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ASSESSMENT OF INDOOR AIR QUALITY IN AN AIR-CONDITIONING SPLIT UNITS (ACSU) OFFICE BUILDING

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Abstract: The indoor air quality (IAQ) in Air-Conditioning Split Units (ACSU) offices depends mainly on recirculated indoor air that has gone through filters. Workers usually spend eight hours in the office space with restricted air circulation. An IAQ assessment was conducted at the administrative office space, USM, to investigate conditions in an ACSU office space; from 8.00 a.m. to 6.00 p.m. It starts with a walkthrough survey followed by the filling of questionnaires, with a sample size of 11 workers for insights into the office operations. The specific physical parameters (T, RH, and AM) and indoor air contaminants (CO, CH_2O, O_3, PM_{10}, TVOC, TBC, TFC, and CO_2) were conducted at three points indoor and one point outdoor. The T and RH were within the acceptable range of 23-26°C and 40-70%, respectively by ICOP, while the AM was very low and less than the acceptable threshold range of 0.15-0.5 m/s at 0.08 m/s, 0.04 m/s, and 0.02 m/s at Point 1, Point 2, and Point 3, respectively. The indoor air contaminants (CO, CH_2O, O_3, TVOC, PM_{10}, and TFC) met the standard level of ICOP, except for TBC and CO_2. TBC exceeded the ICOP limit (500 cfu/m^3) at 1000 cfu/m^3 and 1500 cfu/m^3, at Point 1and Point 2, respectively, whereas CO_2 concentrations exceeded it (1000 ppm) at 1008.93 ppm at Point 2. In essence, the results indicated that the ACSU office space with restricted air circulation was inadequately ventilated as the AM were low, resulting in, high CO_2 concentrations and high TBC. Secondly, the indoor air contaminants (CO, CH_2O, TVOC and CO_2) were higher than those outdoors. The questionnaire survey results reported that the highest present symptom experienced by the workers was drowsiness with 64 %. Therefore, it is prudent to ensure the IAQ is within the acceptable limit to avoid any possible health effects on workers within an office space.

Keywords: Biological contaminants, chemical air contaminant, specific physical parameter, sustainability, ventilation
Abbreviations: *IAQ: Indoor air quality; ACSU: Air conditioning split units; T: Air temperature: RH: Relative humidity; AM: Air movement; CO: Carbon monoxide; CH_2O: Formaldehyde; O_3: Ozone; PM_{10}: Particulate matter; TVOC: Total volatile organic compound; TBC: Total bacterial count; TFC: Total fungal count; CO_2: Carbon dioxide, ICOP: Industry Code of Practice on Indoor Air Quality 2010*

Introduction

The effect of the indoor environment on people's lives, the performance of work and the public's health is of more concern than the outdoor environment because people spend about 70% to 90% of their time in rooms (Yu et al., 2017). The problems with indoor air quality (IAQ) in the office environment in Malaysia are important risk factors to human health (Lim *et al*., 2015; Othman *et al*., 2020). Poor IAQ has been associated with allergies, sick building syndrome (SBS), building-related illnesses (BRI), and acute exposure (de Robles & Kramer, 2017; Othman *et al*., 2020). Atarodi *et al*. (2018) evaluated the symptoms of SBS in an office building in Mashhad, Iran, using the Alberta Indoor Air Quality Tool kit. They found that 21% of the staff viewed the working environment conditions as inappropriate, and they were mostly complaining about the feeling of dusty air, fatigue and headache. Usually, occupants experienced SBS with a series of non-specific symptoms from being in that building (Thach *et al*., 2019). Poor IAQ can also affect the respiratory, neurological, reproductive, dermatologic, and cardiovascular systems of the occupants (Azuma *et al*., 2020).

The analyses of the IAQ took into consideration correlations with the building characteristics (the type of dwelling, the period of construction, dwelling location, type of ventilation system and building material), indoor contaminant sources, outside contaminant sources, maintenance, water intrusion and occupant activity (Prihatmanti & Bahauddin, 2014; Spiru & Simona, 2017). Salonen *et al*., (2018) found that the indoor ozone levels were significantly associated with indoor sources (e.g. printers, photocopiers, and air cleaners), the age of a building, and various housing aspects (carpeting, air conditioning, window fans, and window openings).

Besides that, poor IAQ is often associated with the ventilation within the building. According to Salonen *et al*. (2018), ventilation is vital in controlling the different indoor air pollutants. Ventilation can influence the type and quantity of chemical compounds (both organic and inorganic) in public buildings, such as in schools and offices (Salonen *et al*., 2009; Lyng *et al*., 2015; Vornanen-Winqvist *et al*., 2018). A study conducted by Rasli *et al*., (2019) found that sufficient amounts of air were needed to reduce the indoor chemical air contaminants in mosques.

