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Indoor Air Quality and Prevalence of Sick Building Syndrome among University Laboratory Workers

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Abstract

This study was carried out to investigate the association between indoor air quality (IAQ) and prevalence of sick building syndrome (SBS) among laboratory workers. A cross-sectional comparative study was conducted among 264 laboratory workers in a private university (88% response rate). A self-administrated questionnaire was used to determine the prevalence of SBS. Temperature, air movement, relative humidity (RH), concentration of carbon monoxide, (CO) carbon dioxide (CO_2) and total volatile organic compounds (TVOCs) were measured objectively in 55 laboratories. The average temperature of dry laboratories was significantly higher (M=25.11^{0}C) than wet laboratories (M=23.77^{0}C). The mean of CO in wet laboratories (M=1.15ppm) was significantly higher than in dry laboratories (M=0.89ppm), ($p<0.002$). The prevalence of SBS among respondents at wet laboratories was significantly higher (45.4%) compared to dry laboratories (20%), (χ^2 = 19.5). The most prevalent reported symptoms were drowsiness (18.5%), followed by irritated stuffy runny nose (13.4%), headache (10.9%), and skin rashes or itchiness (10.1%).

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At dry laboratories, higher temperature was found to be significantly associated with SBS among workers (χ^2=-0.38, p =0.042). Low temperature and higher CO at wet laboratories were found to be significantly associated with SBS (χ^2 =-0.33, p =0.021) and (χ^2 =-0.24, p =0.044). In summary, this study revealed that poor IAQ affects the SBS among workers at both laboratories. Thus, further assessment and remedial action are warranted to reduce the SBS symptoms among laboratory workers.

Keywords: Indoor Air Quality (IAQ); Sick Building Syndrome (SBS); dry and wet laboratories

1. Introduction

During the last decades, indoor air quality (IAQ) is recognized as one of the main health concern among workers particularly those who work in modern buildings which are installed with mechanical ventilated air conditioning system [1,2]. Sources of indoor air contaminants that cause poor IAQ may come from both inside or outside the buildings. Previous findings highlighted that there were physical, chemical and biological factors related to poor IAQ [3]. Interactions between building location, weather, air conditioning system, sources of contaminants, and also workers activities in the buildings affect the quality of indoor air [2]. Physical factors such as high temperature and low humidity contribute to illnesses among occupants [4,5]. Also, low temperature and humidity which is below the acceptable limit can cause production of mold that affects workers health [6]. IAQ will get worse with the presence of chemicals such as total volatile organic compounds (VOCs) and carbon dioxides (CO_2) [5,7,8].

Since most people spend up to 90% of their time indoors, IAQ problems contributes to nearly 4% of the global burden of disease [9]. Illnesses related to poor IAQ are collectively known as sick building syndrome (SBS) [10]. SBS is defined as non-specific symptoms generally characterized by the complaint of headache, dizziness, and difficulty in concentrating as general symptoms, also irritation of eye, nose, or throat as mucosal symptoms as well as skin symptoms by building occupants [7,11]. SBS can be manifested by only one or a combination of several symptoms for at least 1 to 3 days per week and the symptoms resolved rapidly when the person leaving the particular area or building [3]. These symptoms may reduce workers health which will lead to the increase of absenteeism or presenteeism and lower work productivity [12,13].

Laboratories are the highest risk environment as compared to the other areas such as office, tutorial room and library because they contain numerous potential hazards including chemicals and biological substances that have been used during teaching and research activities [14,15]. However, they are a limited number of studies that explored the IAQ and SBS among laboratory occupants. The available findings on SBS related to poor IAQ were mostly reported in office buildings [3,16,17]. These studies in office buildings found that IAQ problems including poor ventilation and high concentration of indoor air pollutants triggered the occurrence of SBS among workers [11,3].

Universities are among those institutions that allocate laboratories which are extensively utilized by students and researchers for teaching, research and services activities. In universities, laboratories are typically occupied most of the time by laboratory technicians, sciences officers, graduate students and researchers or scientist who are highly involved with lab work. Prolonged daily workplace exposure to poor IAQ can be particularly harmful for them. Health effects from this hazardous condition among university's personnel have been evidence in a number of previous studies in laboratories [6,18]. Still, there has been inadequate number of studies regarding IAQ in laboratories compared to office buildings and therefore findings regarding on IAQ and SBS among them are still inconclusive. It is the responsibility of universities to provide a safe and conducive working environment to enable staffs to conduct high quality of work in teaching and also research activities. Assessment of IAQ is needed to explore the exposure levels of pollutants and SBS symptoms among university occupants. Results can be used as supportive findings to identify the potential risks of developing SBS among university laboratory workers. Therefore, the aim of this study is to assess the level of IAQ and the prevalence of SBS symptoms among laboratory occupants at both types of laboratories in a large public university, Malaysia.

