,* 2019).



Acceptable limit range: 0.15–0.5 m/s
*Different letters indicate significant differences in air movement between sampling points

Fig. 5. Mean of air movement at sampling points Level 1



Acceptable limit range: 0.15 – 0.5 m/s
*The same letter indicates no significant differences in air movement between sampling points

Fig. 6. Mean of air movement at sampling points, Level 3

Chemical parameters and ventilation performance indicator

Table 1 summarizes the concentrations of chemical parameters, carbon monoxide (CO), formaldehyde, and particulate matter (PM_{10}), alongside the ventilation performance indicator, carbon dioxide (CO_2), measured at all sampling points across both levels.

Carbon Monoxide (CO)

The concentration of CO at all sampling points was well below the acceptable limit of 10 ppm as stated in ICOP IAQ (2010). On Level 1, the highest CO reading was recorded at Sampling Point 3 (1.11±0.02 ppm), while Sampling Points 1 and 2 had the lowest values (1.10±0.00 ppm). Similarly, on Level 3, Sampling Points 4 and 5 recorded the highest values (1.12±0.02 ppm), and Sampling Point 6 showed the lowest (1.10±0.00 ppm). No significant differences were found among sampling points on either level ($p>0.05$).

Although CO is commonly emitted through combustion processes such as cooking and smoking, these activities are prohibited within the library premises. The low CO concentrations are likely due to minimal infiltration from outdoor air, possibly through window gaps or poorly sealed structural elements. This finding aligns with Tran, Park, and Lee (2020), who noted that outdoor CO can penetrate indoor environments, especially in buildings located near vehicular traffic or industrial zones.

Formaldehyde

Formaldehyde levels at all sampling points remained below the acceptable limit of 0.1 ppm, as per ICOP IAQ (2010). On Level 1, the highest reading was at Sampling Point 2 (0.025±0.006 ppm), while Sampling Points 1 and 3 shared the lowest value (0.023±0.005 ppm). On Level 3, Sampling Points 5 and 6 showed the highest concentration (0.023±0.005 ppm), and Sampling Point 7 had the lowest (0.015±0.006 ppm). No statistically significant differences were found between sampling points on either floor ($p > 0.05$).

The presence of formaldehyde is attributed to off-gassing from wood-based furniture, carpets, and adhesives commonly used in libraries. This observation is supported by Chen *et al.,* (2018) and Liu, Miao, and Li (2019), who identified wood composite materials and aging carpets as common indoor sources of formaldehyde.

Particulate Matter (PM_{10})

All PM_{10} measurements were below the ICOP IAQ (2010) limit of 0.15 mg/m³. On Level 1, Sampling Point 3 had the highest reading (0.054±0.002 mg/m³), whereas Sampling Points 1 and 2 recorded the lowest values (0.025±0.005 mg/m³ and 0.025±0.003 mg/m³, respectively). One-way ANOVA indicated significant differences ($p<0.05$) at this level, with Sampling Point 3 differing notably from the rest. This variation may be due to the fact that Sampling Point 3 is located in a storage room for old, unused books-an area prone to dust accumulation and limited cleaning access. Sansuddin and Nordin (2022) also noted that stored books can be a significant source of settled dust contributing to airborne PM levels.

On Level 3, PM_{10} values ranged narrowly between 0.020±0.002 mg/m³ and 0.024±0.005 mg/m³, with Sampling Point 7 having the highest reading. Significant differences were also observed ($p<0.05$), with Sampling Point 7 being the outlier. The higher PM_{10} concentration here could be due to heavier foot traffic or proximity to carpeted and poorly ventilated zones.

Carbon Dioxide (CO_2)

CO_2 levels remained within the acceptable limit of 1000 ppm at all sampling points. On Level 1, the highest average CO_2 concentration was recorded at Sampling Point 1 (466.25±3.63 ppm), while Sampling Point 3 had the lowest (437.75±10.12 ppm). One-way ANOVA revealed significant differences ($p<0.05$) among the sampling points. On Level 3, Sampling Point 7 showed the highest CO_2 level (456.92±37.55 ppm), and Sampling Point 4 the lowest (427.08±26.14 ppm), although no significant differences were noted across points ($p>0.05$).

Lower CO_2 levels during the study period may be attributed to reduced occupancy, as the sampling coincided with the semester break. These findings are consistent with Dorizas *et al.,* (2015) and Sahu and Gurjar (2021), who concluded that CO_2 concentrations are directly influenced by the density and activity level of building occupants.

