ORIGINAL ARTICLE

Indoor Air Quality Level at Medical Clinics, University Hospital in Klang Valley, Malaysia

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ABSTRACT

Introduction: Patient health can be influenced by indoor air quality (IAQ) level, where the risks of IAQ pollution are proportionate with the occupant number in the clinic. This research aims to determine the level of IAQ in Medical Clinic 1 and 2 of University Hospital in Klang Valley, Malaysia. **Methods:** The indoor exposure to physical (temperature, relative humidity and air movement), chemical (formaldehyde, CO_2, CO, TVOC and PM_{10}) and biological (bacterial and fungal count) parameters following Industry Code of Practice (ICOP) IAQ (2010) were assessed in the morning and afternoon using relevant equipment. Data was analysed with One-Sample T Test and Independent T Test using SPSS Version 25. **Results:** No statistically significant mean difference ($p>0.05$) of IAQ parameters between both Medical Clinics (morning & afternoon) except for Rh and CO by Independent T Test analysis. In contrast, the One-Sample T Test showed there was statistically significant mean difference ($p<0.01$) of all parameters as compared to the ICOP (2010) standard in both Medical Clinics (morning and afternoon). There was a positive correlation of CO_2, CO and formaldehyde with bacterial counts (TBC) for both Medical Clinics. Meanwhile, CH_2O concentration was slightly higher in the morning due to the usage of cleaning products which may have released CH_2O gas killing the bacteria, thus lower the rate of bacterial growth in the afternoon. Fungal counts showed no significant impact. **Conclusion:** All measured parameters were complied with the ICOP (2010) standard except air movement and CO_2 in both Medical Clinics.
Malaysian Journal of Medicine and Health Sciences (2022) 18(6):158-165. doi:10.47836/mjmhs18.6.22

Keywords: Indoor Air Quality (IAQ); ICOP IAQ (2010); Physical Parameters; Chemical Parameters; Biological Parameters

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INTRODUCTION

A study on indoor air quality (IAQ) level especially in health facilities have gained more attention by many researchers due to an increasing concern of patients and healthcare workers health (1-3). Many factors contribute to poor IAQ which includes particulate matter, microbial contamination, gas, building materials, human activities, furnishing and outdoor pollutants which can affect the occupant's health (4-6), causing the Health Care Associated Infections (HCAI) (7-8). Among the symptoms are identified as fatigue, headaches, skin irritation, eye irritation, and others (9-11). Factors affecting IAQ can be divided into three categories namely chemical parameters (formaldehyde (CH_2O), carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC) and particulate matters (PM_{10}), physical parameters (temperature, relative humidity (Rh), and air movement) and biological parameters (total bacterial count (TBC) and total fungal count (TFC)) (12-16).

Besides chemical, physical and biological factors, ventilation systems, hygiene and poor waste management of environmental factors might impact the occupant's health too by promoting the growth of microbial (17-19). The ventilation system will control the level of humidity and temperature which contribute to the growth of microbial (18, 20) as well as numbers of occupants and improper building design (18, 20-23). Moreover, higher microbial load in the building is also associated with the chemical parameter like CO_2 concentration (22-25) promoting to a serious medical condition, allergic reactions and even death (26-27). In fact, many researchers have found out that the development of poor IAQ in the building involved interaction between chemical, physical and biological parameters. In Ana et al. (2019) (1) research, they came across of interaction between the growth of microorganisms especially fungi towards Rh in the building. At this point, CO_2, level in the environment may also positively correlated to the

growth of bacteria as found by Fu Shaw et al. (2018) (28) and Ana et al. (2019) (1). Furthermore, research by Pipat et al. in 2019 (15) have shown that the high growth of bacterial and fungal was due to high temperature and Rh concentration in the ward. Meanwhile, study by Cho et al. in 2019 (21) found out the bacterial concentration was not significantly correlated to the physical parameters (temperature, Rh and ventilation) and chemical parameters (CO_2 concentrations and anthropogenic dust levels).

