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Assessment of Indoor Air Chemical Pollutants at Faculty of Health Sciences Administrative Offices Universiti Kebangsaan Malaysia, Kuala Lumpur Campus

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ABSTRACT

The 2010 guidelines for indoor air quality (ICOP IAQ 2010) provide a framework for evaluating and sustaining healthy indoor environments in enclosed spaces, promoting a safer and more comfortable atmosphere for occupants. Chemical pollutants in indoor air measured in this study are particulate matter (PM10), carbon monoxide (CO), carbon dioxide (CO_2), total volatile organic compounds (TVOC), formaldehyde (CH_2O) and ozone (O_3). A total of six sampling locations were selected, namely P1 (ReaCH), P2 (CORE), P3 (H-Care), P4 (iCaRehab & CODTIS), P5 (PD) and P6 (PTD). The results of the study found that all chemical parameters measured were found to comply with the limits allowed by ICOP IAQ 2010 except for ozone (O_3) readings. The average range of carbon monoxide (CO) readings was recorded to be (0.0 ± 0.0 ppm -0.6 ± 0.01 ppm) and still below the ICOP IAQ 2010 limit (10 ppm). CO_2 readings ranged between (582 ± 104 ppm - 847 ± 67 ppm) with all readings at sampling locations complying with ICOP IAQ 2010 limits (1000 ppm). The average value for PM10 readings ranges between (0.01 ± 0.01 ppm -0.03 ± 0.01 ppm) and all readings are below the ICOP IAQ 2010 limit (0.15 ppm). TVOC readings range between (0.0 ± 0.0 ppm -1.8 ± 0.01 ppm) and all readings are below the ICOP IAQ 2010 limit (3 ppm). The average value for formaldehyde concentration between the reading range (0.00 ± 0.00 ppm -0.96 ± 0.01 ppm) and it complies with the ICOP IAQ 2010 limit (0.10 ppm). The average O_3 concentration exceeds the ICOP IAQ 2010 standard (i.e., 0.05 ppm) in the range of 0.00 ± 0.00 -0.06 ± 0.01 ppm. Overall, the indoor air quality in all UKM Faculty of Health Sciences administrative offices is in good condition. However, monitoring indoor air quality periodically needs to be done to ensure that the occupants are always healthy and in a comfortable condition as well as being able to increase work productivity.

Keywords: Indoor air quality, Chemical pollutants, Carbon monoxide, Formaldehyde.

INTRODUCTION

The quality of air within and surrounding buildings and structures is a critical factor known as indoor air quality (IAQ), which plays a significant role in determining the health, comfort, and overall well-being of those who occupy these spaces (Mazlan *et al.,* 2015). Indoor air quality (IAQ) is currently the focus of governments, non-governmental organizations, and researchers to improve the comfort, health, and well-being of building occupants. The health of building occupants is significantly influenced by the IAQ, where a wide range of health problems can be caused by poor indoor air (Kabir *et al.,* 2012); furthermore, people spend over 90% of their time indoors (Cincinelli & Martellini *et al.,* 2017). On average, workers usually spend more than a third of their daily life, which is 5 or 6 days a week at work whether in offices, factories, construction sites, hospitals, laboratories, and so on (Arifin *et al.,* 2021). Therefore, office buildings need to have good indoor air quality for employees because the office environment has a high influence on employee productivity (Fohimi *et al.,* 2022). Most offices now have modern and complex building elements equipped with mechanical, electrical, plumbing, and fire protection control systems. All of these designed systems can indirectly reduce the energy costs required for the control of the internal environment of an office (Sakellaris *et al.,* 2019).

