Indoor Air Quality and Sick Building Syndrome in Selected Public Buildings in Shah Alam, Selangor

Ismaniza Ismail[1*], Mohamad Solehin Zulkarnain[1], Ilyas Syafiq Darul Ridzuan[2], Yahya Thamrin[3], Nasrul Hamidin[4]

[1]Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

[2]Institute of Medical Science Technology, Universiti Kuala Lumpur, 43000 Kajang, Selangor, Malaysia

[3]Department of Occupational Health and Safety, Universitas Hasanuddin, Makassar, Indonesia

[4]Faculty of Civil Engineering & Technology, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

*Authors Correspondence: ismaniza@uitm.edu.my/+60187894018

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ABSTRACT

Indoor Air Quality (IAQ) is always associated with Sick Building Syndromes (SBS) despite the age of the buildings, particularly in buildings where indoor air pollutants may affect occupants' health and productivity. This study assessed IAQ parameters and SBS symptoms in five selected public buildings aged 10 and above in Shah Alam, Selangor. Physical, chemical and biological parameters were measured, while structured questionnaires were completed by 87 respondents occupying the buildings. Most IAQ parameters were within the ranges of the Industry Code of Practice on IAQ (ICOP IAQ 2010), except for air velocity, formaldehyde and Total Volatile Organic Compound (TVOC) in two buildings. Statistical analyses showed no association between the building type and SBS occurrence, and no significant differences ($p > 0.05$) in air velocity, TVOC, CO_2 or fungal count among the buildings. In order to reduce SBS risks and enhance SBS, the source of contaminants should be tackled and regular monitoring should be implemented to ensure compliance with IAQ limits.

INTRODUCTION

The introduction contains the urgency and Most people spend up to 80% to 90% of their time indoors; either at their workplace, in their own homes or in public buildings such as schools, libraries, shops and hospitasl.[1] Although indoor air contains a much wider range of pollutants than outdoor air, Indoor Air Quality (IAQ) issues has not received the supposedly same attention as outdoor air quality, due to a lack of information on the sources, concentrations, the effects and control measures other than ventilation. It is more challenging as IAQ varies immensely with the construction of the building, ventilation, occupancy and the activities involved in it. The United States Environmental Protection Agency listed furnishings and products like air fresheners as continuous sources of indoor air pollutants, while smoking and cleaning as intermittent sources.[2] It is worth noting, however, that higher levels of indoor air pollutants may be contributed by ineffective or malfunctioning ventilation system appliances or improperly used products. Whether harmful gases and vapours, chemicals, fine particles, or microbes, the concentrations of air pollutants can remain in the air for long periods after some activities.

A report by the World Health Organization (WHO) suggested that indoor air pollution is responsible for 2.7% of the global burden of disease.[3] Indoor environmental quality, building characteristics, building dampness, and activities of occupants were listed as factors whose acumulative effects contribute to Sick Building Syndrome (SBS).[4]

A regional study in Thailand found that respiratory and skin-related symptoms were significantly associated with elevated particulate and carbon monoxide levels.[5] Recent Malaysian studies reported varying prevalence of Sick Building Syndrome (SBS) across occupational and educational settings, with overall SBS symptoms affecting 65% of administrative office workers,[6] 34.7% of office staff in older university buildings compared to 27.5% in newer ones,[7] and skin-related, general, mucosal, and respiratory symptoms recorded at 38.5%, 28.3%, 19.2%, and 13.9%, respectively, among occupants of educational facilities.[8]

In the development of Sick Building Syndrome (SBS), a person in the building experinces symptoms and feels uncomfortable without a clear cause.[9,10] The syndrome is characterized by various non-specific subjective symptoms such as headache, dizziness, coughing, and skin irritation, as well as vague symptoms such as fatigue, aches and pains, sensitivity to odours and difficulty in concentration; associated with prolonged exposure to poor indoor air quality.[11,12] The occupant may exhibit at least one symptom of SBS, the onset of two or more symptoms at least twice, and rapid resolution of symptoms when leaving the workstation or building.[8]

Although it is hardly life-threatening and may only be amongst a group of occupants when they are in the building and absent when they are not in the building, these symptoms can be unpleasant and disturbing, resulting in lost work time and lower productivity.[13]

In Malaysia, selected indoor air quality parameters and their acceptable limits are listed in the Industry Code of Practice on Indoor Air Quality 2010 (ICOP IAQ 2010) published by the Department of Occupational Safety and Health. Nevertheless, the challenges lie in the limited research and documentation available to assist government departments in enforcement, as the ICOP serves only as a guide to improve IAQ meanwhile building owners or occupants may be unaware of the health risks and how to control them. It is also an obstacle to understand the unclear etiology of SBS since the exact causes of SBS are cryptogenic and poorly understood. This is compounded by the lack of localized research, especially within the public sector, where buildings are often older and subject to high occupant density and limited ventilation upgrades.

