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Assessing Indoor Air Quality and Sick Building Syndrome in Public University Buildings: A Cross-Sectional Study of Office Worker Health and Well-Being

(Penilaian Kualiti Udara Dalaman dan Sindrom Bangunan Sakit di Bangunan Universiti Awam: Kajian Rentas Perbandingan Kesihatan dan Kesejahteraan Pekerja Pejabat)

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ABSTRACT

Exposure to indoor air pollution among office workers can result in various health issues and increase the incidence of Sick Building Syndrome (SBS). The aim of the present study was to investigate the effect of exposure to Indoor Air Quality (IAQ) among office workers and the relationship with the prevalence of SBS at Universiti Kebangsaan Malaysia (UKM), Bangi. A cross-sectional comparison research involving 144 office workers from various new and old buildings was carried out at UKM, Bangi. Information was gathered and symptoms associated with SBS were determined using a series of questionnaires. During office hours, IAQ parameters were collected using air quality sensor. The old building had substantially higher levels of NO_2 (24.26 ppb), CO (0.62 ppb), and PM_{10} (4.99 µg/m^3) than the new building. It was found that, with a $p < 0.001$, the concentration of O_3 in the new building (11.47 ppb) was significantly higher than in the old building (4.93 ppb). The study's findings also showed that the difference in temperature between the old buildings (26°C) and new buildings (24°C) was statistically significant ($p = 0.003$). Referring to relative humidity (RH), the result of the old building is lower (56%) compared to the new building (62%). Although old buildings exhibited a higher prevalence of SBS (34.7%), it was found that there was no significant difference compared to new buildings (27.5%). According to the study's findings, found that exposure to CO ($\chi^2 = 5.242$, $p = 0.022$), PM_{10} ($\chi^2 = 13.449$, $p < 0.001$), and $PM_{2.5}$ ($\chi^2 = 19.755$, $p < 0.001$) among office workers with the prevalence of SBS has significant association. In conclusion, this study suggests that exposure to high levels of CO, PM_{10} and $PM_{2.5}$ can increase the prevalence of SBS. Good housekeeping and regular maintenance of ventilation can keep good IAQ and reduce health effects among occupants.

Keywords: Health issues; Sick Building Syndrome; indoor air quality; office workers

ABSTRAK

Pendedahan kepada pencemaran udara dalam dalam kalangan pekerja pejabat boleh mengakibatkan pelbagai masalah isu kesihatan dan meningkatkan kejadian Sindrom Bangunan Sakit (SBS). Matlamat kajian ini adalah untuk menyiasat kesan pendedahan kepada Kualiti Udara Dalaman (IAQ) dalam kalangan pekerja pejabat dan hubungan dengan prevalens SBS di Universiti Kebangsaan Malaysia (UKM), Bangi. Kajian perbandingan keratan rentas telah dijalankan di UKM, Bangi, melibatkan 144 pekerja pejabat dari bangunan baharu dan lama yang terpilih. Maklumat dikumpul dan simptom berkaitan dengan SBS ditentukan menggunakan satu siri soal selidik. Parameter IAQ dikumpul menggunakan sensor kualiti udara semasa waktu pejabat. Kepekatan NO_2 (24.26 ppb), CO (0.62 ppb) dan PM_{10} (4.99 µg/m3) dalam bangunan lama adalah jauh lebih tinggi berbanding bangunan baru. Didapati bahawa, dengan $p < 0.001$, kepekatan O_3 di bangunan baru (11.47 ppb) adalah lebih tinggi secara signifikan berbanding di bangunan lama (4.93 ppb). Dapatan kajian juga menunjukkan bahawa perbezaan suhu antara bangunan lama (26°C) dan bangunan baharu (24°C) adalah signifikan secara statistik ($p = 0.003$). Merujuk kepada kelembapan relatif (RH), hasil bangunan lama adalah lebih rendah (56%) berbanding bangunan baru (62%). Walaupun bangunan lama mempamerkan prevalens SBS yang lebih tinggi (34.7%), namun didapati tiada perbezaan yang signifikan berbanding bangunan baharu (27.5). Menurut penemuan kajian, mendapati pendedahan kepada CO ($\chi^2 = 5.242$, $p = 0.022$), PM_{10} ($\chi^2 = 13.449$, $p < 0.001$), dan $PM_{2.5}$ ($\chi^2 = 19.755$, $p < 0.001$) di kalangan pekerja pejabat dengan prevalens SBS mempunyai hubungan yang signifikan. Kesimpulannya, kajian ini mencadangkan bahawa pendedahan kepada tahap CO, PM_{10} dan $PM_{2.5}$ yang tinggi boleh meningkatkan prevalens SBS. Kebersihan yang baik dan penyelenggaraan pengudaraan yang kerap boleh mengekalkan IAQ yang berkualiti dan mengurangkan kesan kesihatan di kalangan penghuni.