Due to the higher demand for indoor thermal comfort, air-conditioning systems are installed indoors in Malaysian buildings for cooling purposes (Jamaludin *et al*., 2015). About 50% of the world's total energy are consumed by buildings (Pérez-Lombard *et al*., 2008), with a maximum percentage consumed in office buildings (Zhou & Haghighat, 2009). Thus, it resulted in a higher energy demand and energy cost, which extended the efforts towards building sustainable cities (Jamaludin *et al*., 2015; Kubota & Toe, 2015; Kassim *et al*., 2016; Cui *et al*., 2017; Laurini *et al*., 2017). A study by Yau and Hasbi (2017) conducted in an air-conditioned office building in Malaysia found that the cooling load from the use of air-conditioning had a negative effect on climate change in the tropical country. The use of air-conditioning contributed to poor indoor air quality and reduced the indoor air contaminants removal process as it recirculates the indoor air instead of refreshing it (Spiru & Simona, 2017; Cui *et al*., 2017). Therefore, the objective of this assessment is to investigate the indoor air quality comprehensively in a restricted air circulation ACSU office space in accordance to the acceptable limits by ICOP (DOSH, 2010).

Materials and Methods

Description of the Site Assessment

The sampling had been carried out in the administrative ACSU office at Universiti Sains Malaysia (USM), Pulau Pinang, which is located at latitude 5°21'20.6"N and longitude 100°18'16.3"E. A total of 11 workers occupy this office, and the dealing work with video display units/computers, photocopiers, and fax machines, as shown in Figure 1. The work schedule is typically from 8.00 a.m. to 6.00 p.m., but the working time is flexible.

The graph showed that most workers (eight out of eleven) use video display units/computers every day and three out of eleven were using it two to three times weekly. Meanwhile, the workers use the photocopier machines (five out of eleven) every day and six out of eleven use it two to three times weekly. Only three workers use fax machines two to three times weekly.

Workplace Survey (Walkthrough Survey and Questionnaire Form)

This assessment was started with the walkthrough survey. The walkthrough survey was conducted in the office area to get the necessary insights into the condition of the office area and the

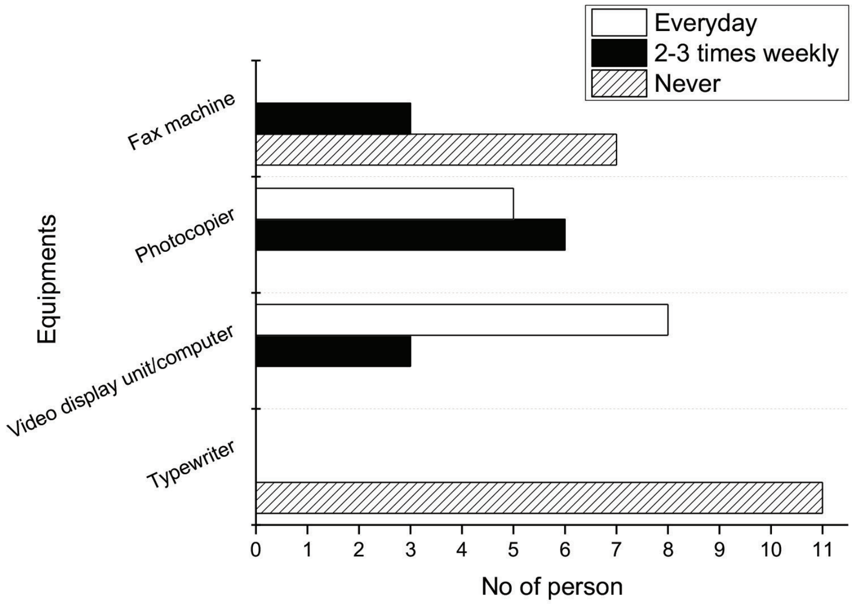

Figure 1: The business activities in the office building

ventilation type (air-conditioning split units (cassette type)). The questionnaires also were distributed to the all workers (11 people) to identify the potential problem and sources of the IAQ and any adverse health effects that may be experienced by the workers. The questionnaire was developed by referring to the Industry Code of Practice on Indoor Air Quality 2010 in Appendix 3 - section B (DOSH, 2010). The questionnaire for building occupants were divided into six (6) sections, and it included general information, background factors, nature of occupation, environmental conditions, past disease/symptoms, and present symptoms. The sample of the questionnaire form is shown in Appendix A.

Assessment of Air-conditioning Split Units

The office uses five (5) units of cassette type of air-conditioning split units. Each unit has a cooling capacity of 60 HP. The indoor unit of the system has four ways of air discharge (supply). Each indoor unit has an area of 1512 cm^2 (Length: 54 cm; Width: 7 cm x 4 outlets) and 3844 cm^2 (Length: 62 cm; Width: 62 cm) for its air outlet and air inlet, respectively, as shown in Figure 2.