Various health issues and risks often exist among the occupants of a building due to workplace environment factors that are caused by several factors such as indoor air quality, lighting, noise, and cleanliness (Arifin *et al.,* 2021). A healthy and comfortable indoor air quality is essential in the workplace setting, as it is critical for maintaining the well-being and productivity of workers and residents, as emphasized by occupational health and safety guidelines (DOSH 2010). According to Kamaruzzaman & Sabrani (2011), many premises in Malaysia rely on mechanical ventilation and air conditioning (MVAC) systems to ensure adequate ventilation and maintain a good indoor air quality (IAQ). However, improper installation, poor maintenance or malfunction of the mechanical ventilation system will cause the IAQ to be at a poor level. This will result in a reduction in the productivity of the occupants and employees in the building (Melikov & Kaczmarczyk 2012). Gwak J. *et al.,* (2019) emphasized the need for adequate ventilation in indoor environments to improve the comfort and productivity of individuals working or studying in enclosed places like offices and classrooms.

Sick Building Syndrome (SBS) is a disease that occurs among occupants associated with time spent in a building. This syndrome can be attributed to multiple causes, with a notable correlation to the IAQ of the building (Syahzanan *et al.,* 2021; Zaza Hulwanee *et al.,* 2019; Kok Ern Jun *et al.,* 2017), as well as poor IAQ and work-related stress (Zamani *et al.,* 2013). The effect of continuous exposure of chemical pollutants on the occupants of a building has become an important factor in IAQ assessment. Indoor air quality (IAQ) is a critical aspect of building health and comfort, as defined by the Environmental Protection Agency (EPA) and other global organizations, which encompasses the assessment of indoor air pollutants and their potential effects on the overall health and wellness of building occupants. IAQ becomes a big problem for the occupants of office buildings when pollutants are detected in the indoor air of the environment (Fauzan *et al.,* 2016). Given that the majority of our daily lives are spent indoors, where pollutant concentrations can be significantly higher than those outdoors. Indoor air quality (IAQ) is a vital concern for a healthy and comfortable environment. Various substances found indoors, even at low concentrations, can indeed have significant impacts on human health and lead to a range of disorders, including nasal and skin irritation, lung cancer, asthma, respiratory infections, allergies, as well as cardiovascular and chronic obstructive pulmonary diseases (Silva *et al.,* 2021).

Numerous substances, including ozone (O_3), carbon monoxide (CO), volatile organic compounds (VOCs), particulate matter (PM), radon, organic and inorganic pollutants, and biological pollutants like bacteria and fungi, can have an impact on indoor air quality (Cincinelli & Martellini 2017). There are pollutants from different sources in indoor air, for instance, formaldehyde from decorative items, O_3 from laser printers and photocopiers, and also VOCs from solvents (DOSH 2010). Biological pollutants like bacteria and fungi can significantly impact indoor air quality in buildings. These pollutants can flourish in environments with optimal temperature and humidity levels (Mazlan *et al.,* 2015). In addition, the identification of indoor air pollution sources is very important for the management of the building in order to develop indoor air pollution control measures (Baek 2019).

Indoor air quality (IAQ) in a building can be assessed according to the guidelines outlined in the Industry Code of Practice on Indoor Air Quality 2010 (ICOP IAQ 2010). Among the parameters evaluated and measured are temperature, relative humidity, air movement, suspended particulate matter (PM), carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (CH_2O), ozone (O_3) as well as total bacterial count and total fungal count. A building maintains a satisfactory and safe indoor air quality when each of the measured levels of potentially harmful contaminants are at or as close to their minimum levels that have been established by standards. Indoor activities such as emissions from building materials, utilization of consumer products and electronics, as well as indoor activities (e.g., cooking and smoking) can lead to indoor air pollution (Tran *et al.,* 2020). The indoor pollutants of concern can be broadly categorized as a multitude within buildings (i.e.,: carbon monoxide, CO) and volatile organic compounds (VOCs), respirable particulates (PM), and biological pollutants among many other hazardous pollutants.