Kata kunci: Isu kesihatan; Sindrom Bangunan Sakit; kualiti udara dalaman; pekerja pejabat

INTRODUCTION

The health of a community can be impacted by multiple factors, and one such factor is the quality of indoor air, also known as indoor air quality (IAQ). More than 80% of people spend their time in an office that is equipped with air-conditioning, photocopy machine, or printer that contribute to air pollution (Zamani et al, 2013; Zamani-Badi et al. 2019). The term IAQ encompasses the air quality present within buildings and their surrounding environments, exerting a substantial influence on the health and welfare of the individuals occupying those spaces. As a result, poor air quality for office employees may lead to an increase in the incidence of Sick Building Syndrome (SBS).

SBS is an extensively acknowledged syndrome characterized by occupants of a building experiencing acute physiological and psychological health symptoms and discomfort resulting from extended periods of building occupancy. Factors such as humidity, particulate matter, and gases (VOC, CO_2, CO) have been found to have an impact on the prevalence of SBS. This has been supported by various studies conducted by Hodgson (2002), Keyvani et al. (2017), Nordstrom et al. (1994), and Zamani (2013). Symptoms that arise due to SBS are like mucosal irritation, which is a prominent symptom, headache, fatigue, and dizziness (Burge, 2004; Hodgson, 2002; Reuben et al. 2019).

Universiti Kebangsaan Malaysia (UKM) main campus is located at Bangi, Selangor. UKM is one of the research universities in Malaysia. The campus used a centralized unit air conditioning system as the main ventilation system for the building. Lack of routine maintenance on central or split air conditioners might foster the development of germs or fungus. Consequently, this elevates the likelihood of infection among the individuals residing in the affected room or building. Symptoms commonly associated with these infections include skin irritation, inflammation, and hypersensitive pneumonia, as evidenced in studies conducted by Norbäck et al. (2016) and Piecková (2012). Therefore, poor central unit maintenance can lead to poor IAQ, which raises the occurrence of SBS among building occupants. The aim of the present study was to investigate the effect of exposure to IAQ among office workers and the relationship with the prevalence of SBS at UKM, Bangi.

METHODOLOGY

STUDY DESIGN

There were 144 office workers from UKM who participated in the comparative cross-sectional study. The participants were divided into two groups. One group was working in a building that was more than 10 years old (old building). The other group worked at the building that was occupied for less than 10 years (new building) (Zainal et al. 2019). The main criteria for choosing the buildings in this research were primarily focused on two fundamental aspects: the age of the structures and the specific ventilation system employed. Specifically, only buildings with central ventilation were chosen for inclusion in the study. Males and females who have worked in the building for over a year were selected at randomly as respondents.

QUESTIONNAIRE SURVEY

A series of questionnaires were utilized to collect data on the socioeconomic and demographic context of the respondents. The questionnaire contains inquiries about background information, workplace details, and health status. The Indoor Environmental Quality Survey and Work Symptoms Survey from the National Institute of Occupational Safety and Health (NIOSH) constituted the foundation for the SBS symptoms questions (Aizat et al. 2009). The subjects were considered to have SBS if at least once a week they had symptoms of SBS. Occupants of buildings in this study were required to report the occurrence of symptoms between 1 and 3 days a week for four weeks and the symptoms showed signs of improvement when they do not work (Ooi et al. 1998)

INDOOR AIR QUALITY MEASUREMENT

The Malaysia Indoor Air Quality Code of Practice (IAQ, COP), published by the Department of Occupational Safety and Health (DOSH), Malaysia (2005), was followed in the assessment of IAQ. To acquire a representative analysis of indoor air pollution (IAP) in the building throughout the day, sampling was conducted during office hours (8:00 a.m. to 5:00 p.m.). The air sample was collected on the same day that respondents filled out the survey. The parameters that were analyzed in this study were Nitrogen dioxide (NO_2), sulfur dioxide (SO_2), Ozone (O_3), carbon monoxide (CO), particulate matter with aerodynamic diameter $\leq$ 2.5 micron ($PM_{2.5}$), particulate matter with aerodynamic diameter $\leq$ 10 micron (PM_{10}), temperature and humidity. The IAQ data of all parameters were collected using AiRBOXSense air quality sensor during office hours. This sensor collected, analyzed, and shared real time IAQ data via wireless communication network. All the data was stored in the cloud and can be downloaded for further analysis (Nadzir et al. 2021)

STATISTICAL ANALYSIS

Data collected was analyzed using the Statistical Package for Science Version 26 (SPSS Ver. 26). Data normality of continuous variables was determined based on Shapiro Wilks. Due to data that is not normally distributed, it was analyzed with a non-parametric test (Mann-Whitney). The Chi-Square test was used to analyze categorical data and for association analysis. The significant value in this study was set at $p < 0.05$.