Table 1: Concentration of chemical parameters and ventilation performance indicators in the library

Level	Sampling Point	Parameters (Mean±SD)			
		Carbon monoxide (ppm)	Formaldehyde (ppm)	Particulate matter (PM_{10}) (mg/m^3)	Carbon dioxide (ppm)
Level 1	Sampling Point 1	1.10 ± 0.00^a	0.023 ± 0.005^a	0.025 ± 0.005^a	466.25 ± 3.63^c
	Sampling Point 2	1.10 ± 0.00^a	0.025 ± 0.006^a	0.025 ± 0.003^a	448.00 ± 8.88^b
	Sampling Point 3	1.11 ± 0.02^a	0.023 ± 0.005^a	0.054 ± 0.002^b	437.75 ± 10.12^a
Level 3	Sampling Point 4	1.12 ± 0.02^a	0.018 ± 0.005^a	0.020 ± 0.002^a	427.08 ± 26.14^a
	Sampling Point 5	1.12 ± 0.02^a	0.023 ± 0.005^a	0.020 ± 0.002^a	432.34 ± 15.19^{ab}
	Sampling Point 6	1.10 ± 0.00^a	0.023 ± 0.005^a	0.020 ± 0.002^a	455.92 ± 25.0^{2b}
	Sampling Point 7	1.11 ± 0.02^a	0.015 ± 0.006^a	0.024 ± 0.005^b	456.92 ± 37.55^b

*Different letters indicate significant differences between sampling points within the same column ($p<0.05$)
*The same letter indicates no significant differences between sampling points within the same column ($p>0.05$)

Total volatile organic compounds (TVOCs) and ozone are below the acceptable limit (3 ppm and 0.05 ppm respectively). However, the reading for these two parameters cannot be measured because the TVOCs and ozone level are below the detection range of the equipment used. In this study, TVOC readings were not detected because there was no storage of large amounts of detergents or disinfectants and no air fresheners were used in the library. This is in line with the study by Maung *et al.,* (2022) which stated that the sources of volatile organic compounds came from household products, cleaning glues, personal care products, and building materials. In addition, the age of the library building, which has been in operation since 1974, also contributed to the decrease in TVOC readings. This is supported by Shin and Jo (2012) where a study conducted by them showed that the concentration of total volatile organic compounds in new buildings decreased after continuous assessment was carried out over 2 years. Besides, the ozone that appears in the indoor air mostly comes from printers and photocopiers operating in a building. However, the printers and photocopiers on Level 1 were not operating on the day the sampling was conducted, while there were no printers and photocopiers on Level 3. This opinion is supported by Spinazze *et al.,* (2019) who argue that the main source of ozone production in office environments is printers and photocopiers.

Biological parameters

Total bacterial count

Figures 7 and 8 illustrate the total airborne bacterial concentrations measured at Level 1 and Level 3 of the library. At Level 1, average counts ranged from 40 to 47 cfu/m³, with the lowest concentration observed at Sampling Point 3 (40±3.46 cfu/m³) and the highest at Sampling Point 1 (47±2.87 cfu/m³). At Level 3, concentrations were slightly higher, ranging from 41 to 49 cfu/m³, with Sampling Point 6 recording the lowest (41±4.90 cfu/m³) and Sampling Point 4 the highest (49±2.87 cfu/m³). Despite minor variations, all values were well below the ICOP IAQ (2010) acceptable limit of 500 cfu/m³.

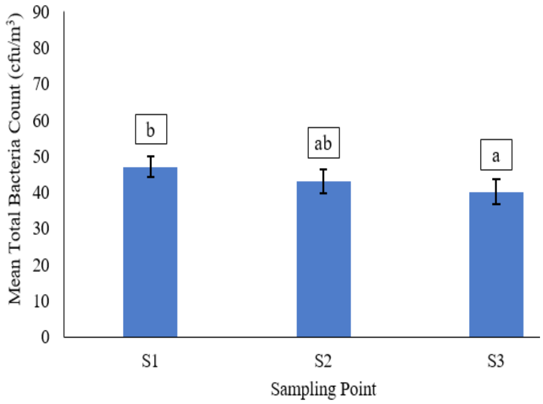
One-way ANOVA revealed no statistically significant differences ($p>0.05$) among sampling points within each floor. The consistently low bacterial concentrations across both levels are likely due to the reduced human presence during the semester break, when data collection occurred. This observation is supported by Hassan, Zeeshan, and Bhatti (2021), who found that higher occupancy levels can increase bacterial counts through the resuspension of microorganisms from shoes, clothing, and human skin. Ghosh *et al.,* (2013) similarly emphasized that human activity is a key contributor to bacterial loading in indoor environments.