2. Methodology

A cross sectional comparative study was conducted among 264 laboratory occupants who fulfilled the inclusive criteria; registered staff and have worked for at least four months. Data collection was done from December 2013 until March 2014. The respondents name lists was obtained from the university administrative of the human resource department. The laboratories were chosen from nine faculties in Universiti Putra Malaysia. Systematic random sampling was used to select the laboratories based on proportion of workers in both wet and dry laboratories. All laboratories selected were equipped with local unit and central unit air conditioning systems. Laboratories which occupied by one worker with no air conditioning system were excluded in this study.

Ethical approval was obtained from Medical Research Ethics Committee of the Faculty Medicine and Health Sciences, Universiti Putra Malaysia dated 7 Oktober 2014 (ref:UPM/TNCPI/RMC/JKEUPM/1.4.18.1/F1).

2.1 Study instruments

A set of self-administered, English and Malay version questionnaire which adapted from Malaysia Industry Code of Practice on Indoor Air Quality 2010 (ICOP-IAQ) was used to obtain socio-demographic information and current SBS symptoms [19]. Respondents were given explanation and they gave their consent voluntarily prior to the distribution of the questionnaire. Questionnaires were distributed manually in selected laboratories during working hours.

This questionnaire consisted of two parts. Part 1 was about socio-demographic characteristics and Part 2 concern on SBS symptoms at working environment for the past 3 months. There were 12-items of SBS symptoms questions which included 5 items on general symptoms such as fatigue, feeling heavy-headed, headache, nausea or dizziness, and difficulty concentrating, 4 items on mucosal irritation such as itching, burning or irritation of eyes, irritated, stuffy or runny nose, hoarse, dry throat or cough, and 3 items on skin symptoms such as dry facial skin, scaling or itching scalp or ears, and dry, itching, red skin. The total scores of this scale ranged from 0 to 12. A pilot study was done to test its validity in term of clarity of the questions. The content of the questionnaire was validated by expert from the Faculty of Medicine and Health Science, UPM. It was pre-tested among 30 laboratory workers in the same university and the reliability was good (Cronbach's alpha = 0.72).

Table 1: Socio-demographic and work characteristics of respondents (N=264)

Variables	**Study groups (n %)**		**Mean (±SD)**
	Dry lab	**Wet lab**	
Gender			
Male	69 (47.6)	49 (41.2)	
Female	76 (52.4)	70 (58.2)	
Age			37.32 ±10.89
<37 years old	91(62.8)	82(68.9)	
≥37 years old	54(37.2)	37(31.1)	
Ethnicity			
Malay	137(94.5)	107(89.9)	
Chinese	3(2.1)	6(5.0)	
Indian	2(1.3)	5(4.2)	
Others	3(2.1)	1(0.9)	
Smoking Status			
No	132(91.0)	109(91.6)	
Yes	13(9.0)	10(8.4)	
Marital Status			
Single	33(22.8)	32(26.9)	
Married	110(75.9)	80(67.2)	
Divorced/Widow	2(1.3)	7(5.9)	
Education Level			
Secondary school	44(30.4)	33(27.7)	
Certificate/ Diploma	65(44.8)	44(37.0)	
Bachelor's/Master's/ PhD	36(24.8)	42(35.3)	
Working hours/day			8.29±0.55
Working days/week			5.10±0.42
Average working hours in laboratory			6.81±1.4

Assessment of IAQ at dry laboratories and wet laboratories was conducted according to ICOP-IAQ [19]. IAQ was assessed in 55 laboratories, 32 dry laboratories and 23 wet laboratories. The number of sampling point was determined based on the estimation of total floor area of each laboratory and it was recorded on the layout plan. Instruments were all run together based on the standard procedure of ICOP-IAQ [19]. Measurements were set as 5-minutes averages within monitoring period and the samples were collected intermittently in 15 minutes for each morning, afternoon and evening phases. Results were calculated as an average of working hours started from 8:30 am until 4:30 pm. The sampler was placed 110cm above the floor at each office room closed to the workers and also at the center of each laboratory.

Parameters of air temperature, relative humidity, and air movement, were measured using Velocicalc meter (Model: TSI 9565) with 2 probes and also indoor air contaminants parameters of CO and CO_2. Parameter of total VOCs was measured using MultiRAE meter. This instrument was calibrated earlier by the manufacturer and the results from the assessment were compared to a standard of procedure by ICOP-IAQ [19]. Data was analysed using SPSS version 22.0. The value of $p<0.05$ was set as a significant level for data analyses.