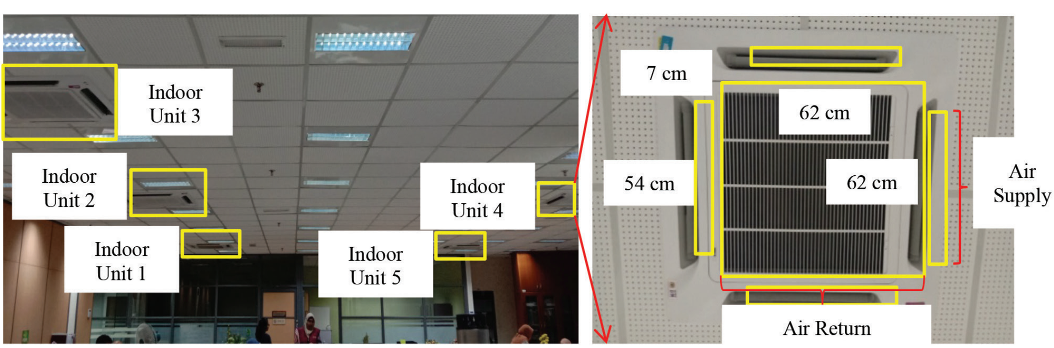

Figure 2: The location and size of each air inlet and outlet

Air Sampling and Instrumentation

Selection of Monitoring Instruments

An Indoor Air Quality probe (IQ-610) was used to measure the levels of carbon monoxide (CO), the total volatile organic compound (TVOC), ozone (O_3), carbon dioxide (CO_2), air temperature (T) and relative humidity (RH), whereas the level of formaldehyde (CH_2O) was monitored using the Formaldehyde Multi-Mode Monitor (FM-801). The AS-201 was used to measure air movement (AM). The instruments used were the GrayWolf Model. Besides that, the Airborne Particle Counter (Handheld 3016 IAQ) Light House Model was used for particulate matter (PM_{10}). Moreover, the total bacterial count (TBC) and total fungal count (TFC) were sampled using a microbial air sampler (MAS-100 Model ECO).

The quality assurance and quality control (QA/QC) for the GrayWolf Model, Lighthouse Model, and ECO model were performed using the annual factory calibration. All instruments were attached on a tripod, and the output parameters were displayed on a setup screen. The parameters reading were obtained after 30 minutes to one hour for stabilisation. Then, the location was set according to the current time and date of monitoring. The data were set to one-minute real-time average (100% data logging). The selected sampling points were at least 0.5 m from the walls, corners and windows, but not directly in front of the air-conditioning system units and floor fans; and not within 2 m of the doors.

Sampling Strategy

A total of three sampling points indoors were selected for the IAQ assessment, as shown in Figure 3. The office has an area of 134.022 m^2 and a volume of 367.086 m^3. The chosen points represented the whole floor area of the office and based on the primary workstation, work activities, and the highest occupancy. This assessment was conducted by taking a real-time measurement intermittently (four slots of 30 minutes each) for nine hours from 8.00 a.m. until 6.00 p.m. at three sampling points within the office area; and one sampling point outdoors for 30 minutes.

For the biological (TBC and TFC) samplings, the air samples were collected to measure the total count for both parameters in colony-forming unit per cubic meter of air (cfu/m^3) within the office area. A microbial air sampler (100 Model Eco Pump, Merck, and Darmstadt, Germany) was used for all collections; it has a flow rate of 100 L/min, and a sampling time of five minutes to avoid the accumulation of unaccountable microorganisms. The airborne microorganisms were targeted one after another using a 20 mL nutrient plate of Tryptic Soy Agar (TSA) for bacteria, and Sabouraud Dextrose Agar with Chloramphenicol (SDAC) for fungi, which was coupled inside the stage sampler at the three sampling points. The Petri plates had been prepared according to the sampler manufacturer's recommendations for both bacteria and fungi by referring to the National Institute for Occupational Safety and Health (NIOSH) Method 0800 – Bioaerosol Sampling of Indoor Air by the National Institute for Occupational Safety and Health (NIOSH, 1998). When changing the collection plates, the stage hole was sterilised with a 70% ethanol solution to prevent cross-contamination. The collected samples were kept in a cool box. After sample collection, the agar plates were transported to the laboratory and incubated at 35 ± 1 °C for 24 hours for bacteria and at 25 ± 1 °C for five days for fungi (*Park et al*., 2013).