According to Ismail *et al.,* (2022) and Mata *et al.,* (2022), environmental monitoring for indoor air exposure assessment can be categorized into three key components: chemical agents, which include pollutants such as formaldehyde (HCHO), total volatile organic compounds (TVOCs), carbon dioxide (CO_2), and carbon monoxide (CO); physical properties, comprising ventilation parameters such as relative humidity (RH), air movement, and volume flow rate (CFM); and particle size, including PM10, PM2.5, PM5, and PM0.5. Health risk analysis is commonly used as the framework for setting exposure limits because long-term exposure to indoor air pollutants at relatively low concentrations can result in substantial negative impacts on occupants of a building (Wong *et al.,* 2022). As employee awareness of health in the workplace is increasing, this study was conducted with the aim of assessing the IAQ status in the administration office of the Faculty of Health Sciences, UKM. The assessment of the IAQ status in the administrative office was carried out because there were several complaints by employees who felt discomfort during their work. A survey at the location involved has found that there are sources that have the potential to affect IAQ at that location.

MATERIALS AND METHODS

Sampling Location

Sampling was conducted at 6 sampling locations as shown in Table 1, namely Community Health Research Center (ReaCH) (P1), Center for Toxicology and Health Risk Studies (CORE) (P2), Center for the Study of Healthy Aging and Wellness (H-Care) (P3), Rehabilitation & Special Needs Study Center (iCaRehab) & Center for Diagnostic, Therapeutic and Investigational Studies (CODTIS) (P4), Dean's Office (PD) (P5) and Deputy Dean's Office (PTD) (P6). To determine the number of sampling stations, a survey cross-survey referring to the ICOP IAQ, 2010 was conducted to determine the position of the sampling stations.

Walkthrough Inspection

The survey developed by the Department of Occupational Safety and Health (DOSH) in ICOP-IAQ (2010) was used to obtain basic information such as office characteristics and factors that have the potential to affect indoor air quality at sampling locations. Factors that can impact indoor air quality include the number of occupants at a workplace, the MVAC system, and contaminant sources. This survey has four sections. The first section of the survey related to the location of the study such as cleanliness, physical condition of the building, and ventilation in the building that need to be seen during the walkthrough inspection. Next, the second section contains a survey for human exposure to pollutants and comfort levels. Then, the third section covers potential sources of contaminants such as furniture and printing presses. The last sections include ventilation and air conditioning in the building.

Table 1: Details of sampling locations

No	Code	Administration office	Sampling location	Descriptions
1	P1	ReaCH (R)	Level 3, Blok P	Chairman's room has 1 split aircond unit. The open cubicle space accommodates 3 staff using 1 unit standing fan because 1 split aircond unit is not functioning. The open space of the cubicle accommodates 2 staff using 1 split aircond unit. There are copiers and printers in the open staff room.
2	P2	H-Care (H)	Ground Floor, Blok J	The Chairman's P.A room has a printer and the aircond is centralized. The open space at the counter accommodates 2 staff members and the aircond is centralized. Studio kitchen and discussion room have 1 split aircond unit. There are copiers and printers in the open space.
3	P3	CORE (C)	Level 4, Blok H ● ● ●	The Chairman's room has 1 split aircond unit and there is a printer. The Chairman's P.A room has 1 split aircond unit and there is a printer. The open cubicle space accommodates 3 staff using 2 split aircond units, but 1 unit is not functioning. There are copiers and printers in the open staff room.
4	P4	CODTIS & iCaRehab (iC)	Ground Floor, Blok E ● ● ●	Central Chairman's room has 1 split aircond unit. The meeting room has 2 split aircond units. The open cubicle space accommodates 6 staff with 2 split aircond units. There are copiers and printers in front of the staff cubicle spaces.
5	P5	Dean's Office ●(PD)	Ground Floor, Blok A ● ● ● ●	Dean's P.A room has 1 split aircond unit and there is a printer. The undergraduate Deputy Dean's room has 1 split aircond unit and there is a printer. The photocopier room has 1 split aircond unit. The open counter space accommodates 1 staff member with 1 split aircond unit. The open cubicle space accommodates 12 staff with 2 split aircond units. There is a printer in the open cubicle space.
6	P6	Deputy Dean's Office (PTD)	Level 1, Blok A ● ● ● ● ●	Deputy Dean's (Research & Innovation) P.A room has 1 split aircond unit and there is a printer. The prayer room has 1 split aircond unit. The photocopier room has 1 split aircond unit. Pantries have 1 split aircond unit and it is not functioning. The open cubicle space accommodates 8 staff with 2 split aircond units. There is a printer in the open staff room.