Total Fungal Count

Figures 9 and 10 illustrate the total fungal concentrations recorded on Level 1 and Level 3 of the library. On Level 1, concentrations ranged from 40 to 43 cfu/m³, with the lowest values at Sampling Points 1 and 3 (40±5.00 cfu/m³ and 40±4.72 cfu/m³, respectively), and the highest at Sampling Point 2 (43±4.72 cfu/m³). On Level 3, concentrations ranged from 40 to 49 cfu/m³, with the lowest at Sampling Point 6 (40±4.72 cfu/m³) and the highest at Sampling Point 5 (49±2.87 cfu/m³). All measurements were well below the ICOP IAQ (2010) threshold of 1000 cfu/m³.

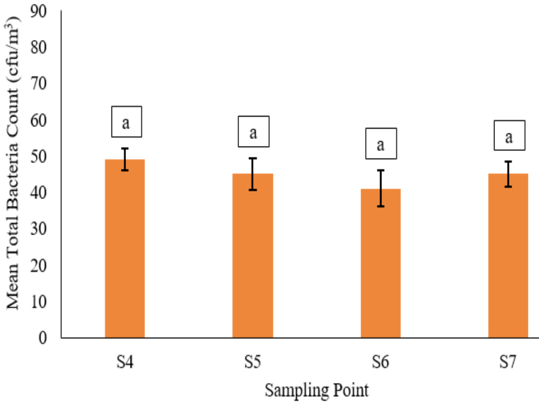
One-way ANOVA showed no significant differences between sampling points on either floor ($p>0.05$). The consistently low fungal concentrations on Level 1 may be explained by moderate temperature and humidity levels, which are less conducive to fungal growth. As noted by Kadaifciler (2017), environmental factors such as humidity, temperature, and the presence of organic matter play a central role in microbial proliferation.

On Level 3, although temperatures were slightly higher, certain sampling points-particularly those farther from bookshelves-recorded lower fungal counts. This may be due to reduced exposure to fungal reservoirs such as books and organic materials. Caicedo *et al.,* (2022) observed that fungal concentrations tend to be higher in close proximity to bookshelves. These materials, especially those made from paper and leather, provide ideal substrates for fungal growth due to fungi's enzymatic ability to degrade complex organic compounds (Pyrri *et al.,* 2020).



Acceptable limit: 500 cfu/m³
*Different letters indicate significant differences in total bacteria count between sampling points

Fig. 7. Mean of total bacteria count at sampling points Level 1



Acceptable limit: 500 cfu/m³
*The same letter indicates no significant differences in total bacteria count between sampling points

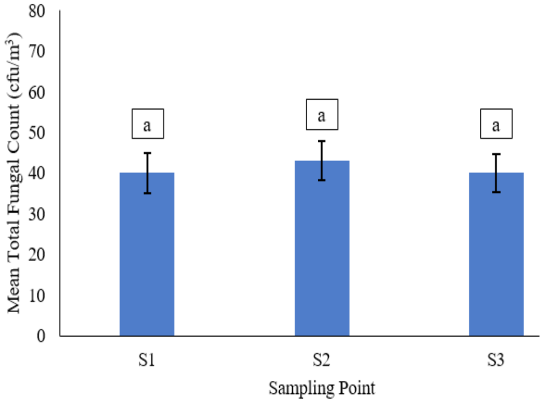
Fig. 8. Mean of total bacteria count at sampling points Level 3

Next, Fig. 9 and Fig. 10 present the overall results of the total fungal count at Level 1 and Level 3, respectively. At Level 1, the average readings ranged between 40 cfu/m³ and 43 cfu/m³, with the lowest counts recorded at Sampling Points 3 and 1 (40±4.72 cfu/m³ and 40±5.00 cfu/m³, respectively), and the highest at Sampling Point 2 (43±4.72 cfu/m³). Meanwhile, the readings at Level 3 ranged from 40 cfu/m³ to 49 cfu/m³, with the lowest at Sampling Point 6 (40±4.72 cfu/m³) and the highest at Sampling Point 5 (49 ± 2.87 cfu/m³).