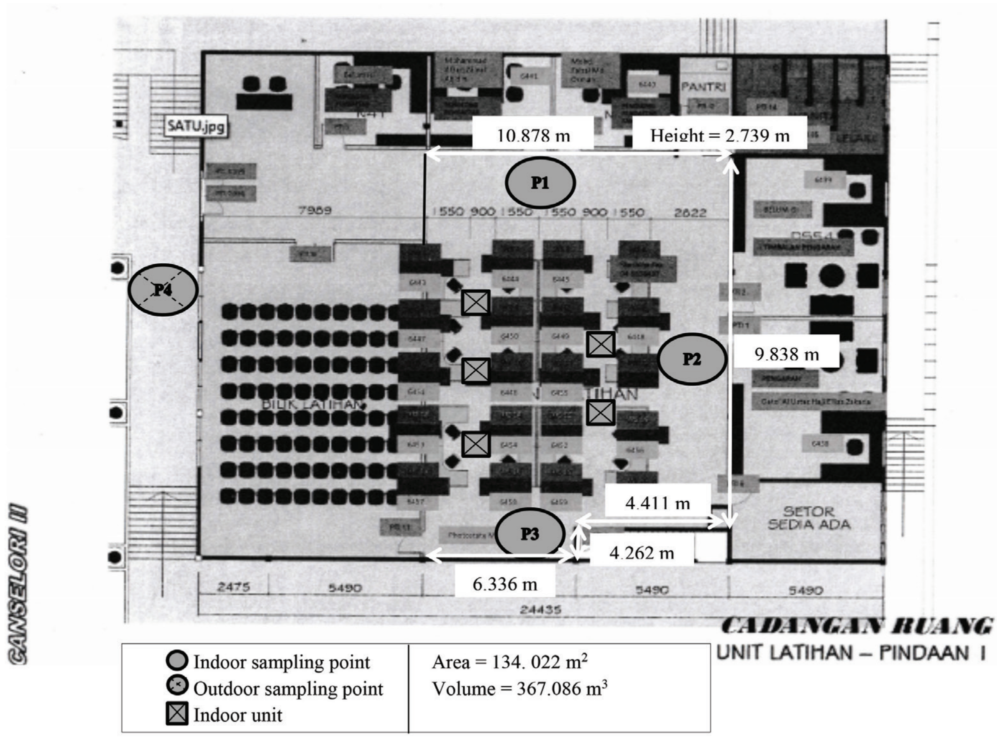

Figure 3: The layout of the sampling points and the dimensions of each sampling points at the administrative office

Results and Discussion

Specific Physical Parameters

Table 1 shows the descriptive statistic of specific physical parameters following the Industry Code of Practice (ICOP) limits (DOSH, 2010). The results obtained suggested that the T and RH at Point 1, Point 2, and Point 3 were within the acceptable range of 23-26 °C and 40-70%, respectively. The T recorded were 22.64°C, 23.14°C, and 24.69°C at Point 1, Point 2, and Point 3, respectively, whereas the RH were 54.50 %, 52.73 %, and 51.06 %, respectively. However, the AM at Point 1 (0.08 m/s), Point 2 (0.04 m/s), and Point 3 (0.02 m/s) were less than the acceptable range (0.15 – 0.5 m/s) as recommended by ICOP. The results indicated that the office area could be considered as inadequately ventilated. The office area has restricted air circulation as the split unit air-conditioning systems (cassette type) have no built-in provisions for ventilation. This resulted in notable increases in indoor air contaminant levels (Al-Awadi, 2018). Elbayoumi *et al*. (2015) found that air movement is very significant for indoor air circulation (wind) inside the building. Higher air movements can improve thermal comfort with a pleasant internal sensation (Chow *et al*., 2010).

Indoor Air Contaminants

The indoor air contaminants were divided into the chemical contaminants (CO, CH_2O, O_3, PM_{10}, and TVOC), biological contaminants (TBC and TFC), and ventilation performance indicator (CO_2). Table 2 shows the descriptive statistic of indoor air contaminants following the ICOP limit standards. The results showed that all the chemical air contaminants (CO, CH_2O, O_3, PM_{10}, and TVOC) at Point 1, Point 2, and Point 3 were within the acceptable limits as recommended by ICOP. However, for biological contaminants, the TBC at Point 1

Table 1: Descriptive statistics of specific physical parameters following ICOP limits

Parameter	Descriptive Statistical	Point 1	Point 2	Point 3	ICOP Limit	Unit
a. T	N	120	120	120	23 – 26	°C
	Mean	22.64	23.14	24.69		
	Std. Dev.	0.25	0.32	0.28		
	Min.	21.9	22.4	24.1		
	Max.	23.2	23.8	25.3		
b. RH	N	120	120	120	40 – 70	%
	Mean	54.50	52.73	51.06		
	Std. Dev.	1.89	1.65	1.61		
	Min.	50.5	50.2	48.1		
	Max.	58.9	55.8	54.3		
c. AM	N	120	120	120	0.15 – 0.5	m/s
	Mean	0.08	0.04	0.02		
	Std. Dev.	0.04	0.02	0.02		
	Min.	0.02	0.01	0.01		
	Max.	0.22	0.12	0.12		

and Point 2 exceeded the acceptable ICOP limit (500 cfu/m^3) at 1000 cfu/m^3 and 1500 cfu/m^3, respectively. Meanwhile, the total fungal counts at Point 1, Point 2, and Point 3 were within the recommended limit of 1000 cfu/m^3.

The TBC was high as it exceeded up to two times the acceptable limit (500 cfu/m^3) for indoor air at Point 1 (1000 cfu/m^3), and three times at Point 3 (1500 cfu/m^3). The higher total bacterial count in the office space could be influenced by temperature, relative humidity, the building itself (including ventilation strategies, moisture levels, and building materials), and the air-conditioning system. There were many other factors that contributed to the high concentrations of biological contaminants, including a higher level of occupancy and activity, such as breathing, sweating, and movements causing secondary dust lifting, as well as the air distribution system, water damage ventilation problems, poor lighting, and poor housekeeping (Adams *et al*., 2016; NIOSH, 2016; Basińska *et al*., 2019; Rasli *et al*., 2019). Hameed and Habeeballah (2013) found that high concentrations of biological pollutants have been found in mosques in the Kingdom of Saudi Arabia due to the low ventilation rates.