Thus, particular care should be taken to the IAQ contamination in the health facilities especially in hospital (29-30). In this study, the level of IAQ in Medical Clinic 1 and Medical Clinic 2 of University Hospital in Klang Valley, Malaysia will be determined by comparing the measurement of chemical, physical and biological parameters to the Industry Code of Practice (ICOP) on IAQ (2010) standard (31).

MATERIALS AND METHODS

Walkthrough Survey

The study was carried out in three phases namely preliminary survey, sampling and statistical analysis. In the preliminary survey phase, information through scientific reading was done to gain a comprehensive overview of the project. Thereafter, visits to the clinic (Medical Clinic 1 and Medical Clinic 2) that provide medical treatment in University Hospital in Klang Valley, Malaysia (MCUH) was conducted to identify the sampling point. Finally, ethic application letter was obtained for approval from National University of Malaysia (JEP-2020-131) to implement the project.

Identify Sampling Point

The next phase was to identify the sampling point of Medical Clinic 1 and Medical Clinic 2. A total of eight sampling points (four sampling points per medical clinic) was selected based on the total area (ICOP IAQ 2010). All tools and media were prepared earlier to avoid difficulties while doing sampling by checking the record of quality control and maintenance for each equipment, and strictly follow the manual instruction and ICOP IAQ 2010 standard procedure (sampling frequency and time interval).

Measurement of Parameter

Physical parameters readings were done by direct reading method using EVM 3 (Shawcity Ltd, Oxfordshire, UK). Similarly, chemical parameters were also used in the same method as the Aeroqual series 500 (Aeroqual Ltd, Auckland, New Zealand), Tetra 3 Crowcon (Crowcon Detection Instruments Ltd, Abingdon, UK) and Formaldemeter (ENMET, Ann Arbor, USA) to measure O_3 and TVOC, CO and CH_2O respectively. The sampling frequency at each station was three times and the readings were taken at intervals of five minutes for 15 minutes. Meanwhile, the total bacterial and fungal counts were determined by using Trypticase Soy Agar (TSA) and Sabouraud Dextrose Agar (SDA) media exposure method, using Colony Counter Galaxy 230 (WIGGENS GmbH, Straubenhardt, Germany).

Statistical Analysis

The recorded data was analysed using IBM SPSS Statistics Version 25. Based on the data obtained, the mean difference of physical, chemical, and biological parameters in the morning and afternoon between Medical Clinic 1 and Medical Clinic 2 was measured by the Independent T Test. Meanwhile, the mean difference of all parameters as mentioned above for both Medical Clinics when compared to the standard set by the Industrial Code of Practice (ICOP) on IAQ (2010) was measured by One-Sample T Test.

RESULTS

Overall IAQ in Medical Clinic 1 and Medical Clinic 2

The mean with standard deviation of all physical, chemical and biological parameters (temperature, Rh, air movement, CH_2O, CO_2, CO, TVOC, PM_{10}, TBC and TFC) for Medical Clinic 1 and Medical Clinic 2 have given in Table I. All the temperature and Rh readings (physical parameter) at the studied site were within accepted limit of ICOP IAQ (2010) standard, except Medical Clinic 2 (Station 2 - 22.89 ± 0.25°C & Station 3 - 22.81 ± 0.57°C) for temperature, and Medical Clinic 1 (Station 3 - 70.07 ± 5.60%) for Rh respectively. In contrast, with air movement readings which less than the standard for all station in Medical Clinic 1 and Medical Clinic 2. All chemical and biological parameters, however, do not exceed the standard except CO_2 for both Medical Clinics. Finally, the average value of all physical, chemical and biological parameters was within accepted limit of ICOP IAQ (2010) standard for both Medical Clinics except air movement and CO_2.