Based on both figures, all sampling points at Levels 1 and 3 were well below the acceptable limit of 1000 cfu/m³ as stipulated in the ICOP IAQ (2010). One-way ANOVA analysis indicated no significant differences ($p>0.05$) between sampling points at Level 1. Similarly, at Level 3, no significant differences ($p>0.05$) were observed between Sampling Points 4 and 7 in comparison to the others.

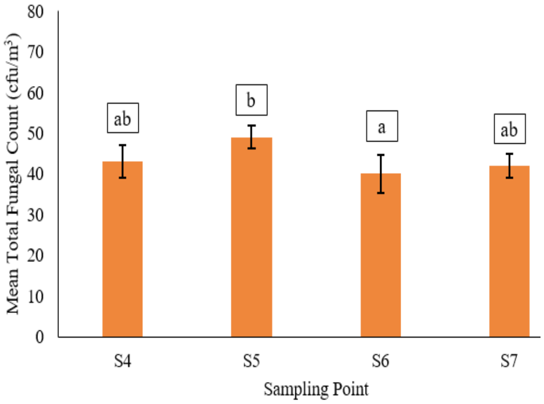
The low fungal readings at Level 1 can be attributed to moderate temperature and humidity conditions, which were not conducive for fungal growth. This observation is supported by Kadaifciler (2017), who identified organic matter, humidity, and temperature as critical factors influencing microbial proliferation. Caicedo *et al.,* (2022) also noted that physical and chemical factors-particularly temperature and humidity-can significantly affect fungal counts in indoor environments such as libraries.

At Level 3, another contributing factor was the distance of the sampling points from the bookshelves. Despite slightly elevated temperatures at this level, fungal counts remained low where sampling points were positioned farther from bookshelves. This finding aligns with the observations of Caicedo *et al.,* (2022), who reported that sampling points located near bookshelves tended to record higher fungal concentrations. Library items such as books and leather-bound materials provide an ideal substrate for biodeterioration. Fungi, in particular, possess a high capacity to break down organic matter due to their unique enzymatic capabilities, enabling them to decompose even the most complex organic compounds (Pyrri *et al.,* 2020).



Acceptable limit: 1000 cfu/m³
*The same letter indicates no significant differences in total fungal count between sampling points

Fig. 9. Mean of total fungal count at sampling points Level 1



Acceptable limit: 1000 cfu/m³
*Different letters indicate significant differences in total fungal count between sampling points

Fig. 10. Mean of total fungal count at sampling points Level 3

CONCLUSION

This study provides a comprehensive assessment of indoor air quality (IAQ) at two different floors of the Dr. Abdul Latiff Library, Universiti Kebangsaan Malaysia, Kuala Lumpur Campus. The findings highlight that most IAQ parameters, including carbon monoxide, formaldehyde, particulate matter (PM_{10}), carbon dioxide (CO_2), bacterial and fungal counts, remained within the acceptable limits outlined in the ICOP IAQ (2010). However, significant concerns were observed regarding thermal comfort and ventilation. Temperatures at several sampling points on Level 3 exceeded acceptable thresholds, and air movement at all measured points on both floors was consistently below recommended levels. These conditions may adversely affect the comfort, concentration, and health of library occupants. Additionally, visible microbial growth and deteriorating carpet conditions may exacerbate indoor pollution, while occupant-reported symptoms such as headaches, fatigue, and coughing underscore the need for proactive IAQ management. To address these issues, it is recommended that localized air conditioning units or additional fans be installed on Level 3 to mitigate elevated temperatures and improve air circulation. Regular carpet maintenance or replacement, coupled with cleaning protocols to prevent microbial growth, should also be prioritized. In academic environments like libraries, where cognitive performance and prolonged occupancy are critical, routine IAQ monitoring and targeted environmental improvements are essential. The insights from this study can inform institutional strategies to ensure healthier, more comfortable indoor environments that promote both academic success and occupant well-being.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the management and staff of Dr. Abdul Latiff Library, Universiti Kebangsaan Malaysia, Kuala Lumpur Campus, for their support and cooperation during the data collection process. Special thanks are also extended to Dana Mutiara with the grant code, TKS672, Faculty of Health Sciences, for providing financial support for this research. We also acknowledge the Environmental Health and Industrial Safety Program and the Faculty of Health Sciences, Universiti Kebangsaan Malaysia, for supplying the equipment and laboratory facilities that made this study possible.