Also, moisture problems in air-conditioned buildings, also known broadly as "dampness" could contribute to the most consistent risk factors for health problems, air quality, and atmospheric dynamics (Mendell *et al*., 2011; Kanchongkittiphon *et al*., 2015; Li *et al*., 2015; Xie *et al*., 2018; Gong *et al*., 2020). A previous study by Rasli *et al*. (2019) also found that the total bacterial count and total fungal count were higher in ACSU Malaysian mosques compared with non-ACSU mosques. The airborne disease infection across the built environment can be spread by bacteria and virus (Li *et al*., 2019). A study by Zock *et al*., (2002) on dampness at home found that indoor microbe growth had a negative impact on adult asthma. The air relative humidity, either intentionally or unintentionally, is sufficient to support microbial growth (Adams *et al*., 2016). Tang *et al*., (2019) found that the relative humidity of 65% to 75% in inpatient buildings during summer influenced the microbial growth on indoor surfaces.

Table 2: Descriptive statistics of indoor air contaminants following ICOP limit standards

Indoor air Contaminants	Descriptive Statistical	Point 1	Point 2	Point 3	ICOP Limit	Unit
			Chemical contaminants			
CO	N	120	120	120	10	Ppm
	Mean	1.33	1.64	1.64		
	Std. Dev.	0.45	0.47	0.31		
	Min.	0.6	1.1	1.1		
	Max.	2.2	2.4	2.3		
CH_2O	N	120	120	120	0.1	Ppm
	Mean	0.011	0.021	0.014		
	Std. Dev.	0.008	0.006	0.007		
	Min.	0.011	0.012	0.011		
	Max.	0.031	0.032	0.033		
O_3	N	120	120	120	0.05	Ppm
	Mean	0.00	0.00	0.00		
	Std. Dev.	0.00	0.00	0.00		
	Min.	0.00	0.00	0.00		
	Max.	0.00	0.00	0.00		
PM_{10}	N	120	120	120	0.15	mg/m^3
	Mean	0.023	0.023	0.011		
	Std. Dev.	0.017	0.015	0.002		
	Min.	0.008	0.008	0.008		
	Max.	0.060	0.056	0.015		
TVOC	N	120	120	120	3	Ppm
	Mean	0.706	0.721	0.673		
	Std. Dev.	0.068	0.075	0.045		
	Min.	0.606	0.634	0.589		
	Max.	0.862	0.856	0.735		
			Biological contaminants			
TBC	N	3	3	3	500	cfu/m^3
	Count	1000	1500	170		
TFC	N	3	3	3	1000	cfu/m^3
	Count	200	170	170		
			Ventilation performance indicators			
CO_2	N	120	120	120	C1000	Ppm
	Mean	995.83	1008.93	916.53		
	Std. Dev.	116.90	86.26	57.19		
	Min.	664.00	761.00	711.00		
	Max.	1042.00	1039.00	941.00		

For ventilation performance indicator, the CO_2 concentrations at Point 1 (995.83 ppm) and Point 3 (916.53 ppm) were within the acceptable limits of 1000 ppm as recommended by ICOP (DOSH, 2010), except for Point 2 (1008.93 ppm). Although the CO_2 levels at Point 1 (995.83 ppm) and Point 3 (916.53ppm) did not exceed the limits, they were approaching the acceptable limit. The high CO_2 concentrations recorded in the office space show that the office space was inadequately ventilated in the restricted air circulation of the ACSU office building as the air movements recorded was low and could perhapse provide the conditions for bacterial growth. The CO_2 concentration in indoor air indicates ventilation rate, comfort status, indoor air quality, high occupancy rate and pollution levels (Godwin & Batterman, 2007; Mahayuddin & Awbi, 2012; Batog & Badura, 2013; McGill *et al*., 2015; Fan *et al*., 2017; Hussin, 2017; Al-Awadi, 2018). Thus, the high CO_2 concentrations level in the office space reflected the lack of ventilation, poor air quality, and the indoor air is not refreshed enough within the office building. An office space should have adequate air exchange in addition to cooling. Recirculating 100% of the indoor air, and having no fresh air entrainment would not be healthy for occupants of the office buildings (Al-Awadi, 2018). The studies by Ocak *et al*. (2012) and Rasli *et al*., (2019) also found that inadequate ventilation rates, high number of occupants, and their activities contributed to high CO_2 concentrations in mosque buildings. Besides that, the high CO_2 level within the office area might have an effect on human metabolism as the exhale rate for light work is 0.3 L/min (Mahayuddin and Awbi, 2012; NIOSH, 2016). At relatively low concentration (< 3%), CO_2 can cause headaches, increase in pulse rates, uncharacteristically high fatigue and breathing difficultness. High levels of CO and CO_2 can contribute to nausea, dizziness, vomiting, and loss of consciousness (NIOSH, 2016).