Questionnaire/Survey

The questionnaire used in this study was also obtained from ICOP IAQ (2010). This questionnaire is used to identify potential sources of IAQ pollutants. In addition, this questionnaire contains five sections. The first and second sections have questions related to general information as well as the resident's background factors. Next, the third section contains questions about job descriptions such as the resident's position and the duration of time the resident has been working in the building. The questions in the fourth section include environmental conditions that help to identify the source of potential pollutants and the last section includes matters related to the history of the disease, and present and past symptoms.

Apparatus and Instruments

There are several instruments used for indoor air sampling activities in this study as shown in Table 2. All this equipment is calibrated before use.

Indoor Air Quality Sampling

After receiving a complaint related to an IAQ problem from an occupant, an investigation of the IAQ problem is conducted. Walkthrough inspection was done as the first step in this study. This inspection aims to gather fundamental data about the office and factors that could impact the IAQ at the research site. In addition, questionnaires will also be distributed to office residents. The questionnaire helps in the identification of potential sources of IAQ pollutants. After completing the two qualitative methods, the quantitative method is performed, which is sampling activities. Sampling activities are carried out through an intermittent measurement strategy at the four-time slots recommended in ICOP IAQ (2010). In addition, the four time slots are divided evenly between the office's operating hours the first slot is from 8.00 a.m. to 10.00 a.m and the second slot is from 10.00 a.m. to 12.00 noon. The third slot starts from 1.00 p.m to 3.00 p.m and the last slot is from 3.00 p.m to 5.00 p.m.

Table 2: List of equipment for sampling activities

No	Parameter	Device/model name
1	Formaldehyde (CH_2O)	Portable Environmental Sensor's Formaldehyde Meter/PPM Technology
2	Ozone (O_3)	Aeroqual Series 500
3	-Carbon Monoxide (ppm) -Carbon Dioxide (ppm)	TSI 9565
4	Particulate Matter PM10 (mg/m³)	Real Time Direct Reading Particulate Monitor (EVM_3)
5	Total Volatile Organic Compound TVOC (ppm)	MultiRAE Lite monitor, 10,6 PID sensor (TVOC)/RAE System MultiRAE Lite

Chemical Parameters

In this study, a total of 6 chemical parameters were measured in-situ. All readings were read with 3 replicates. All these parameters are measured using direct reading measurement equipment and integrated sampling methods. For the measurement of inhaled particles (PM10), measurements are made using Real-Time Direct Reading Particulate Monitor (EVM3) equipment. While to measure the concentration of carbon monoxide (CO) and carbon dioxide (CO_2), the TSI 9565 tool is used. Portable Environmental Sensor's Formaldehyde Meter/PPM Technology is used to take formaldehyde concentration readings. MultiRAE Lite monitor, 10, 6 PID sensor (TVOC)/RAE System MultiRAE Lite is used for the detection of volatile organic compounds (TVOC) and ozone (O_3) readings using the Aeroqual Series 500 device.

Statistical Analysis

To analyze the data, we employed R software (R Core Team, 2022). We first examined the normality of the data distribution using the Shapiro-Wilk test. If the data followed a normal distribution, we used a one-sample t-test to compare it to a standard value. However, if the data was non-normal, we opted for the Wilcoxon signed rank test to identify significant differences at an alpha level of 0.05. To investigate the variations in sampling locations based on specific factors, we conducted a one-way ANOVA test with a significance threshold of $p<0.05$.