RESULTS AND DISCUSSION

A questionnaire survey was conducted among respondents from October 2021 to January 2022, and a total of 144 respondents participated in this survey, which consisted of 75 respondents from the old building and 69 respondents from the new building. The respondent sociodemographic, characteristics, environmental and IAQ parameters are simplified in Tables 1 and 2. This study includes 26 males (34.7%) from the old building and 27 males (39.1%) from the new building. While the distribution of female respondents was 49 (65.3%) in the old building and 42 (60.9%) in the new building. Most of the respondents were Muslim and married with tertiary education. The non-smoking respondents made up the highest number in this survey. According to Table 1, it was found that all the variables were not significantly different between both study groups with $p > 0.05$.

The results obtained from this research indicated that the data related to IAQ parameters did not display normal distribution pattern. As a result, Table 2's data analysis employed the Mann-Whitney U test. The table indicated that only SO_2 and $PM_{2.5}$ of indoor air pollutants were not significantly different for both the old and new buildings. While NO_2, O_3, CO, temperature, RH, and PM_{10} showed significantly different results for both old and new buildings. With a median of 2.00 µg/m^3 and 1.64 µg/m^3, respectively, the old building had a somewhat higher level of $PM_{2.5}$ than the new building. The concentration of NO_2 (24.26 ppb), CO (0.62 ppb) and PM_{10} (4.99 µg/m^3) in the old building was significantly higher than in the new building. According to the findings of the study, the concentration of O_3 in the new building (11.47 ppb) was significantly higher with a p = 0.001 indicating statistical significance. Meanwhile, with p = 0.003, the indoor air temperature of the old building (26 °C) was found to be significantly higher compared to the new building (24 °C). Referring to relative humidity (RH), the old building results are lower (56%) compared to the new building (62%).

The present study found that O_3, CO, PM_{10}, temperature, and humidity were all within the DOSH Industry Code of Practice permitted limit values (ICOP, 2010). However, the $PM_{2.5}$, NO_2 and SO_2 were compared to the acceptable level of the Environmental Protection Agency and found to be within the limit (US-EPA, 1991). Based on these findings, the IAQ for all buildings included in this research were excellent and the centralized air conditioning system across the UKM campus in Bangi is in good working order. Earlier investigations conducted by Fadilah and Juliana (2012) as well as Zamani et al. (2013) found that particulate matter (PM) levels are greater in old buildings than in new buildings, and this study confirms those findings. The old building has somewhat higher PM_{10} and $PM_{2.5}$ levels than the new building, according to the results of our study. However, both types of buildings are still within the limits that have been set by the Environmental Protection Agency (EPA).

TABLE 1. Comparison of Socio-demographic characteristics of respondents

Variables	Study groups N (%)		
	Old Building (75)	**New Building (69)**	***p***
Sex			
Male	26 (34.7)	27(39.1%)	0.579
Female	49(65.3)	42(60.9)	
Religion			
Islam	75(100.0)	66(95.7)	0.189
Buddha	0 (0.0)	1(1.4)	
Hindu	0(0.0)	2(2.9)	
Marital Status			
Single	16(21.3)	11(15.9)	0.054
Married	54(72.0)	58(84.1)	
Widow	5(6.7)	0(0.0)	
Education Status			
secondary education	17(22.7)	16(23.2)	0.501
tertiary education	58(77.3)	58(76.8)	
Smoking status			
Yes	5(6.7)	11(15.9)	0.077
No	70(93.3)	58(84.1)	

N = 144

TABLE 2. Comparison of Office Indoor Air Pollutants among Respondents

Variables	Office	**Median**	**IQR**	***p***
NO_2 (ppb)	Old Building	24.26	7.96	**<0.001***
	New Building	16.67	4.50	
O_3 (ppb)	Old Building	4.93	8.54	**<0.001***
	New Building	11.47	7.84	
CO (ppb)	Old Building	0.62	0.37	**0.001***
	New Building	0.59	0.12	
SO_2(ppb)	Old Building	4.42	37.04	0.242
	New Building	9.82	30.30	
Temperature (°C)	Old Building	26	3	**0.003***
	New Building	24	3	
RH (%)	Old Building	56	4	**<0.001***
	New Building	62	6	
$PM_{2.5}$(μg/m^3)	Old Building	2.00	0.75	0.131
	New Building	1.64	1.20	
PM_{10}(μg/m^3)	Old Building	4.99	1.14	**<0.001***
	New Building	3.46	1.38	