Comparison of IAQ Parameters in the Morning and Afternoon between Medical Clinic 1 and Medical Clinic 2

Mean difference by the Independent T Test of all physical, chemical and biological parameters in the morning and afternoon (temperature, Rh, air movement, CH_2O, CO_2, CO, TVOC, PM_{10}, TBC and TFC) between Medical Clinic 1 and Medical Clinic 2 were showed in Table II, III and IV. There were no statistically significant mean difference ($p>0.05$) in air movement readings (morning, $p=0.751$ & afternoon, $p=0.315$) and temperature reading (morning, $p=0.638$), but there were statistically significant mean difference ($p<0.05$) for Rh (morning, $p=0.000$ & afternoon, $p=0.004$) and temperature (afternoon, $p=0.042$) respectively, between Medical Clinic 1 and Medical Clinic 2 (Table II). Medical Clinic 2 was found to be higher of Rh reading in the morning (67.358 ± 1.801%), while in the afternoon it showed high temperature reading (23.933 ± 0.4072 °C) compared to Medical Clinic 1 (66.267

Table I: Physical, chemical and biological readings in Medical Clinic 1 and Medical Clinic 2

Station Point	Temp (°C) mean ± SD	Rh (%) mean ± SD	AM (ms^{-1}) mean ± SD	CH_2O (ppm) mean ± SD	CO_2 (ppm) mean ± SD	CO (ppm) mean ± SD	PM_{10} (mg/m^3) mean ± SD	O_3 (ppm) mean ± SD	TVOC (ppm) mean ± SD	Total bacterial counts (cfu/m^3)	Total fungal counts (cfu/m^3)
Medical Clinic 1											
Station 1	23.93 ± 0.38	68.41 ± 0.77	0.14 ± 0.07	0.02 ± 0.01	1769 ± 260.49	0.55 ± 0.48	0.04 ± 0.01	0.00	0.00	*302 **180	*18 **10
Station 2	23.56 ± 0.21	69.35 ± 2.04	0.11 ± 0.03	0.02 ± 0.00	1714 ± 227.24	0.33 ± 0.33	0.05 ± 0.01	0.00	0.00	*230 **246	*16 **4
Station 3	24.03 ± 0.73	70.07 ± 5.60	0.13 ± 0.07	0.00	1551 ± 48.68	0.21 ± 0.20	0.06 ± 0.01	0.00	0.00	*224 **220	*16 **10
Station 4	23.46 ± 1.08	64.04 ± 1.99	0.13 ± 0.05	0.01 ± 0.01	1639 ± 163.95	0.38 ± 0.37	0.03 ± 0.01	0.00	0.00	*160 **238	*8 **12
Average	**23.74 ± 0.277**	**67.96 ± 2.71**	**0.13 ± 0.01**	**0.01 ± 0.01**	**1668 ± 94.60**	**0.37 ± 0.14**	**0.05 ± 0.01**	**0.00**	**0.00**	***229 ± 58.07 **221 ± 29.42**	***15 ± 4.46 **9 ± 3.46**
Medical Clinic 2											
Station 1	23.23 ± 0.20	68.25 ± 1.51	0.13 ± 0.05	0.02 ± 0.01	1411 ± 385.66	0.43 ± 0.57	0.02 ± 0.01	0.00	0.00	*290 **208	*12 **14
Station 2	22.89 ± 0.25	66.05 ± 1.61	0.10 ± 0.00	0.01 ± 0.01	1614 ± 383.05	0.53 ± 0.46	0.02 ± 0.01	0.00	0.00	*394 **106	*16 **6
Station 3	22.81 ± 0.57	69.48 ± 2.21	0.13 ± 0.05	0.02 ± 0.01	1395 ± 463.99	0.42 ± 0.45	0.02 ± 0.01	0.00	0.00	*308 **140	*8 **16
Station 4	23.53 ± 0.34	67.66 ± 0.31	0.10 ± 0.00	0.02 ± 0.01	1515 ± 207.71	0.38 ± 0.43	0.03 ± 0.01	0.00	0.00	*288 **240	*14 **14
Average	**23.11 ± 0.33**	**67.86 ± 1.43**	**0.12 ± 0.02**	**0.02 ± 0.01**	**1484 ± 101.83**	**0.44 ± 0.06**	**0.02 ± 0.01**	**0.00**	**0.00**	***320 ± 50.15 **174 ± 61.35**	***13 ± 3.42 **13 ± 0.44**
Standard Value (ICOP IAQ 2010)	**23.0 -26.0**	**40 - 70**	**0.15 – 0.50**	**0.1**	**1000**	**10**	**0.15**	**0.05**	**3.0**	**500**	**1000**