Experts have suggested monitoring the indoor environment in public spaces as a standard practice and an investment for indoor emission inventories.[14] Failure to address the issues immediately and efficiently could be detrimental to human health.[6]

Shah Alam, the state capital of Selangor, represents an ideal study location due to its dense concentration of administrative, cultural, and public facilities within a rapidly urbanizing environment. These buildings are typically air-conditioned, experience heavy daily use, and are surrounded by major traffic corridors—conditions conducive to IAQ challenges. Assessing SBS occurrence and IAQ in Shah Alam's public build-

ings provides valuable insight into the urban public health implications of indoor environments in Malaysia and supports efforts to strengthen preventive occupational health strategies. This study therefore, aims to investigate the levels of selected IAQ parameters and to determine its association with symptoms of SBS.

MATERIAL AND METHOD

Study Location

A cross sectional comparative study was conducted from to 2022 at five selected buildings; the Sultan Alam Shah Museum, Shah Alam Royal Theatre, Shah Alam Gallery, Raja Tun Uda Public Library and the Selangor Islamic Arts Park Complex, as shown in Figure 1. All the buildings selected were categorized as old (more than 10 years) as classified in a previous study[15], with the library being the newest one considering relocation to the new site, while the museum was the oldest one since it was opened in 1989.

These buildings were selected to represent various types of public activities, including cultural exhibitions, performing arts, administrative offices, and library services, and to capture variations in occupant density and ventilation characteristics. Daily occupancy ranged between 40 and 120 workers and staff, with intermittent visitor presence depending on the building's function. All buildings were air-conditioned, smoking was prohibited indoors, and they underwent daily cleaning using standard chemical cleaning agents.

Figure 1. Locations of The Study

Assessment of Indoor Air Quality

The assessment of IAQ in the identified buildings was conducted in line with the ICOP IAQ 2010. Measurements were taken at strategic sampling points for each floor of each location, in the morning and in the afternoon. TSI Quest EVM-7 was used to measure temperature, relative humidity, air velocity, particulate matter, total volatile organic compounds (TVOCs), formaldehyde, ozone, carbon monoxide (CO), and carbon dioxide (CO_2). Instruments were factory-calibrated and verified using zero and span checks before field deployment to ensure measurement accuracy. Measurements were taken at strategic sampling points on each floor, representing occupied zones and areas of prolonged human activity (e.g., workstations, exhibition halls, and reading areas). Sampling was carried out twice daily (morning and afternoon) for three consecutive working days at each location to account for temporal variations in building operation and occupancy.

Microbiological air samples were taken using Quick Take 30 Sample Pump (SKC, Eight Four, PA, USA) at respiratory height (1.2–1.5 m) using a Quick Take 30 Sample Pump (SKC, Eighty Four, PA, USA) at a flow rate of 28.3 L/min for 5 minutes. Samples were incubated at 25 °C for five days prior to enumeration of viable fungal colonies, expressed as colony-forming units per cubic meter (cfu/m^3).

Questionnaire Survey

A total of 87 respondents aged, between 23 and 51 years, were randomly selected from among the full-time employees working in the selected buildings. All were workers who had been employed in the buildings for at least 6 months, to minimize transient exposure effects. Expectant mothers and workers with pre-existing medical conditions were excluded, as these parameters align with validated SBS exposure study designs.[6]

While the study primarily focused on IAQ parameters, it did not assess non-IAQ factors such as psychosocial stressors, lighting, or ergonomics, which could act as potential confounders in SBS symptom reporting a limitation acknowledged in this study.