For the outdoor sampling at Point 4, the results show that there were no potential severe sources from outdoors as the chemical air contaminants (CO, CH_2O, PM_{10}, O_3, and TVOC) and ventilation performance indicator (CO_2) did not exceed the acceptable limits set by ICOP (DOSH, 2010) as shown in Table 3. Indeed, some of the indoor chemical contaminants (CO, CH_2O and TVOC) and ventilation performance indicator (CO_2) were higher than the outdoor air contaminants. The high indoor air contaminants compared to outdoors may indicate that the sources came from the indoor space itself. The sources of CO concentration may have come from the heater in the nearby pantry; the CH_2O may have come from the building materials, the TVOC may have come from building materials and furnishings, and CO_2 may have comes from human metabolism, from breathing. Growing scientific evidence during the last few decades has indicated that the concentrations of certain pollutants in indoor air maybe 2 to5 times, and occasionally more than 100 times higher, than those in outdoor air (USEPA, 2017; Zock *et al*., 2002).

Table 3: The air contaminants and specific physical parameters outdoors

Indoor air Contaminants	Descriptive Statistical	Point 4 (Outdoor)	ICOP	Unit
Chemical contaminants				
CO	N	30	10	Ppm
	Mean	1.00		
	Std. Dev.	0.19		
	Min.	0.70		
	Max.	1.30		

CH_2O	N	30	0.1	Ppm
	Mean	0.014		
	Std. Dev.	0.003		
	Min.	0.011		
	Max.	0.020		
O_3	N	30	0.05	Ppm
	Mean	0.03		
	Std. Dev.	0.01		
	Min.	0.02		
	Max.	0.05		
PM_{10}	N	30	0.15	mg/m^3
	Mean	0.027		
	Std. Dev.	0.23		
	Min.	0.026		
	Max.	0.027		
TVOC	N	30	3	Ppm
	Mean	0.392		
	Std. Dev.	0.015		
	Min.	0.357		
	Max.	0.421		
Ventilation performance indicators				
CO_2	N	30	C1000	Ppm
	Mean	505.17		
	Std. Dev.	30.99		
	Min.	444.00		
	Max.	556.00		
Specific physical parameters				
T	N	30	23 – 26	°C
	Mean	32.38		
	Std. Dev.	0.31		
	Min.	31.80		
	Max.	32.90		
RH	N	30	40 – 70	%
	Mean	49.45		
	Std. Dev.	1.35		
	Min.	47.50		
	Max.	52.90		

Therefore, the indoor air quality in the office building needs to be monitored as it is an essential factor in maintaining employee productivity and health (Kubba, 2009; Hussin 2017). Vasile *et al.* (2016) suggested increasing the airtightness of the building envelope by analysing and making use of the natural ventilation system. Rasli *et* al. 2019 suggested inducing optimum air movement through pores for better ventilation. Batog and Badura (2013) also recommended applying proper air vents near airtight windows. Besides that, it is recommended to use only small air streams that can improve CO_2 and dust concentrations to lower the total bacterial count in the office building (Basińska *et al.*, 2019). Besides, it is recommended to reduce the relative humidity levels through ventilation strategies as it could potentially reduce the proliferation of microbes, but not below than 30% as it may cause sensory irritation (McGill *et al.*, 2015). The building owner or building management needs to ensure to remove the excess water and make the necessary repairs to prevent further microbe accumulation (DOSH, 2010).

Thus, the results obtained could indicate that indoor air contaminants can originate from a range of sources. The possible sources of indoor air contaminants may arise from a variety of sources, including the fabric of buildings, the occupants' activities, biological sources, the combustion of substances for heating or fuel, emission from building materials, and it can also be a byproduct of activities within the buildings (Azuma *et al.*, 2020).

Health Complaints (Signs and Symptoms Related to Indoor Air Quality Problem)

The results from the questionnaire forms in Figure 4 shows the factors that had bothered the workers during the last three months at the workstation. The workers sometimes experienced varying room temperature (eight persons), room temperature that is too high (six persons), room temperature that is too low (five persons), stuffy "bad" air (four persons), unpleasant odour (three persons), draught (two persons), and one vote each for dust and dirt, passive smoking, and dry air. Meanwhile, Figure 5 shows the past symptoms of diseases. Based on the questionnaires, there was only one person who experienced eczema, two experienced sinusitis and one had asthmatic problems.