**, morning; **, afternoon, Temp, temperature; Rh, relative humidity; AM, air movement; CH_2O, formaldehyde; CO_2, carbon dioxide; CO, carbon monoxide; TM_{10}, particulate matters; O_3, ozone; TVOC, total volatile organic compounds.*

Table II: Comparison of temperature, relative humidity and air movement readings in the morning & afternoon between Medical Clinic 1 and Medical Clinic 2

Time	Parameter	Medical Clinic 1	Medical Clinic 2	t	p
		Mean ± SD	Mean ± SD		
Morning	Temperature (°C)	24.229 ± 0.3782	23.300 ± 0.444	7.802	0.638
	Relative Humidity (%)	66.267 ± 3.348	67.358 ± 1.801	1.047	0.000*
	Air Movement (ms^{-1})	0.121 ± 0.509	0.125 ± 0.442	0.303	0.751
Afternoon	Temperature (°C)	23.258 ± 0.6248	23.933 ± 0.4072	2.135	0.042*
	Relative Humidity (%)	69.992 ± 3.702	68.367 ± 2.031	1.885	0.004*
	Air Movement (ms^{-1})	0.125 ± 0.044	0.113 ± 0.045	0.972	0.315

**Significant value is at p<0.05*

Table III: Comparison of formaldehyde, carbon dioxide, carbon monoxide and PM_{10} readings in the morning and afternoon between Medical Clinic 1 and Medical Clinic 2

Time	Parameter	Medical Clinic 1	Medical Clinic 2	t	p
		Mean ± SD	Mean ± SD		
Morning	Formaldehyde (ppm)	0.0183 ± 0.014	0.0213 ± 0.012	-7.57	0.498
	Carbon Dioxide (ppm)	1741.670 ± 234.886	1508.88 ± 440.496	2.285	0.000*
	Carbon Monoxide (ppm)	0.675 ± 0.259	0.800 ± 0.371	-1.354	0.222
	PM_{10} (mg/m^3)	0.025 ± 0.008	0.024 ± 0.003	0.509	0.010*
Afternoon	Formaldehyde (ppm)	0.0104 ± 0.009	0.0137 ± 0.011	-1.173	0.443
	Carbon Dioxide (ppm)	1595.04 ± 136.877	1458.83 ± 292.947	2.064	0.000*
	Carbon Monoxide (ppm)	0.583 ± 0.114	0.071 ± 0.171	-2.99	0.373
	PM_{10} (mg/m^3)	0.058 ± 0.019	0.038 ± 0.012	4.304	0.064

**Significant value is at p<0.05*

± 3.348 % & 23.258 ± 0.6248°C). Meanwhile, Table III showed no statistically significant mean difference (p>0.05) of CH_2O (p=0.443), CO (p=0.373) and PM_{10} readings (p=0.064) in the afternoon, while there was a significant mean difference (p<0.05) for CO_2 (morning,

Table IV: Comparison of total bacterial and fungal counts in the morning & afternoon between Medical Clinic 1 and Medical Clinic 2

Time	Parameter	Medical Clinic 1	Medical Clinic 2	t	p
		Mean ± SD	Mean ± SD		
Morning	Total bacterial count (cfu/m³)	229.00 ± 58.069	320.00 ± 50.146	-2.372	1.000
	Total fungal count (cfu/m³)	14.50 ± 4.435	12.50 ± 3.416	0.715	0.633
Afternoon	Total bacterial count (cfu/m³)	221.00 ± 29.417	173.50 ± 61.349	1.396	0.059
	Total fungal count (cfu/m³)	9.00 ± 3.464	12.30 ± 4.435	-1.244	0.639