RESULTS AND DISCUSSION

The Shapiro-Wilk normality test was conducted and it was found that the data distribution was not normal. Therefore, the t-test was not conducted and was replaced by the Wilcoxon signed rank test. A one-way ANOVA test was used to find the difference between the investigated parameters and the sampling location at a significance level of $p<0.05$.

Table 3 shows the overall results of chemical parameters (particulate matter (PM10), carbon monoxide (CO), carbon dioxide (CO_2), total volatile organic compounds (TVOC), formaldehyde (CH_2O), and ozone (O_3). From the table, it is observed that all parameters comply with the 2010 ICOP IAQ limit except for the ozone concentration at P6 exceeding the 2010 ICOP IAQ limit (0.05 ppm).

Table 3: Concentration of parameters of chemical pollutants in administrative offices

Sampling location	Parameter (Mean ± SD)					
	PM10	CO	CO_2	TVOC	CH_2O	O_3
P1	0.02 ± 0.01	0.0 ± 0.0	847 ± 67	1.8 ± 0.01	0.96 ± 0.01	0.00 ± 0.00
P2	0.03 ± 0.00	0.0 ± 0.0	787 ± 68	1.2 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
P3	0.02 ± 0.01	0.0 ± 0.0	788 ± 78	0.0 ± 0.0	0.02 ± 0.01	0.02 ± 0.01
P4	0.01 ± 0.01	0.1 ± 0.01	582 ± 104	0.1 ± 0.01	0.05 ± 0.01	0.02 ± 0.01
P5	0.03 ± 0.01	0.3 ± 0.01	684 ± 79	0.1 ± 0.01	0.04 ± 0.01	0.04 ± 0.01
P6	0.02 ± 0.01	0.6 ± 0.01	653 ± 67	0.3 ± 0.01	0.04 ± 0.01	0.06 ± 0.01

CO is a colorless, odorless, tasteless, and non-irritating gaseous pollutant that is present in the environment from natural and anthropogenic sources (Langston *et al.,* 2010). Fig. 1 shows the reading of carbon monoxide (CO) showing an average reading range between (0.0 ± 0.0 ppm -0.6 ± 0.01 ppm) with P6 giving the highest which is (0.6 + 0.01 ppm) while P1, P2, and P3 do not show any readings because the readings are very low and below the detection range of the equipment. All readings at the sampling location comply with the ICOP IAQ 2010 limit (10 ppm). A one-way ANOVA test showed no significant differences were noted. Locations that do not record readings are due to readings taken when the doors and windows of the office are closed, and this causes the office space not to be exposed to outside pollution. In addition, this location is far from sources of CO emissions such as kitchen gas, tobacco smoke, wood-burning furnaces, fireplaces, and other fossil fuel burners produced in the office (Fohimi *et al.,* 2022). In addition, this location is also far from motor vehicles and industrial areas which according to Chowdhury *et al.,* (2013) these two sources are also major contributors to atmospheric CO pollution in urban areas. The CO reading at P6 was the highest reading among the 6 sampling locations. The issue arose from the office windows being open because the AC system in the office was not functioning. Additionally, the building's proximity to the car park and the major road also contributed to the problem.

