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An Experimental Study of Indoor Air Pollution in New Office Building

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ABSTRACT

Air pollution is a major environmental risk to health. The new building normally has a facing problem with indoor air pollutant. New construction materials and furniture will contribute higher contaminants compared to old materials. The effect of indoor air pollutants can result in human health problems, discomfort and reduces their productivity. The purpose of this present work is to experimental study the indoor air pollution status regarding carbon dioxide, carbon monoxide, volatile organic compounds, and formaldehyde concentration in an administration office at the new building faculty of mechanical engineering in Johor Bahru, Malaysia. The contaminants concentration values are investigated through field measurements and then compared to the limits stated in the Occupational Safety and Health Act standard. The field measurement of contaminant concentration level was conducted at the intersect plane between the vertical plane at the center of the air conditioning diffuser and the horizontal plane at 1.2 m from the floor. The contaminant concentration readings were taken at 6 locations inside the office. The data were conducted during actual working conditions. The reading of contaminants concentration is taken in 30 minutes. One minute is equal to one number of samples. It was found that only the formaldehyde concentration is exceeding the maximum limit.

1. Introduction

In recent decades, indoor air pollution has been one of the major interesting research subjects due to the fast developments that have been developed. The effects of development have been indirect effects such as indoor air pollution inside the building itself. A considerable amount of literature has been published on indoor air pollution in an office building. These studies indicated indoor air pollutant refers to the air pollutant within and around buildings and structures, especially as it relates to the health and comfort of building occupants. Understanding and controlling common pollutants indoors can help reduce people's risk of indoor health concerns. Health effects from indoor air pollutants may be experienced soon after exposure or possibly years later. It is stated in studies

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conducted on this subject that poor indoor air quality may cause various respiratory diseases, allergic diseases, and cancer [1,2].

Humans spend most of their time indoors, and most of the world's population lives in urban areas and work in an office environment [3]. Therefore, office buildings need to create good indoor air quality performance for occupants because an office environment has a high level of influence on its occupant's productivity [4]. Thus, there is a need to investigate the quality of the indoor workplace environment. This study investigates the contaminant concentration in an office.

There is some pollution in the building that affects indoor air quality. The indoor air distribution system has a major influence on various indoor environmental system parameters such as indoor air quality [5]. The most common indoor air pollutants monitored at the building are particulate matter (PM), formaldehyde, volatile organic compounds (VOCs), carbon dioxide (CO_2), carbon monoxide (CO), airborne bacteria, and mold [6]. A variety of chemicals are used indoors and emitted into indoor air. The main sources of indoor air pollutants are building construction materials and decoration materials, such as carpet, pressed wood, floor coverings, wall paint [7]. Contaminants gave a higher rate in natural aeration compared to when using air conditioner [8]. The governmental, national, and global influential organizations have established guidelines and standards such as ASHRAE 55, DOSH, OSHA, and ICOP to protect the occupants from exposure to airborne contaminants.

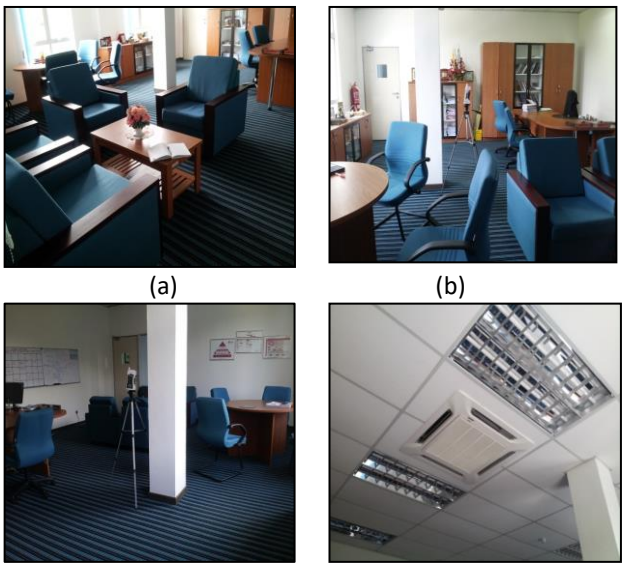
There are two common strategies in building design that is employed to deal with the indoor air quality in a building. The first one found by Daisey *et al.,* [9] with increasing the ventilation rate, that can reduce air pollutants. The second one is by reducing the source of pollution inside and outside the building which in turn reduces the introduction of pollutants in the indoor air. The concentration of pollutants inside the building will vary depending on the number of occupants and load. Several studies have revealed that increasing outdoor air supply rates can improve air quality and reduce the concentration of air pollutants [10].