**Significant value is at p<0.05*

p=0.000 & afternoon, p=0.000) and PM_{10} (morning, p=0.010) respectively. CO_2 readings in Medical Clinic 1 (morning, 1741.670 ± 234.886 ppm & afternoon, 1595.04 ± 136.877 ppm) were higher compared to Medical Clinic 2 (morning, 1508.88 ± 440.496 ppm & afternoon, 1458.83 ± 292.947 ppm) in the morning and afternoon respectively. PM_{10}'s reading was found higher in Medical Clinic 1 (0.025 ± 0.008 ppm) compared to Medical Clinic 2 (0.024 ± 0.003 ppm) in the morning. For biological (TBC and TFC) parameters, there were no statistically significant mean difference (p>0.05) indicated between both Medical Clinics (Table IV) in the morning and afternoon.

Comparison of IAQ Parameters in the Morning and Afternoon between Medical Clinics and ICOP IAQ (2010) Standard

The mean difference by the One-Sample T Test of physical, chemical and biological parameters in Medical Clinic 1 and Medical Clinic 2 to the ICOP standard, ICOP IAQ (2010) in the morning and afternoon (temperature, Rh, air movement, CH_2O, CO_2, CO, TVOC, PM_{10}, TBC and TFC) were given in Table V, VI and VII. The physical, chemical and biological readings were found to have significant mean difference (p<0.01) with the standard values of ICOP IAQ (2010) in the morning and afternoon for both Medical Clinics. The temperature and relative humidity readings in Medical Clinic 1 (morning, 24.230 ± 0.378 oC & 66.267 ± 3.348 % and afternoon, 23.0.378 ± 0.625 °C & 69.991 ± 3.702 %) and Medical Clinic 2 (morning, 23.300 ± 0.444 °C & 67.358 ± 1.800 % and afternoon, 23.932 ± 0.407 °C and & 68.367 ± 2.031 %) were within the standard range in the morning and afternoon respectively. In contrast, the readings of air movement were lower compared to the standard for Medical Clinics 1 (morning, 0.121 ± 0.051 ms^{-1} & afternoon, 0.125 ± 0.044 ms^{-1}) and Medical Clinic 2 (morning, 0.125 ± 0.044 ms^{-1} & afternoon, 0.112 ± 0.045 ms^{-1}) in the morning and afternoon respectively. Meanwhile, all chemical parameters were within the standard range in the morning and afternoon for both

Table V: Comparison of physical parameters with standard ICOP IAQ (2010) value at Medical Clinic 1 & Medical Clinic 2 in the morning and afternoon

Location	Parameter	Mean ± SD		t		p	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
Medical Clinic 1	Temperature (°C)	24.230 ± 0.378	23.0.378 ± 0.625	-35.893	-29.338	0.000*	0.000*
	Relative Humidity (%)	66.267 ± 3.348	69.991 ± 3.702	-5.462	-0.110	0.000*	0.000*
	Air Movement (ms^{-1})	0.121 ± 0.051	0.125 ± 0.044	-36.495	-41.533	0.000*	0.000*
Medical Clinic 2	Temperature (°C)	23.300 ± 0.444	23.932 ± 0.407	-40.798	-48.928	0.000*	0.000*
	Relative Humidity (%)	67.358 ± 1.800	68.367 ± 2.031	-7.187	-3.939	0.000*	0.000*
	Air Movement (ms^{-1})	0.125 ± 0.044	0.112 ± 0.045	-41.533	-42.334	0.000*	0.000*

**Significant value is at p<0.01*
Standard Value ICOP IAQ (2010): Temperature, 23.0 - 26.0 °C; Relative humidity, 40 - 70 %; Air movement, 0.15 - 0.50 ms^{-1}.