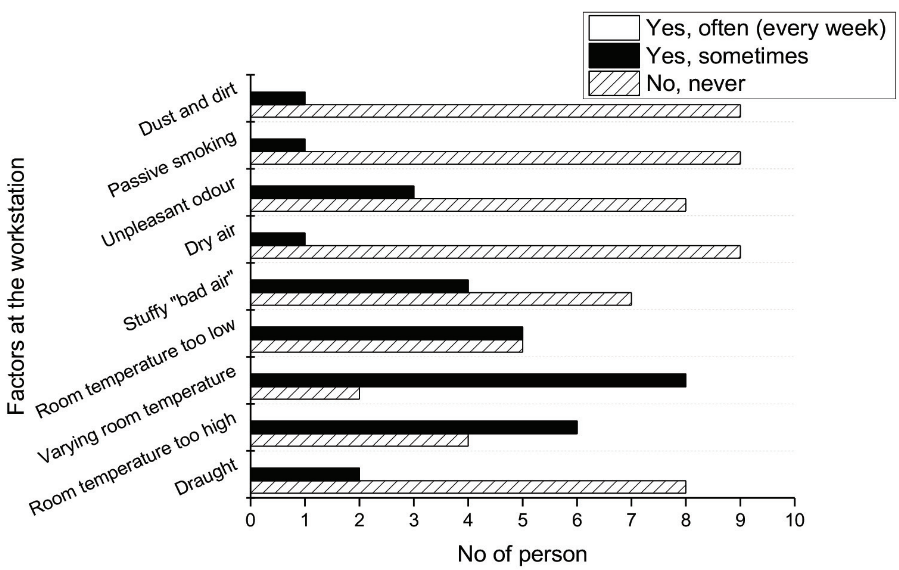

Figure 4: Factors that had bothered the workers during the last three (3) months at the workstation

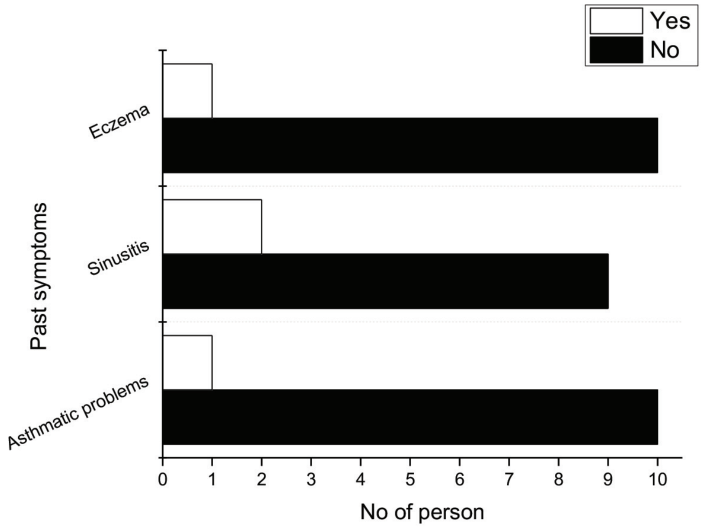

Figure 5: The past symptoms of diseases

Figure 6 shows the present symptoms of diseases during the last three months at the workstation. The symptoms, such as headaches, fatigue/lethargy, drowsiness, and irritated stuffy nose, were experienced by the workers often (every week), but only voted by one person for each. Health-related symptoms experienced by the workers sometimes (two to three times/week), in descending order, were drowsiness (seven people), headache, heavy-headedness, and fatigue/lethargy (voted by five people each), dizziness, cough, irritated and stuffy nose, hoarse/dry throat, and irritation of the eyes (voted by three people each), whereas skin rash/itchiness and scaling/itching scalp was voted by one person each.

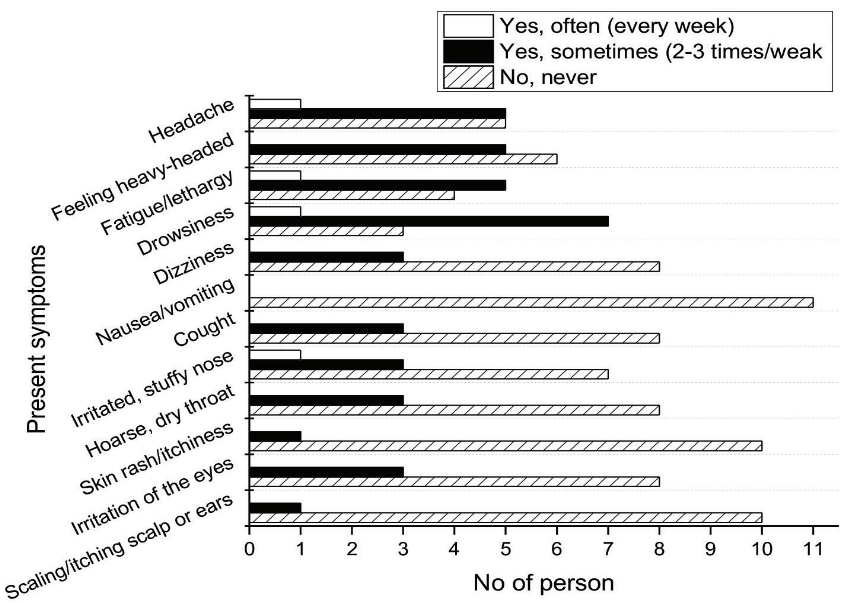

Figure 6: The present symptoms of diseases during the last three (3) months at the workstation

Besides, based on questionnaires, the highest (73 %) factor that had bothered the workers during the last three months at the workstation was varying room temperature. This could be because the air could not be equally distributed within the office building, and the ACSU needed to be checked for maintainance. The past symptoms experienced by the workers were eczema, sinusitis, and asthmatic problems at 9%, 18%, and 9%, respectively, whereas the highest present symptoms were drowsiness at 64%. Even though there were some inadequacies in the physical results of the IAQ, the symptoms of illnesses among the space occupants are still low. Care should be taken as inadequate ventilation in the office building caused the risk of SBS and BRI, which can affect the comfort and the health of the occupants (Vasile *et al*., 2016; Kubba, 2009).