*Significant at $p < 0.05$, N = 144; old building =75; new building = 69

Comparing the prevalence of SBS symptoms among respondents is depicted in Table 3. The study showed that all reported symptoms were not significantly different between both study groups. Although the frequency of SBS (34.7% versus 27.5%) was higher among respondents in the old building, the observed difference did not reach statistical significance (p = 0.356). However, the findings suggest that both buildings were affected by SBS, as indicated by the prevalence of symptoms in over 20% of the residents in each building, as reported in the studies by Rosner (2007) and Fadilah & Juliana (2012). According to our findings, the most common symptoms reported by respondents are headaches (25.3%), sneezing (22.7%), and fatigue, unusual tiredness, or drowsiness (21.3%). In addition, the study found that the proportion of respondents who reported having SBS symptoms was somewhat greater in the old building than in the new building. There is, however, no significant difference between them.

According to previous studies, general symptoms are significantly associated with workload and workplace conflict (headache, abnormal tiredness, sensation of cold or nausea) (Quoc et al. 2020). Based on a study conducted by Lu et al. (2018), office dryness has a significant association with upper respiratory symptoms and general symptoms. Our findings show that humidity in the old building is low, and that upper respiratory symptoms such as sneezing and sore or dry throat and general symptoms like headaches and fatigue, unusual tiredness, or drowsiness are more common SBS symptoms among respondents. This shows that working in an office with low humidity might make it more likely for employees to have both general and upper respiratory problems. Furthermore, too-crowded offices and a lack of job satisfaction are linked to upper respiratory problems (Quoc et al. 2020). This may prolong SBS symptoms, resulting in decreased work productivity, an increase in work absences, and higher healthcare costs.

TABLE 3. Comparison of respondents' reporting of Sick Building Syndrome (SBS) symptoms

Variables	Study groups n (%)			
	Old Building (75)	**New Building (69)**	χ^2	***p***
Sick Building Syndrome (SBS)				
Yes	26(34.7)	19(27.5)	0.850	0.356
No	49(65.3)	50(72.5)		
Dry, itchy, or irritated eyes				
Yes	15(20.0)	7(10.1)	2.697	0.100
No	60(80.0)	62(89.9)		
Stuffy or irritated nose				
Yes	15(20.0)	8(11.6)	1.892	0.168
No	60(80.0)	61(88.4)		
Sore or dry throat				
Yes	10(13.3)	10(14.5)	0.040	0.840
No	65(86.7)	59(85.5)		
Dry or itchy skin				
Yes	11(14.7)	8(11.6)	0.296	0.586
No	64(85.3)	61(88.4)		
Chest tightness				
Yes	4(5.3)	1(1.4)	1.618	0.203
No	71(94.7)	68(98.6)		
Sneezing				
Yes	17(22.7)	13(18.8)	0.319	0.572
No	58(77.3)	56(81.2)		
Wheezing				
Yes	6(8.0)	3(4.3)	0.818	0.365
No	69(92.0)	66(95.7)		
Shortness of breath				
Yes	3(4.0)	1(1.4)	0.866	0.352

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No	72(96.0)	68(98.6)		
Cough				
Yes	10(13.3)	8(11.6)	0.099	0.752
No	65(86.7)	61(88.4)		
Headache				
Yes	19(25.3)	11(15.9)	1.922	0.165
No	56(74.7)	58(84.1)		
Nausea/vomit				
Yes	3(4.0)	5(7.2)	0.722	0.395
No	72(96.0)	64(92.8)		
Fatigue, unusual tiredness or drowsiness				
Yes	16(21.3)	13(18.8)	0.139	0.709
No	59(78.7)	56(81.2)		
Difficulty in remembering things or concentrating				
Yes	15(20.0)	8(11.6)	1.892	0.168
No	60(80.0)	61(88.4)		
Dizziness or lightheaded				
Yes	8(10.7)	5(7.2)	0.512	0.474
No	67(89.3)	64(92.8)		
Tension, irritability or nervousness				
Yes	10(13.3)	7(10.1)	0.351	0.553
No	65(86.7)	62(89.9)		

N = 144

Table 4 shows SBS incidence and indoor air pollution/quality among respondents. The median value of each IAQ parameter studied was used to differentiate between high and low levels. According to the study's results, there is a connection between three environmental factors (CO, PM_{10}, and $PM_{2.5}$) and the occurrence of SBS among office workers at UKM. The present study discovered that respondents who were exposed to high concentrations of CO exhibited a twofold increased likelihood of experiencing symptoms of SBS. Those exposed to high levels of PM_{10}, on the other hand, are five times more likely to develop SBS symptoms. On the other hand, individuals who are exposed to elevated levels of $PM_{2.5}$ face a seven-fold higher likelihood of experiencing symptoms related to SBS.