Table VI: Comparison of chemical parameters with standard ICOP IAQ (2010) value at Medical Clinic 1 & Medical Clinic 2 in the morning and afternoon

Location	Parameter	Mean ± SD		t		p	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
Medical Clinic 1	Formaldehyde (ppm)	0.018 ± 0.014	0.010 ± 0.009	-27.889	-48.339	0.000*	0.000*
	Carbon Dioxide (ppm)	1741.67 ± 234.880	1595.041 ± 136.877	15.469	21.297	0.000*	0.000*
	Carbon Monoxide (ppm)	0.675 ± 0.259	0.0583 ± 0.114	-176.26	-427.64	0.000*	0.000*
	PM_{10} (mg/m^3)	0.025 ± 0.008	0.0586 ± 0.019	-71.784	-23.212	0.000*	0.000*
Medical Clinic 2	Formaldehyde (ppm)	0.021 ± 0.012	0.014 ± 0.010	-31.443	-40.031	0.000*	0.000*
	Carbon Dioxide (ppm)	1508.875 ± 440.495	1458.833 ± 292.947	5.659	7.673	0.000*	0.000*
	Carbon Monoxide (ppm)	0.800 ± 0.371	0.0708 ± 0.171	-121.594	-285.089	0.000*	0.000*
	PM_{10} (mg/m^3)	0.0242 ± 0.003	0.0387 ± 0.012	-175.386	-46.158	0.000*	0.000*

**Significant value is at p<0.01*
Standard Value ICOP IAQ (2010): Formaldehyde, 0.1 ppm; Carbon Dioxide, 1000 ppm; Carbon Monoxide, 10 ppm; PM_{10}, 0.15 mg/m^3.

Table VII: Comparison of biological parameters with standard ICOP IAQ (2010) value at Medical Clinic 1 & Medical Clinic 2 in the morning and afternoon

Location		Mean ± SD		t		p	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
Medical Clinic 1	Total bacterial count (cfu/m^3)	229 ± 58.069	221.00 ± 29.417	-9.334	-18.969	0.003*	0.000*
	Total fungal count (cfu/m^3)	13.50 ± 3.817	10.75 ± 4.132	-730.956	-677.199	0.000*	0.000*
Medical Clinic 2	Total bacterial count (cfu/m^3)	320 ± 50.146	173.50 ± 61.349	-7.179	-10.644	0.006*	0.002*
	Total fungal count (cfu/m^3)	12.50 ± 3.146	12.50 ± 4.435	-578.221	-445.35	0.000*	0.000*

**Significant value is at p<0.01*

Standard Value ICOP IAQ (2010): Total bacterial count, 500 cfu/m^3; Total fungal count, 1000 cfu/m^3.

Medical Clinics except for CO_2. The morning reading for CO_2 (1741.67 ± 234.880 ppm) was higher compared to the afternoon (1595.041 ± 136.877 ppm) in Medical Clinic 1. On contrary, the afternoon reading (1508.875 ± 440.495 ppm) was higher compared to the morning (1458.833 ± 292.947 ppm) in Medical Clinic 2. All biological parameters for both Medical Clinics were below the standard either in the morning or in the afternoon. The morning readings (229 ± 58.069 cfu/m^3 & 320 ± 50.146 cfu/m^3) were higher compared to the afternoon (221.00 ± 29.417 cfu/m^3 & 173.50 ± 61.349 cfu/m^3) respectively for bacterial counts in both Medical Clinics. The fungal counts, however, showed not much difference between morning and afternoon.

DISCUSSION

Temperature, relative humidity, and air movement of physical parameters were measured in this study. It was found that temperature readings in Medical Clinic 1 and Medical Clinic 2 were within accepted limit of ICOP IAQ (2010) standard except for Station 2 (22.89±0.25 C) and Station 3 (22.81±0.57 C) of Medical Clinic 2, even though temperature in both Medical Clinics were controlled by the hospital's infrastructure centre. Therefore, the most reasonable factor for this finding was a smaller number of patients and healthcare workers when the data was collected. Presence of humans in the atmosphere increase heat and can affect the environment (32-34). Furthermore, the low carbon dioxide reading (Table I) also proved fewer human activities in Station 3, Medical Clinic 2 (28, 35).