Conclusions

The workers usually spend eight hours in the ACSU office space with restricted air circulation. Therefore, this assessment aims to investigate the indoor air quality comprehensively in the restricted air circulation of an ACSU office space in accordance to acceptable limit by ICOP. An IAQ assessment was initalised with a walkthrough survey, followed by the filling of questionnaires for fundamental insights (i.e. general information of the office building, background factor of the occupant, nature of occupation, environmental condition, past disease/symptoms, and present symptoms) into the office operations. Then, the assessment was continued by monitoring the specific physical parameters (i.e. T, RH, and AM) and indoor air contaminants, which included chemical contaminants (CO, CH_2O, O_3, PM_{10}, and TVOC), biological contaminants (TBC and TFC), and ventilation performance indicator (CO_2) at three points indoors and one point outdoors. For specific physical parameters, the results showed that the T at Point 1 (22.64 °C), Point 2 (23.14 °C), and Point 3 (24.69 °C) and RH at Point 1 (54.50 %), Point 2 (52.73 %), and Point 3 (51.06 %) were within the acceptable range (23-26 °C) and (40-70 %)according to ICOP, whereas the AM (0.15-0.5 m/s) did not. The air movements recorded at Point 1, Point 2, and Point 3 were 0.08 m/s, 0.04 m/s, and 0.02 m/s, respectively. For indoor air contaminants (CO, CH_2O, PM_{10}, TVOC, O_3, and TFC), they were within the acceptable limits by ICOP, except for CO_2 at Point 1 and TBC at Points 1 and 2. The CO_2 concentrations exceeded the ICOP limit of 1000 ppm at 1008.93 ppm. Meanwhile, TBC exceeded the ICOP limit (500 cfu/m^3) at two times over the limit (1000 cfu/m^3) and three times over the limit (1500 cfu/m^3) at Point 1and Point 2, respectively. The office area has an improper ventilation or deficiencies in the ventilation system, which contributes to the poor air distribution within the office area. The lower AM recorded resulted in the high CO_2 concentrations and high TBC within the office space. Besides, this study also found that the indoor chemical contaminants (CO, CH_2O and TVOC) and ventilation performance indicator (CO_2) recorded within the office area were higher than the outdoor air contaminants. It may indicate that the sources of indoor air contaminants originated indoors. Besides, based on the questionnaire survey analysis, the highest present symptom experienced by the workers was drowsiness at 64 %. Even though there are element of adequacies in the physical results of the IAQ, the symptoms of illnesses among the space occupants are low. Therefore, the air movement needs to be ensured in the recommended range to aid in lowering the CO_2 concentrations and control of microbial growth to avert any possible health effects on workers within the office buildings. Some fresh air also needed to be introduced into the ACSU office building, which has restricted air circulation, for a better IAQ.

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Appendix A

Questionnaire for Building Occupants

1) General Information

Date :

Building/Company Name :

Department/Division :

Has your Company carried out any assessment related to IAQ:

Yes

No

In progress

Not sure

2) Background Factor

Sex:	Age:	Do you smoke:
Male	< 25 yrs	Yes
Female	25 - 39 yrs	No
	40 - 55 yrs	Sometimes
	>55 yrs	

3) Nature of Occupation

Occupation/Position:

How long have you been at your present place of work?

No. of hours spent per day at your main workstation :

Brief description of your work:

4) Environmental Conditions

Type of workstation:

Enclosed room

Open concept

No. of people sharing your workstation:

How is your area air-conditioned:

Central unit

Local unit (spilt unit)

Please indicate if you work near the following equipment:

	Everyday	2-3 times weekly	Never
a) Typewriter			
b) Video display unit/computer			
c) Photocopier			
d) Fax machine			

Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught			
b) Room temperature too high			
c) Varying room temperature			
d) Room temperature too low			
e) Stuffy "bad" air			
f) Dry air			
g) Unpleasant odour			
h) Passive smoking			
i) Dust and dirt			

5) Past/Present Diseases/Symptoms

	Yes	No
Have you ever had asthmatic problems?		
If yes, during last year?		
Have you ever suffered from sinusitis?		
If yes, during last year?		
Have you ever suffered from eczema?		
If yes, during last year?		

6) Present Symptoms

During the last three months, have you had any of the following symptoms at work:

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never
a) Headache			
b) Feeling heavy-headed			
c) Fatigue/lethargy			
d) Drowsiness			

e) Dizziness

f) Nausea/vomiting

g) Cough

h) Irritated, stuffy nose

i) Hoarse, dry throat

j) Skin rash/itchiness

k) Irritation of the eyes

l) Scaling/itching scalp or eras

No of days in the past one (1) month that you had to take off work because of these complaints:

When do these complaints occur?

Mornings

Afternoons

No noticeable trend

When do you experience relief from these complaints?

After I leave my workstation

After I leave the building

No noticeable trend

If female, are you currently pregnant?

Yes

No

Not sure