Questionnaires adopted from ICOP IAQ 2010 were distributed to the respondents. The ques-

tionnaires include gender, age, duration spent in the buildings, the occurrence of SBS and the quality of the air inside buildings. The respondents were defined as having SBS if they had at least one symptom of SBS, with the symptom(s) appearing at least once a week. To fit the description of SBS, the occurrence must be at least 1 to 3 days per week during the last four weeks, and most importantly, the symptoms disappear when they are away from the place of work.[6] All respondents were guided by trained field assistants to avoid misinterpretation of the questions.

Ethics Approval

Ethical approval for this study was obtained from the Faculty Ethics Review Committee (FERC), Faculty of Applied Sciences, UiTM (Ref. No: FERC/FSG/22/071(UG).

Statistical Analysis

The Chi-square test was applied to examine the association between building type and SBS symptom occurrence. For comparison of continuous IAQ parameters (e.g., air velocity, TVOC, CO_2, fungal count) across the five buildings, one-way ANOVA/Kruskal–Wallis test was performed depending on normality of data, with significance set at $p < 0.05$. Given the relatively small sample size (n = 87), the study did not perform a formal power calculation, and findings should therefore be interpreted with caution when generalizing beyond the sampled population.

RESULTS

Building Characteristics

The selected public buildings assessed in this study were located in the city centre of Shah Alam with typical heavy traffic, except for the library which was situated in the golf club greeneries, potentially affecting outdoor-indoor pollutant infiltration rates.[14]

The buildings varied in architectural layout, ventilation design and prohibited smoking indoors, factors known to affect IAQ and occupant exposure levels.[13-17]

Demographics of The Respondents

Although visitors may occupy the buildings during the study, the survey only focused on workers in the building, to reflect on the symptoms of SBS. However, since this is a cross sectional study, timing of the snapshot is not guaranteed to be representative and therefore may be difficult to identify changes in variables over time.

The socio-demographic information was derived from the questionnaires by the respondents in the five buildings as per Table 1.

The proportions of male and female respondents were almost equivalent for the buildings, except for the museum where one third of them were male. While the gender and age distribution were relatively balanced across buildings, sensitivity to air quality and other psychosocial stressors can vary by age and job role- factors not deeply explored in this study.

The average duration spent indoors in the buildings was high (approximately 35 to 40 hours/week), indicative of chronic exposure. The respondents were mainly administrative and technical staff, a work population with high sedentary exposure during working hours.

Indoor Air Quality Assessment

The results of IAQ parameters assessment for physical, chemical and microbiological parameters are summarized in Table 2.

Physical Parameters

The indoor temperature and relative humidity across all the buildings in this study were within acceptable limits of ICOP IAQ 2010 (23-26°C; 40-70% RH). However, air movement (velocity) was suboptimal in the museum (0.11 m/s) and gallery (0.13 m/s), below the minimum acceptable limits, with 0.11(±0.2) and 0.13(±0.1) respectively. This could lead to reduced occupant satisfaction and productivity.[16]

Chemical Parameters

Most chemical parameters including particulates, ozone, CO and CO_2 were within recommended limits. High levels of TVOC and formaldehyde were recorded in the theatre (TVOC 4.02 ppm; formaldehyde 0.29 ppm) and library (TVOC 3.68 ppm; formaldehyde 0.38 ppm). These findings supported the potential ongoing sources pointed out in previous studies[18,19] which were products like air fresheners and chemical products used for daily cleaning in indoor public buildings.

In contrast, low CO and CO_2 levels indicate adequate dilution ventilation, implying that mechanical ventilation systems are operating.

Microbiological Parameters

Fungal count were below the acceptable limits set (1000 cfu/m³) in ICOP IAQ 2010. Dominant isolated species were *Cladosporium sp.*, *Penicillium sp.* and *Aspergillus sp.*; typical fungi found in indoor settings with mechanically ventilated buildings.

Inter-Building Statistical Comparison

Statistical analysis showed no significant difference between the buildings in terms of air velocity. TVOC, CO_2 or fungal count (p>0.05). This suggests that SBS symptoms often result from cumulative exposures to low level air pollutants rather than single-point exceedances.[22]

Prevalence of Sick Building Syndrome (SBS)

All five buildings had non-uniform prevalence of the similar SBS symptoms, with the highest prevalence the theatre and gallery, as shown in Table 3.

The main four symptoms of SBS identified were ophthalmic symptoms (dry, itchy and irritation of eyes, 33% to 60%); neurological symptoms (dizziness and lightheadedness, 30% to 50%); cognitive symptoms (difficulty to concentrate and remember (33% to 60%); and psychological symptoms (depression, 13% to 50%).