This article presents findings of an indoor air pollution study conducted on an administration office at the new building Faculty of Mechanical Engineering in Johor Bahru, Malaysia. The goal is to measure the contaminants concentration and level of indoor air pollution inside the building that affects psychological performance as well as health impact to the occupants. It is expected that a good suggestion can be made to improve the indoor air quality performance to create a comfortable working environment for occupants.

2. Methodology

2.1 Description of the office building

The measurements that are presented in this paper were done in an administration office at the new building Faculty of Mechanical Engineering in Johor Bahru, Malaysia. The office, 7.3m (L) × 5.8m (W) × 2.9m (H), is served by two units of ceiling cassette air conditioning that can control the air temperature and velocity. Every unit of ceiling cassette air conditioning has 4 units of 380mm × 90mm rectangular supply air diffuser and one unit of 305mm × 305mm square exhaust air diffuser located at the ceiling. Figure 1 below shows the furnishing configuration and the design of ceiling cassette air conditioning inside the office.



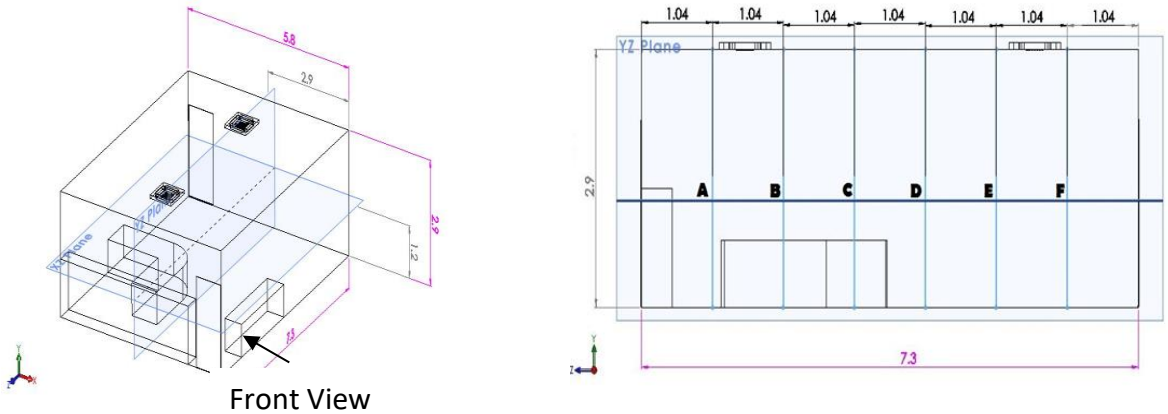
(a) (b)

(c) (d)

Fig. 1. The furnishing configuration and the design of Ceiling Cassette Air-Conditioning in the office a) The view from the main door b) The view from the side and center of the office c) The view from the meeting door d) Ceiling Cassette Air-Conditioning

2.2 Field Measurement and Instrumentation

The following contaminant concentrations were measured inside the office: formaldehyde (CH_2O), carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compound (VOC). Measurements were made at six locations inside the office. The measuring instruments were placed at a height of 1.2m from the floor as indicated in Figure 2 below. The sampling points were placed at the occupant's breathing level which is 1.2 m above floor level. The data were conducted during actual working conditions. The reading of contaminants concentration is taken in 30 minutes. One minute is equal to one number of samples.



Front View

(a) (b)

All dimensions are in meter (m)

Fig. 2. The six-sampling point (A-F) for taking contaminant concentration reading in office a) 3D view b) 2D from a front view

The equipment using during conduct the field measurement is Bacharach's IEQ Chek (IEQ Chek) used to determine the contaminant concentration in the office. The measurement device can measure four species of a contaminant which are formaldehyde (CH_2O), carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compound (VOC). The percentage error of IEQ Chek is ±2% over range. Figure 3 below shows IEQ Chek used to monitor the contaminant concentration in the office.

Fig. 3. Contaminant Concentration Device, IEQ Chek

The contaminants concentration data compared with Occupational Safety and Health Act (OSHA) standard. Table 1 below has shown the maximum limit by OSHA standard.

Table 1
List of indoor air contaminants and the maximum limits by OSHA

Indoor Air Contaminants	Unit (ppm)
Carbon Dioxide (CO_2)	1000
Carbon Monoxide (CO)	10
Formaldehyde (CH_2O)	0.1
Volatile Organic Compound (VOC)	3

3. Results

3.1 Formaldehyde (CH_2O)

The concentration of formaldehyde was conducted by field measurements. Measurements were taken at 6 locations inside the office. Every location consists of 30 samples for formaldehyde concentration measurements. Figure 4 below shows the graph of formaldehyde concentration versus the number of samples for location A until F.