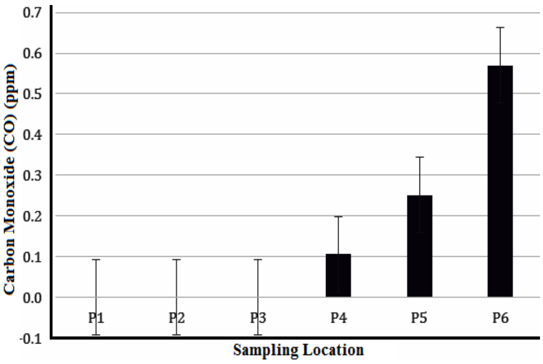

Fig. 1. Average concentration of carbon monoxide (CO) in administrative offices

The same thing was also shown for the CO_2 parameter, which can be seen in Fig. 2, and it was found that all sampling locations recorded an average reading range between (582 ± 104 ppm -847 ± 67 ppm) with P1 giving the highest reading value (847 ± 67 ppm) and P4 gave the lowest reading (582 ± 104 ppm). All readings at the sampling location comply with the ICOP IAQ 2010 limit (1000 ppm). A one-way ANOVA test showed no significant differences were noted. The highest value was caused by the malfunction of the AC system and the cramped staff cubicles in the office, leading to inadequate ventilation and elevated CO_2 levels in that area. However, the actions of residents at the sampling station to install fans can reduce the concentration of CO_2 to maintain the temperature and reduce SBS syndrome in residents. In general, a large number of occupants, the use of solid fuels for domestic heating, and inappropriate ventilation can increase the concentration of CO_2 in buildings. Christina *et al.,* (2022) stated that carbon dioxide gas and water vapor resulting from breathing activities can also be contributors to the increase in CO_2 concentration in the air. His study in the museum room recorded a CO_2 concentration of over 1000 ppm due to the high number of occupants. CO_2 levels are mostly used as indicators of adequate ventilation to maintain occupant comfort levels. High indoor CO_2 levels are directly linked to discomfort levels, and ineffective ventilation systems that will result in dissatisfaction among occupants (Mentese *et al.,* 2012; Syazwan *et al.,* 2009). High levels of CO_2 will cause sleepiness and subsequently lower work productivity and can even cause headaches, dizziness, fatigue, and other symptoms among building occupants.

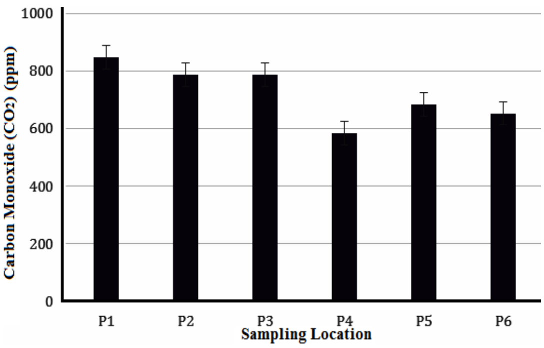

Fig. 2 Average concentration of carbon dioxide (CO_2) in administrative offices

According to Hamzah *et al.,* (2021), pollutants can be categorized into two main types: gases and suspended particulate particles. These particles can exist in either liquid or solid form and are generally small in size, with a diameter of less than 10 micrometers and commonly referred to as particulate matter (WHO, 2018). Inhaled particulate matter typically consists of a mixture of organic and inorganic complex compounds that are suspended in the air. The main components of suspended particulate matter include sulfate, ammonia, nitrate, black carbon, sodium chloride, mineral particles, and water. Fig. 3 shows the average value of the PM10 reading range between (0.01 ± 0.01 ppm – 0.03 ± 0.01 ppm) with P5 giving the highest value (0.03 ± 0.01 ppm) and P4 giving the lowest value (0.01 ± 0.01 ppm). A one-way ANOVA test indicated no statistically significant changes. The results of the study also show that the average value of PM10 at all sampling locations complies with the ICOP IAQ 2010 limit of 0.15 mg/m^3. As stated by the USEPA, indoor PM10 levels are not only influenced by outdoor PM10 levels, but also activities carried out by occupants, indoor sources, as well as the systems applied for filtration and ventilation. Meanwhile, in the absence of cigarettes or other particulate sources, indoor PM10 should be similar to or less than outdoor PM10 levels. In addition, the concentration of PM10 is often associated with the intensity of use of office space where the occupants of P5 are more numerous than P4. Movement from office occupants can cause dust from the floor to fly in the air (Ugranli *et al.,* 2015). Furthermore, the concentration of PM10 can be associated with high-speed air movement at floor level which can cause dust on the floor to fly back into the air and increase the concentration of PM10 in the airspace (Goldasteh Ahmadi & Ferro 2010).