The findings mirror those reported in large-scale SBS surveys in Europe and Asia[10,13]. The cognitive and psychological symptoms may signal an overlap with job-related stress, underscoring the importance of integrating IAQ data with occupational psychosocial assessments. It is plausible, however, that symptom reporting may be influenced by awareness of environmental health issues or perceived control over the work environment.

Complaints on respiratory and dermal symptoms were rare, suggesting non-infectious and non-allergenic origins, which is more aligned with sensory irritation or neuropsychological effects.[1]

DISCUSSION

Despite uniform airconditioning, daily cleaning, and no-smoking policies, the inconsistencies in building layout and ventilation design across sites may have influenced airflow dynamics and pollutant dispersion patterns. This could lead to localized zones of poor air circulation, especially in areas with high occupant density or limited mechanical ventilation. This aligns with observations from a previous study that microclimatic IAQ zones can differ significantly due to architectural and functional design, despite the buildings are of similar categories.[17]

Older buildings may lack modern low-emission materials, which can result in continued offgassing from interior surfaces, as previously reported[1]. This is critical, as aging construction materials and furnishings can release volatile organic compounds (VOCs) over time, particularly in environments with restricted ventilation. Although the thermal and humidity conditions observed in this study generally indicate effective airconditioning performance, the low air velocity measured in some areas raises concerns about stagnant zones that may allow pollutant accumulation. Although the thermal conditions in this study generally suggest functioning airconditioning systems, it may still raise concerns over stagnant zones that may trap airborne pollutants where the air velocity was low. In Malaysia's hot and humid climate, higher air movement is often desired for both thermal comfort and perceived freshness, even when temperature readings fall within acceptable range.[16,17]

Regarding the chemical parameters, most contaminants were within regulatory limits, however, elevated levels of TVOC and formaldehyde were noted in two buildings. Although not acutely toxic at the levels measured, chronic low-level exposure to TVOC has been implicated in ocular irritation and neurobehavioral symptoms associated with SBS.[2,18] Formaldehyde, a known mucosal irritant and Group 1 carcinogen, is often emitted from treated wood, glues, and cleaning agents compounds still widely used in public facilities in Southeast Asia.[14]

For biological contaminants, the fungal species detected were typical indoor strains, such as *Cladosporium, Penicillium*, and *Aspergillus*, consistent with the findings reported inprevious studies on libraries and houses free of water damage.[20,21] Although no signs of water intrusion were observed, individual sensitivity to fungal spores may vary, and even low concentrations could contribute to SBS-type symptoms in susceptible occupants and that subclinical exposures may still contribute to SBS-type symptoms in hypersensitive populations.[20,21]

Table 1. Demographic Information of the Respondents

Characteristics	Museum n=18	Theatre n=15	Library n=21	Gallery n=17	Art complex n=16
Gender (%)					
Male	33.3	53.3	57.1	58.8	50.0
Female	66.7	46.7	42.9	41.2	50.0
Age of respondents (mean years)	38.5	34.1	39.3	32.9	35.7
Duration spent in workplace (indoor) (hours)	40.2	35.5	39.8	37.1	36.4

Source: Primary Data, 2022

Table 2. Levels of the Indoor Air Quality Parameters Assessed

Parameter	Acceptable Limit	Museum	Theatre	Library	Gallery	Art Complex
Temperature (°C)	23-26	23.3 (±1.1)	23.6 (±2.0)	23.1 (±2.3)	24 (±1.4)	23.4 (±0.9)
Relative humidity (%)	40-70	64.7	61	57.3	63.8	60.8
Air movement (m/s)	0.15 – 0.50	0.11 (±0.2)	0.44 (±0.6)	0.25 (±0.3)	0.13 (±0.1)	0.27 (±0.2)
Particulates (mg/m³)	0.15	0.12	0.07	0.14	0.12	0.06
TVOC (ppm)	3	0.28	4.02	3.68	2.02	1.65
Formaldehyde (ppm)	0.1	0.2	0.29	0.38	0.02	0.04
Ozone (ppm)	0.05	0.01	0.01	0.02	0.01	0.02
CO (ppm)	10	0.3 (±0.1)	1.4 (±0.3)	0.4 (±0.2)	0.9 (±0.2)	1.2 (±0.7)
CO₂ (ppm)	C1000	410 (±15.4)	372 (±12.1)	711 (±30.7)	504 (±30.5)	236 (±23.9)
Total fungal count (cfu/m³)	1000	296 (±39)	255 (±18)	144 (±42)	123 (±20)	276 (±15)