3. Results

3.1 Socio-demographic characteristics

The response rate was 88% (N=264). Table 1 shows the socio-demographic and work characteristics of respondents at both laboratories. Table 1 indicates that the mean age of respondents were 37.32 (18-25 years old). Majority of respondents were Malay (89.9%), non-smokers (91.6%), married (67.2%) and were working in normal working hours with six average hours and normal working days for both buildings.

Table 2: Comparison of IAQ level between dry and wet laboratories (N=264)

Parameters	**Acceptable limit (DOSH, 2010)**	**Dry labs (n=33)**	**Wet labs (n=23)**	**z**	**p-value**
		Mean ±SD (Range)	**Mean ±SD (Range)**		
Temperature (^{0}C)	23 – 26°C	25.1±1.6 (22.0 – 8.3)	23.8 ±0.8 (22.4 – 25.7)	-2.15	0.032*
RH	40 – 70 %	57.3±8.2 (44.7 – 73.6)	58.8 ±7.0 (45.6 – 71.0)	-0.44	0.659
Air movement (m/s)	0.15 – 0.50 m/s	0.3±0.2 (0.09 – 0.50)	0.2 ±0.1 (0.08 – 0.44)	-1.03	0.061
CO (ppm)	10 ppm (ceiling)	0.9±0.2 (0.6 – 1.4)	1.2 ±0.4 (0.7 – 2.0)	-3.13	0.002*
CO_2 (ppm)	1000 ppm (ceiling)	584.2±86.2 (492 - 883)	583.1±57.5 (505.5 – 691.5)	-0.39	0.693
Total VOC (ppm)	3 ppm	0.06±0.07 (0 – 0.2)	0.09 ±0.1 (0 – 0.3)	-0.87	0.380

*significance at $p<0.05$, Note: RH=Relative Humidity; CO= Carbon Monoxide; CO_2=Carbon dioxide; VOC=Volatile Organic Compounds

3.2 Indoor air quality between office in dry and wet laboratories

Table 2 presents the IAQ parameters at both dry and wet laboratories. The mean temperature of dry laboratories was significantly higher compared to wet laboratories (z= -2.15, p<0.032). Meanwhile, the mean of CO level at wet laboratories was significantly higher compared to dry laboratories (z=-3.13, p<0.002). However, there were no significant differences of the other parameters between dry and wet laboratories.

3.3 Prevalence of SBS among workers

Table 3 shows that the prevalence of SBS was significantly higher at wet laboratories (45.4%) than dry laboratories (20%) (χ^2 = 19.5, p =0.039). Table 4 presents the comparison of reported SBS of respondents at both dry and wet laboratories. The prevalence of SBS at wet laboratories was significantly higher compared to dry laboratories in terms of drowsiness, irritated stuffy or runny nose, headache and skin rashes or itchiness with (χ^2 = 7.19, p =0.007), (χ^2 = 6.24, p =0.012), (χ^2 = 9.40, p =0.005), and (χ^2 = 4.36, p =0.037) respectively. The highest SBS at wet laboratories include drowsiness (18.5%), irritated stuffy or runny nose (13.4%), headache (10.9%), and fatigue (10.1%). While at dry laboratories, most frequent reported of SBS symptoms were drowsiness (6.9%), fatigue (5.5%), irritated, stuffy or runny nose (4.1%) and headache (1.4%).

Table 3: The association between prevalence of SBS and types of laboratories (N=264)

Variables	**Prevalence of SBS N= 264 (%)**		X^2	**p-value**
	Yes	**No**		
Dry lab (n=145)	29 (20%)	116 (80%)	19.5	0.039*
Wet lab (n=119)	54 (45.4%)	65 (54.6%)		

***significance at p<0.05

Table 4: The difference of reported SBS symptoms among workers in dry and wet laboratories (N=264)

	Dry lab	**Wet lab**		
SYMPTOMS	**n (%)**	**n (%)**	X^2	**p-value**
Drowsiness	10(6.9)	22(18.5)	7.19	0.007*
Irritated, stuffy or runny nose	6(4.1)	16(13.4)	6.24	0.012*
Headache	2(1.4)	13(10.9)	9.40	0.005*
Fatigue or lethargy	8(5.5)	12(10.1)	1.35	0.25
Irritation of eyes	2(1.4)	8(6.7)	3.76	0.053
Hoarse, dry throat	2(1.4)	6(4.1)	5.51	0.051
Skin rashes or itchiness	1(0.7)	7(5.9)	4.36	0.037*
Cough	3(2.1)	4(3.4)	0.07	0.79
Feeling heavy-headed	2(1.4)	3(2.5)	0.05	0.82
Dizziness	1(0.7)	2(1.7)	0.73	0.39

***significance at p<0.05

Table 5 shows that high temperature level was found to be significantly associated with the SBS among respondents (χ^2 =-0.38, p =0.042). However, no significant association was found between the other parameters and SBS in dry laboratories. Table 6 shows low temperature and high CO level were significant associated with SBS among workers at wet laboratories (χ^2 =-0.33, p =0.021) and (χ^2 =-0.24, p =0.044) respectively.