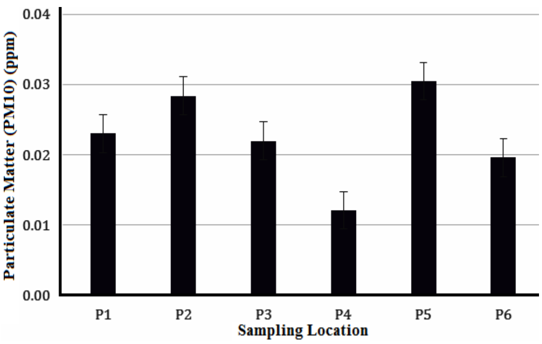

Fig. 3. Average concentration of particulate matter (PM10) in administrative offices

Total volatile organic compounds (TVOC) recorded in this study were below the ICOP IAQ 2010 limit (3 ppm) at all sampling locations. Fig. 4 shows the range of readings between (0.0 ± 0.0 ppm –1.8 ± 0.01 ppm) with P1 giving the highest (1.8 ± 0.01 ppm) and P3 not showing any readings (0.0 ± 0.0 ppm) because the readings are very low and below the range of equipment detection. A one-way ANOVA test showed no significant differences were noted. The high TVOC reading at P1 is due to the presence of a copier working close to the sampling location. Small office spaces, and poor ventilation systems, coupled with malfunctioning air conditioners, have contributed to increased TVOC readings at the sampling location. According to Jiang *et al.,* (2013), most TVOCs are widely used in construction, furniture, textile, carpentry, and chemical industries. However, in offices, TVOC sources often originate from new furniture, paint, air fresheners, and office equipment such as copiers that can release TVOC pollutants into the air (Shamsudin *et al.,* 2020). The study conducted by Wu *et al.,* (2018) revealed that volatile organic compounds (TVOC) are a common type of chemical pollutants found indoors. These compounds include organic acids such as acetic acid and formic acid, as well as aldehydes like acetaldehyde and formaldehyde. It is important to note that formaldehyde and TVOC are known to be highly toxic and carcinogenic indoor air pollutants that can cause respiratory-related illnesses. Among the early symptoms that show the effects of exposure to TVOC are fatigue, dizziness, irregular breathing, and coughing.

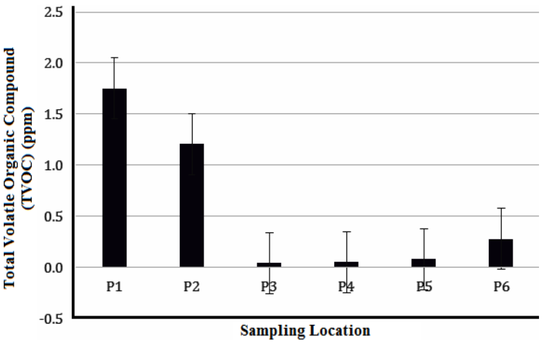

Fig. 4. Average concentration of total volatile organic compounds (TVOC) in administrative offices

Meanwhile, Fig. 5 shows the average formaldehyde concentration reading with a range (0.00 ± 0.00 ppm –0.96 ± 0.01 ppm) with P1 recording the highest reading of 0.96 ± 0.01 ppm and P2 not showing any reading (0.0 ± 0.0 ppm) because the reading very low and is below the detection range of the equipment. All readings at the sampling location complied with the ICOP IAQ 2010 limit (0.10 ppm). A one-way ANOVA test showed no significant differences were noted. According to Hong *et al.,* (2017), the presence of formaldehyde in building materials is the primary cause of indoor air pollution, and it poses a health risk to building occupants. Chronic exposure to elevated levels of formaldehyde indoors can lead to severe respiratory illnesses, asthma, eye irritation, inflammation, headaches, and hyperplastic changes in the nasal mucosa (Lim et al., 2011; Delikhoon *et al.,* 2018; Zhang *et al.,* 2021). Based on the Integrated Risk Information System (IRIS) of the United States Environmental Protection Agency (USEPA), benzene, formaldehyde, and acetaldehyde have been classified as Group A, B1 and B2 carcinogenic substances, which have been identified as substances that have the potential to pose a risk to health.