Source: Primary Data, 2022

Table 3. Prevalence of SBS Symptoms

Symptoms	Museum (n=18)	Theatre (n=15)	Library (n=21)	Gallery (n=15)	Art Complex (n=16)
Ophtalmic symptoms					
Itchy, dry, eye irritation	6	9	8	5	8
Headache	1	0	0	0	0
Unusual tiredness, lethargy	1	0	1	0	2
Strained eyes, tired eyes	0	1	0	0	0
Dizziness or lightheadedness	7	5	7	4	8
Respiratory symptoms					
Asthma (wheezing)	0	0	0	0	0
Dry and sore throat	0	1	0	0	0
Difficulty to breathe	0	0	0	0	0
Stuffy nose, runny nose, sinus	0	0	0	1	0
Coughing	1	1	0	0	1
Sneezing	0	0	1	2	1
Shortness of breath	0	0	0	0	0
Psychological symptoms					
Tension, irritability	0	0	0	0	0
Difficulty to concentrate	6	7	5	9	5
Depression	9	7	8	7	2
Dermal symptoms					
Dryness/itchy/rashes	0	0	0	0	0
Others: Nausea, etc.	0	0	0	0	0

Source: Primary Data, 2022

Despite the presence of reported symptoms, statistical analysis (Chi-square test, p = 0.481) found no significant association between building type and SBS occurrence. This finding suggests that SBS symptoms cannot be attributed solely to measurable IAQ parameters. Instead, SBS is likely multifactorial, influenced by a combination of environmental, psychosocial, and ergonomic factors. Occupational stress, workstation ergonomics, lighting conditions, and perceived control over the work environment have all been implicated as co determinants of SBS in recent literature manifestation.[4,10,11]

The cross-sectional nature of this study limits causal inference, as measurements were conducted during a single season and may not represent annual variation in indoor conditions. Additionally, instrument precision and short-term sampling duration could constrain pollutant characterization, particularly for parameters with diurnal fluctuations such as CO_2 and VOCs. Furthermore, the reliance on self-reported questionnaires may introduce recall or perception bias, as symptom reporting can be influenced by individual awareness, workload, or subjective comfort.

Overall, the findings provide valuable indications of SBS-related symptoms rather than definitive evidence of "sick" buildings. Future research should adopt longitudinal and multi-seasonal designs with larger sample sizes, integrating psychosocial, ergonomic, and environmental data to provide a more comprehensive understanding of SBS determinants in Malaysian public buildings.

CONCLUSION AND RECOMMENDATION

Most parameters measured in this study fell within the range set by the Department of Safety and Health (DOSH Malaysia) in the ICOP IAQ 2010, except for air movement, TVOC, and formaldehyde in two of the buildings. Although causal relationships cannot be confirmed due to the multifactorial nature of Sick Building Syndrome (SBS), the findings indicate possible SBS-related symptoms among occupants of the theatre and gallery. No statistically significant association was found between building type and SBS occurrence across the five study sites.

The IAQ can be improved by good housekeeping and minimizing the use of chemical cleaning agents and air fresheners in the buildings as they are sources of air contaminants despite the pleasant smell. Workers in the buildings must be aware of these sources, as they may contribute to the increased risk. Detailed research can provide a more accurate picture of the sick buildings, which may include factors such as lighting, ergonomics, stress levels, and position within the organization.

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AUTHOR CONTRIBUTIONS

All authors contributed significantly to the research and development of this manuscript. Study design, conceptualization, supervision of fieldwork, and manuscript writing = II; Data collection, analysis, drafting = MSZ; Questionnaire survey, statistical analysis, data interpretation = ISDR; review and editing = YT; technical framework for IAQ measurement and validation of sampling protocols = NH. II = Ismaniza Ismail; MSZ = Mohamad Solehin Zulkarnain; ISDR = Ilyas Syafiq Darul Ridzuan; YT = Yahya Thamrin; NH = Nasrul Hamidin.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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