According to research done by Zamani et al. (2013), there is a notable correlation between high CO levels and the prevalence of SBS among building occupants. This research yielded similar results. Hence, individuals exposed to high concentrations of CO have an increased likelihood of developing symptoms related to SBS. Most of the office equipment, for example centralized air conditioning systems, photocopiers, printers, or fax machines, produce PM that contribute to IAQ (Zainal et al. 2019). According to Wang et al. (2022), PM is one of the sources that contribute to the prevalence of SBS. According to Yildiz (2020), PM_{10} has the capacity to raise the occurrence and frequency of SBS. The findings of this study corroborate those of earlier studies since they show that PM_{10} and $PM_{2.5}$ have a strong link with the occurrence of SBS. Inefficient centralized air conditioning systems contribute to the contamination of indoor air quality. Poor maintenance worsens the ventilation in rooms and the IAQ because pollutants are not removed and instead tend to collect throughout the structure (Zainal et al. 2019).

TABLE 4. SBS incidence and indoor air pollution/quality

Variables	SBS					
	Yes	No	χ^2	*p*	PR	95% CI
	Total (%)					
NO_2						
High (≥19.55ppb)	23(30.3)	53(69.7)	0.073	0.787	0.907	0.44 - 1.83

Low (<19.55ppb)	22(32.4)	46(67.6)				
O_3						
High (≥7.19ppb)	27(30.0)	63(70.0)	0.175	0.676	0.857	0.41 - 1.76
Low (<7.19ppb)	18(33.3)	36(66.7)				
CO						
High (≥589.49ppb)	34(38.2)	55(61.8)	5.242	**0.022***	2.472	**1.13 - 5.43***
Low (<589.49ppb)	11(20.0)	44(80.0)				
SO_2						
High (≥4.42ppb)	29(30.8)	65(69.2)	0.020	0.887	0.948	0.45 - 1.98
Low (<4.42ppb)	16(32.0)	34(68.0)				
Temperature (°C)						
High (≥25.0°C)	23(35.3)	42(64.7)	0.943	0.331	1.418	0.69 - 2.87
Low (<25.0°C)	22(27.8)	57(72.2)				
Relative Humidity (%RH)						
High (≥60%)	22(28.2)	56(71.8)	0.734	0.391	0.734	0.36 - 1.48
Low (<60%)	23(34.8)	43(65.2)				
$PM_{2.5}$						
High (≥1.69μg/m^3)	39(45.3)	47(54.7)	19.755	**0.001***	7.191	**2.79 - 18.51***
Low (<1.69μg/m^3)	6(10.3)	52(89.7)				
PM_{10}						
High (≥3.85μg/m^3)	38(42.2)	52(57.8)	13.449	**0.001***	4.907	**2.00 - 12.03***
Low (<3.85μg/m^3)	7(13.0)	47(86.0)				

N = 144; *Significant at $p < 0.05$; **significant at 95% CI > 1

CONCLUSION

The study's findings may be utilized as a manual for implementing source reduction measures for IAP in both new and existing structures. It is possible to take the necessary steps to control and enhance IAQ in the future by comparing the building's IAQ levels to the benchmarks established by the DOSH (Department of Occupational Safety and Health) in 2010. This finding provides valuable insights for the UKM management to proactively address indoor air problems and prevent recurring occurrences of SBS among their employees. By focusing on improving air quality levels, appropriate measures can be implemented to safeguard the health and well-being of the employees in the future. The present study demonstrates that the old building had much higher levels of NO_2 (24.26 ppb), CO (0.62 ppb), and PM_{10} (4.99 µg/m^3) than the new structure. While O_3 and RH were significantly higher in the new building. However, all the IAQ parameters for both buildings were within the standard limit set by DOSH. The prevalence of SBS for both groups did not show a significant difference. Factors that significantly influenced the prevalence of SBS among respondents in this study were CO, $PM_{2.5}$ and PM_{10}. Residents should follow excellent cleaning standards, disconnect fax and printers, and regularly ventilate the maintenance system in order to preserve healthy IAQ in the building. Controlling the problem at the source is the most feasible way to solve indoor air quality issues. This is crucial since healthy office workers perform better at work and higher indoor air quality may guarantee their wellbeing.

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