Measurement of relative humidity has shown that all sampling locations were within the standard range of ICOP IAQ (2010) except in Station 3 of Medical Clinic 2 which were slightly higher. Therefore, careful inspection and maintenance of building air quality are essential in order to maintain good IAQ (30), as high relative humidity may contribute for the growth of microbial (17, 24, 36-37), which affects occupants' health (16, 38).

Independent T Test showed a statistically significant mean difference ($p<0.05$) for relative humidity in Medical Clinic 1 compared to Medical Clinic 2 in the morning and afternoon respectively. Statistically significant mean difference ($p<0.01$) was also found when analysed with One-Sample T Test for both Medical Clinics in the morning and afternoon, where afternoon readings (69.991±3.702% & 68.367±2.031%) were higher than morning (66.267±3.348% & 67.358±1.800%) (Table V). In contrast, both Medical Clinics showed a high bacterial and fungal counts reading in the morning compared to the afternoon (Table VII). This finding is agreeable with other researcher findings showing that Rh is one of the factors influencing microbial growth besides air conditioning systems, number of occupants, ventilation, heat and temperature (39-40).

Air movement readings for both Medical Clinics, however, were below the ICOP IAQ (2010) standard (0.15 ms^{-1} - 0.5 ms^{-1}) which is statistically significant mean difference ($p<0.01$) in the morning and afternoon respectively (Table V). Therefore, installation, design and testing such as careful inspection and maintenance of air quality are also essential to maintain good IAQ as mentioned above for Rh, where a low wind speed can influence the increasing of temperature resulting in inadequacy of ventilation and high microbial load (18, 25, 41).

For chemical parameters, measurements of CH_2O, CO, CO_2, PM_{10}, TVOC and O_3 were taken at Medical Clinic 1 and Medical Clinic 2. All readings met the ICOP IAQ (2010) standard except CO_2, which was above the standard value of 1000 ppm (Table I), thus showing inadequate ventilation (42-43). The CO_2 readings were found to have significant mean difference ($p<0.01$) in the morning and afternoon for both Medical Clinics respectively (Table VI), where the morning readings (1741.67±234.880 ppm & 1508.875±440.495 ppm) were higher than the afternoon (1595.041±136.877 ppm & 1458.833 ± 292.947 ppm). This finding has shown that there were more patients in the morning compared to the afternoon for both Medical Clinics as the concentration of CO_2 was high during tight rush hours (15) and may exceed the standard (28, 35). Interestingly, from this study, CO_2 value was also found to has positive correlation with bacterial count, where morning value was higher than afternoon session for both Medical Clinics. This in line with Ana et al. (2019) (1) who reported that CO_2 had positive correlation with bacterial count. This finding also agreed to the statements made by previous researchers that microbial load can be

influenced by number of occupants (17, 35, 39-40).

Other important parameter in an indoor environment for human health is CH_2O. It was commonly found in wood, carpet, building materials, textiles, and furniture (5, 44-46), and also detected in cleaning products (47). CH_2O measurements for both Medical Clinics showed low readings, ranging from 0.010±0.009 to 0.021±0.012 ppm (Table VI) but it met the ICOP IAQ (2010) standard of 0.1 ppm. Statistically, no significant mean difference ($p>0.05$) between both clinics (Table III) but had a significant mean difference ($p<0.01$) when compared to the standard in the morning and afternoon respectively (Table VI). CH_2O concentrations had a positive correlation not only to bacterial counts, but also to fungal counts, in which the morning values of TBC and TFC were higher than those in the afternoon for both Medical Clinics. This finding obviously showed that the use of cleaning product which contain CH_2O in the morning may inhibit the microbial growth in the afternoon.