Conflict of interest

The author declare that we have no conflict of interest.

REFERENCES

1. Caicedo, Y. C.; Perez, H. B.; Fuentes, M. M.; Vergara-Vasquez, E., & Velez-Pereira, A. M., Assessment of fungal aerosols in a public library with natural ventilation., *Aerobiologia.*, **2022**, *39*, 37–50.
2. Chen, W. H.; Mendell, M.; Li, N., & Kumagai, K., Formaldehyde emissions from seams and cut edges of laminate flooring: Implications for emission testing protocols and exposure estimation., *Building and Environment.*, **2018**, *143*, 652–660.

3. Corlan, R.; Balogh, R.; Ionel, I., & Kilyeny, S., The importance of indoor air quality (IAC) monitoring., *Journal of Physics: Conference Series.*, **2021**, *1781*, 1–8.
4. Dorizas, P. V.; Assimakopoulos, M. N.; Helmis, C., & Santamouris, M., An integrated evaluation study of the ventilation rate, the exposure and the indoor air quality in naturally ventilated classrooms in the Mediterranean region during spring., *Science of the Total Environment.*, **2015**, *502*, 557–570.
5. Er, C. M.; Sunar, N. M.; Leman, A. M.; Othman, N.; Emparan, Q.; Parjo, U. K., Gani, P., Jamal, N. A., & Ideris, N. A., The evaluation of indoor microbial air quality in two new commissioning higher educational buildings in Johor, Malaysia. *Applied Mechanics and Materials.*, **2015**, *773–774*, 1068–1072.
6. Ghosh, B.; Lal, H.; Kushwaha, R.; Hazarika, N., Srivastava, A., & Jain, V. K., Estimation of bioaerosol in indoor environment in the university library of Delhi., *Sustainable Environment Research.*, **2013**, *23*(3), 199–207.
7. Hassan, A.; Zeeshan, M., & Bhatti, M. F., Indoor and outdoor microbiological air quality in naturally and mechanically ventilated university libraries. *Atmospheric Pollution Research.*, **2021**, *12*(8), 1–8.
8. Hou, J.; Sun, Y. X.; Dai, X. L.; Liu, J. J.; Shen, X.; Tan, H. W.; Yin, H. G.; Huang, K. L.; Gao, Y.; Lai, D. Y.; Hong, W. P.; Zhai, X. P.; Norback, D., & Chen, Q. Y., Associations of indoor carbon dioxide concentrations, air temperature, and humidity with perceived air quality and sick building syndrome symptoms in Chinese homes. *Indoor Air.*, **2021**, 00, 1–11.
9. Islam, S. K. M., The roles of libraries and education., *Information Society Today.*, **2004**, *1*(1), 48–51.
10. JKKP., Tataamalan industri kualiti udara dalaman 2010. Kuala Lumpur: Jabatan Keselamatan dan Kesihatan Pekerjaan, Kementerian Sumber Manusia, Malaysia., **2010**.
11. Kadaifciler, D. G., Indoor air quality of the library at Istanbul University, Turkey. *Hacettepe Journal of Biology and Chemistry.*, **2017**, *45*(1), 43–53.
12. Kumar, P.; Singh, A. B.; Arora, T.; Singh, S., & Singh, R., Critical review on emerging health effects associated with the indoor air quality and its sustainable management., *Science of the Total Environment.*, **2023**, *872*, 162–163.
13. Liu, C.; Miao, X. Y., & Li, J. G. Outdoor formaldehyde matters and substantially impacts indoor formaldehyde concentrations., *Building and Environment.*, **2019**, *158*, 145–150.
14. Mahyuddin, N., & Law, J. B., Indoor environmental quality assessment in a learning space: University of Malaya's main library., *Journal of Surveying, Construction and Property.*, **2019**, *10*(1), 1–15.
15. Maung, T. Z.; Bishop, J. E.; Holt, E.; Turner, A. M., & Pfrang, C., Indoor air pollution and the health of vulnerable groups: A systematic review focused on particulate matter (PM), volatile organic compounds (VOCs) and their effects on children and people with pre-existing lung disease., *International Journal of Environmental Research and Public Health.*, **2022**, *19*(14), 8572–8596.
16. Mentese, S.; Mirici, N. A.; Elbir, T.; Palaz, E.; Mumcuoglu, D. T.; Gotuker, O.; Bakar, C.; Oymak, S., & Otkun, M. T. A long-term multi-parametric monitoring study: Indoor air quality (IAQ) and the sources of the pollutants, prevalence of sick building syndrome (SBS) symptoms, and respiratory health indicators., *Atmospheric Pollution Research.*, **2020**, 00, 1–12.
17. Mohd Khalid, S. J., Marketing of library and information services in university libraries: A case study of University of Malaya Central Library, Kuala Lumpur, Malaysia., *The Eurasia Proceedings of Educational and Social Sciences.*, **2019**, *13*, 50–59.
18. Mujan, I.; Andelkovic, A. S.; Muncan, V.; Kljajic, M., & Ruzic, D., Influence of indoor environmental quality on human health and productivity–A Review. *Journal of Cleaner Production.*, **2019**, *217*, 646–657.
19. Naghizadeh, A.; Sharifzadeh, G.; Tabatabaei, F.; Afzali, A.; Yari, A. R.; Geravandi, S., & Mohammadi, M. J., Assessment of carbon monoxide concentration in indoor/outdoor air of Sarayan City, Khorasan Province of Iran., *Environmental Geochemistry and Health.*, **2019**, *41*(5), 1875–1880.
20. Ozdamar, M., & Umarogullari, F., Thermal comfort and indoor air quality., *International Journal of Scientific Research and Innovative Technology.*, **2018**, *5*(3), 90–109.