Table 5: Association between SBS with the level of IAQ in dry laboratories

Variables	**SBS**		**X^2**	**p-value**
	Yes (%)	**No (%)**		
Temperature			-0.38	0.042*
High	3(60.0)	15(55.6)		
Low	2(40.0)	12(44.4)		
RH			0.11	0.97
High	2(40.0)	11(40.7)		
Low	3(60.0)	16(59.3)		
Air movement			4.609	0.53
High	0(0)	14(51.9)		
Low	5(100.0)	13(48.1)		
CO			0.349	0.55
High	1(20.0)	9(33.3)		
Low	4(80.0)	18(66.7)		
CO_2			1.045	0.31
High	1(20.0)	12(44.4)		
Low	4(80.0)	15(55.6)		
TVOC				
High	1(20.0)	12(44.4)	0.613	0.41
Low	4(80.0)	15(55.6)		

χ^2= chi square test, *significant at p<0.05

4. Discussion

The overall prevalence of SBS obtained in this study was 45.4% among workers at wet laboratories and 20% among workers at dry laboratories. This prevalence was equivalent to the findings of a previous study in office where the prevalence of SBS was 47.5% among office workers at new building and 33.8% at old building in Universiti Putra Malaysia [17]. Considering the hazardous chemicals and materials used in laboratories, these unexpected results may indicate that the ventilation system in these laboratories were better than in the offices studied from the previous study. These findings can be explained by the presence data found for IAQ. Overall, the average of all parameters including temperature, air movement, and concentration of CO, CO_2, and TVOCs for both laboratories were within the acceptable limit range based on Malaysia Industry Code of Practice on Indoor Air Quality 2010.

However, despite the fact that the IAQ measured in this study was within the acceptable limit range, several IAQ parameters were found to be significantly associated with SBS symptoms. Results indicated that high temperature at dry and wet laboratories was significantly associated with higher prevalence of SBS symptoms (p=0.032) and (p=0.021). According to Fang, Clausen, and Fanger, high temperature reduced the air quality and triggered irritation of airways [20]. A weak association was found between CO level and the prevalence of SBS at wet laboratories (p=0.044). CO that come from gas usages and environmental tobacco smoke (ETS) that spread enclosed the room caused respiratory symptoms and headache among occupants. This finding is consistent with the results of a previous study which shows that the concentration of CO more than 10ppm is significantly associated with SBS symptoms such as dizziness, fatigue and headache [21].

Table 6: Association between SBS with the level of IAQ in wet laboratories

Variables	**SBS**		X^2	**p-value**
	Yes (%)	**No (%)**		
Temperature			-0.33	0.021*
High	1 (25.0)	8(42.1)		
Low	3 (75.0)	11(57.9)		
RH			1.011	0.32
High	1(25.0)	10(52.6)		
Low	3(75.0)	9(47.4)		
Air movement			0.009	0.92
High	2(50.0)	10(52.6)		
Low	2(50.0)	9(47.4)		
CO			-0.24	0.044*
High	3(75.0)	11(57.9)		
Low	1(25.0)	8(42.1)		
CO_2			1.011	0.32
High	3(75.0)	9(47.4)		
Low	1(25.0)	10(52.6)		
TVOC			0.195	0.65
High	1(25.0)	3(15.8)		
Low	3(75.0)	16(84.2)		

χ^2= chi square test, *significant at p<0.05

In this study, the prevalence of SBS was not significantly different between males and females in both laboratories. This finding was in contrary to the findings among Swedes workers where the females reported more complaint of SBS than males because they were burden with housework [22]. High concentration and usage of chemical and biological substances and exposures in wet laboratories caused the symptoms were more prevalent than workers in dry laboratories.

5. Conclusion

In conclusion, the average temperature, RH, CO, CO2, air movement, and TVOCs parameters at both types of laboratories were within recommended acceptable range. Yet, high temperature and high level of CO were found to be significantly associated with more prevalence of SBS. The present finding which indicated that almost half of the occupants in wet laboratories suffered from SBS should not be ignored. Further assessment should be performed to discover the source of health complaints among workers. Results obtained can be used as a baseline data for IAQ level in university laboratory buildings which in the future can be used as a reference to formulate the new IAQ standard specific for laboratories.

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