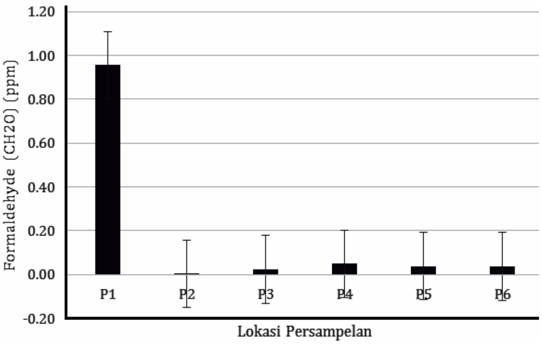

Fig. 5. Average concentration of formaldehyde (CH_2O) in administrative offices

Based on the results of the study obtained, Fig. 6 displays the average O_3 concentration exceeding the ICOP IAQ 2010 limit of 0.05 ppm, falling within the range of 0.00 ± 0.00 ppm to 0.06 ± 0.01 ppm. The highest value of 0.06 ± 0.01 ppm was observed at P6, while P1 and P2 did not register any reading (0.0 ± 0.0 ppm) due to their extremely low levels falling below the equipment's detection range. A one-way ANOVA test showed no significant differences were noted. The location of P6 that got the highest reading is due to high sunlight penetration due to the absence of window protection such as blinds and curtains and close to the copy machine that is actively being used. Ozone is a molecule made up of three oxygen atoms. The basic oxygen molecule required for life is composed of two oxygen atoms. The third oxygen atom can be removed from the ozone molecule, and reattached to the molecule of another substance, and will change its chemical composition and be able to react with other substances (USEPA). Copiers and printers are among the main sources of ozone and TVOC pollutants in the office environment (Salonen *et al.,* 2018; Tran. *et al.,* 2020; Khatri *et al.,* 2013). Ozone released by copying machines can react with other indoor primary pollutants, which will produce more dangerous secondary pollutants (Norgaard *et al.,* 2014).

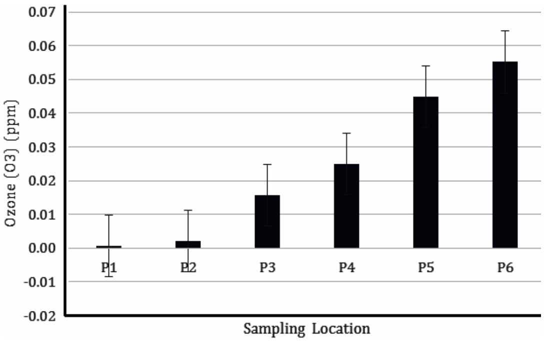

Fig. 6. Average concentration of ozone (O_3) in administrative offices

CONCLUSION

A comprehensive analysis of the data did not uncover any statistically significant variations among the six sampling locations examined. Moreover, all measured chemical parameters were found to be within the acceptable limits set by the Indoor Air Quality (IAQ) guidelines established in 2010. It is crucial to conduct routine IAQ inspections and promptly address complaints from building occupants to ensure compliance with the standards outlined in the ICOP IAQ 2010. This will help create a comfortable, safe, and healthy work environment, ultimately enhancing worker productivity. Related parties should be responsible to ensure that measures are taken to improve IAQ from time to time. In addition, monitoring indoor air quality is also important so that action can be taken quickly against the deterioration of indoor air quality. Finally, as outlined in the ICOP IAQ 2010, it is compulsory to maintain IAQ from the legal point of view.

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Conflict of interest

The author declare that we have no conflict of interest.

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