21. Pyrri, I.; Tripyla, E.; Zalachori, A.; Chrysopoulou, M.; Parmakelis, A., & Kapsanaki-Gotsi, E., *Fungal contaminants of indoor air in the National Library of Greece. Aerobiologia*., **2020**, *36*(3), 387–400.
22. Raftery, P.; Fizer, J.; Chen, W.; He, Y.; Zhang, H.; Arens, E.; Schiavon, S., & Paliaga, G. Ceiling fans: Predicting indoor air speeds based on full scale laboratory measurements., *Building and Environment*., **2019**, *155*, 210–223.
23. Rohizan, N. A., & Abidin, E. Z., Assessment on physical factors of thermal comfort, sick building syndrome symptoms and perception of comfort among occupants in a public research university laboratory building., *International Journal of Public Health and Clinical Sciences*., **2015**, *2*(3), 59–70.
24. Sahu, V., & Gurjar, B. R., Spatio-temporal variations of indoor air quality in a university library., *International Journal of Environmental Health Research*., **2021**, *31*(5), 475–490.
25. Sansuddin, N., & Nordin, S. M., Assessment of PM_{10} and $PM_{2.5}$ concentrations at different floor levels of USM Health Campus's Library., *Journal of Energy and Safety Technology.,* **2022**, *5*(1), 63–72.
26. Seng, K. T.; Shen, L. C.; Ling, N. S.; Chin, S. P., Xin, T. J.; En, T. K.; Jama, A. A.; Hariri, A., & Nasir, N. F., Comparative study on the indoor air quality in critical areas of hospitals in Malaysia., *Nature Environment and Pollution Technology.,* **2023**, *22*(2), 921–927.
27. Shin, S. H., & Jo, W. K. Longitudinal variations in indoor VOC concentrations after moving into new apartments and indoor source characterization., *Environmental Science and Pollution Research*., **2012**, *20*(6), 3696–3707.
28. Spinnazze, A.; Campagnolo, D.; Cattaneo, A.; Urso, P.; Sakellaris, I. A.; Saraga, D. E.; Mandin, C.; Canha, N.; Mabilia, R.; Perreca, E.; Mihucz, V. G.; Szigeti, T.; Venture, G.; Fernandes, E. D. O.; Kluizenaar, Y. D.; Cornelissen, E.; Hanninen, O.; Carrer, P.; Wolkoff, P.; Cavallo, D. M., & Bartzis, J. G., Indoor gaseous air pollutants determinants in office buildings–The officair project., *Indoor Air.,* **2019**, 00, 1–12.
29. Tran, V. V.; Park, D., & Lee, Y. C., Indoor air pollution, related human diseases, and recent trends in the control and improvement of indoor air quality., *International Journal of Environmental Research and Public Health*., **2020**, *17*(8), 2927–2954.