Likewise CH_2O, CO readings showed a statistically no significant mean difference ($p>0.05$) between both clinics (Table III) but had a statistically significant mean difference ($p<0.01$) in the morning and afternoon (Table VI) when analysed by the Independent T Test and the One-Sample T Test, respectively. Morning session (0.675±0.259 ppm & 0.800±0.371 ppm) showed higher readings compared to the afternoon (0.0583±0.114 ppm & 0.0708±0.171 ppm) for Medical Clinic 1 and Medical Clinic 2 (Table VI), as well as CO_2 readings as mentioned above. Therefore, this proves a high load of occupants in the morning compared to the afternoon may result in high CO concentration as tobacco smoke from outside the building is one of the sources of carbon monoxide (48-49).

Finally, very low PM_{10} readings were found, ranging from 0.0242±0.003 to 0.0586±0.019 mg/m^3 in the morning and afternoon (Table VI) compared to ICOP IAQ (2010) standard of 0.15 mg/m^3, and zero concentrations of TVOC and O_3 (Table I) when measured at both Medical Clinics. Although similar to CH_2O and CO, where no significant mean difference ($p>0.05$) between Medical Clinic 1 and Medical Clinic 2 was found for these three parameters, the mean difference ($p<0.01$) is significant in the morning and afternoon when compared with the ICOP standard (Table III & Table VI). Therefore, no indoor air pollutant by PM_{10}, and Medical Clinics 1 and 2 were free from O_3 and TVOC contaminations as well.

Besides CO_2, CH_2O and PM_{10} of chemical parameters, measurement of biological (TBC and TFC) parameters also showed no significant mean difference ($p>0.05$) between Medical Clinics 1 and Medical Clinics 2 but had significant mean difference ($p<0.01$) in the morning and afternoon when compared with ICOP standard (Table IV & Table VII). In addition, both TBC and TFC were complied to the ICOP IAQ (2010) standard. TBC was found to be higher in the morning (229±58.069 cfu/m^3 & 320±50.146 cfu/m^3) than the afternoon (221.00±29.417 cfu/m^3 & 173.50±61.349 cfu/m^3) in Medical Clinic 1 and Medical Clinic 2, respectively. In contrast with fungal count, the morning reading (13.50±3.817 cfu/m^3) was higher than the afternoon reading (10.75±4.132 cfu/m^3) in Medical Clinic 1, but not Medical Clinic 2. However, the TFC in both Medical Clinics were very low compared to the standard. Therefore, there was no significant impact of physical and chemical parameters for the growth of fungal in both Medical Clinics.

There was positive correlation between CO_2 and bacterial concentrations in this study where high number of patients or occupants in the morning resulting in high number of bacteria present in the air (28, 35). Furthermore, humans can be a major source of bacteria reproduction through the respiratory system, coughing, sneezing and on the human skin itself (16, 34, 50). But too many patients at the sampling site are one of the potential limitations of this study. On top of that, using colony count method for biological measurement may allow information only on total concentration of biological airborne contamination but not to a specific pathogenic microorganism (bacteria and fungi) found in hospital buildings.

CONCLUSION

All measured parameters (physical, chemical and biological) were complied to the ICOP IAQ (2010) standard except air movement and carbon dioxide in both Medical Clinics. Continuous monitoring of air movement and carbon dioxide should be performed as well as maintaining a good ventilation system to avoid negative health effects to the patients and healthcare workers. Interestingly, the carbon dioxide, carbon monoxide and formaldehyde concentration in this study had positive correlation to the bacterial count at the studied Medical Clinics but gave no impact to the growth of fungi. High CO_2 and CO concentration related to the number of occupants in this study needs an effective control strategy to be introduced in order to reduce the airborne contamination, for example implementation of digital monitoring to limit patient numbers in the clinic at certain time or by an appointment. Limitation of this study suggest that there is a need to identify airborne microorganism (bacteria and fungi) to the species level and a study on the disinfectant regarding its concentration, frequency and time in order to control the microbial growth in the medical clinic.

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