The percentage difference between the maximum value which is location A about 0.24 ppm and the minimum value which is location F about 0.21 ppm not more than 15%. The formaldehyde concentration exceeds the maximum limit of OSHA standard is 0.1 ppm. Formaldehyde is a common pollutant emitted from decoration materials, such as particleboards and wood-based materials [11, 12]. The highest formaldehyde concentration is recorded at Location A about 0.23 ppm until 0.24 ppm. Location A was found to have a high concentration value due to its nearest to furniture made from wood-based material such as tables and cupboards. The occupants standing at 1.2 m from the floor were exposed to a high level of formaldehyde concentration.

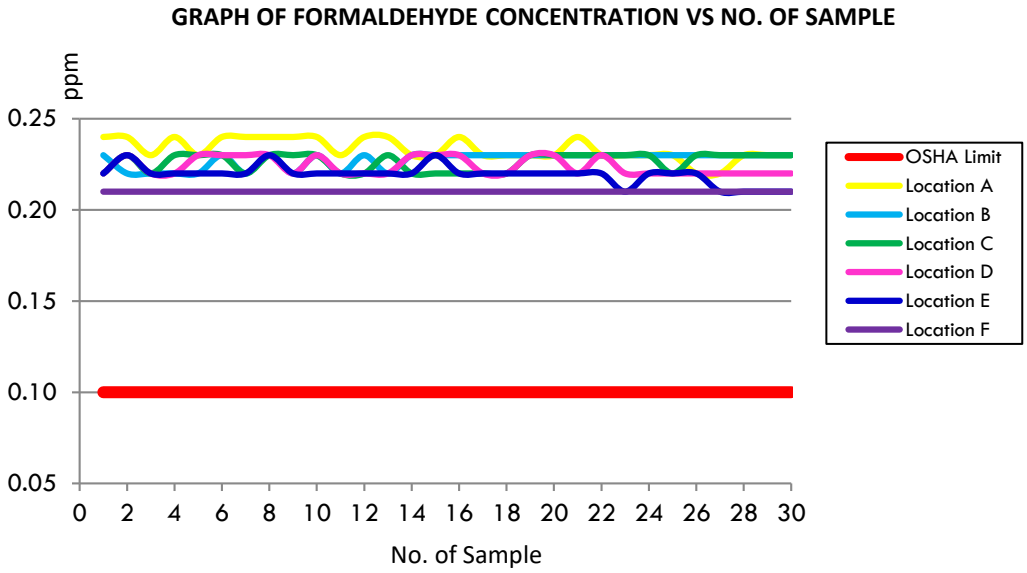


Fig. 4. Graph of formaldehyde concentration versus the number of samples for six sampling points

The indoor air pollution caused by formaldehyde concentration can result in serious respiratory diseases, eye irritation, headache, asthma, as well as in degenerative, inflammatory, and hyperplastic changes of the nasal mucosa [13]. So, the formaldehyde concentrations in an office need to control to achieve good indoor air quality.

3.2 Carbon Dioxide (CO_2)

The concentration of carbon dioxide was conducted by field measurements. Measurements were taken at 6 locations inside the office. Every location consists of 30 samples for carbon dioxide concentration measurements. Measurements of CO_2 concentrations were taken every minute for 30 minutes during working hours. The CO_2 concentration values are considered together with the number of people in the office, and the door and windows are closed.

Normally, the main contributor to the CO_2 concentration was observed due to high occupancy density, use of solid fuel for domestic heating, and/or inappropriate ventilation. CO_2 levels are mostly used as an indicator of adequate ventilation for sustaining the comfort level of the occupants [14]. Levels of indoor CO_2 concentration are assumed to be an indicator of the adequacy of ventilation and/or occupancy and thus elevated indoor CO_2 levels are directly linked with the discomfort level of the occupants, resulting in dissatisfaction [15-18].

Figure 5 below shows the graph of carbon dioxide concentration versus the number of samples for location A until F. The carbon dioxide measurements were taken indicating acceptable conditions. The CO_2 concentration ranged between 680 ppm until 800 ppm for all locations and the percentage difference between the two values is about 20 % during all experimental days while the limit set by Occupational Safety and Health Art for indoor space characterizes satisfactory air quality lower than 1000 ppm. The concentration of CO_2 in the office is influenced by the number of people and the ventilation system. During the measurement was taken only one person was in the office.

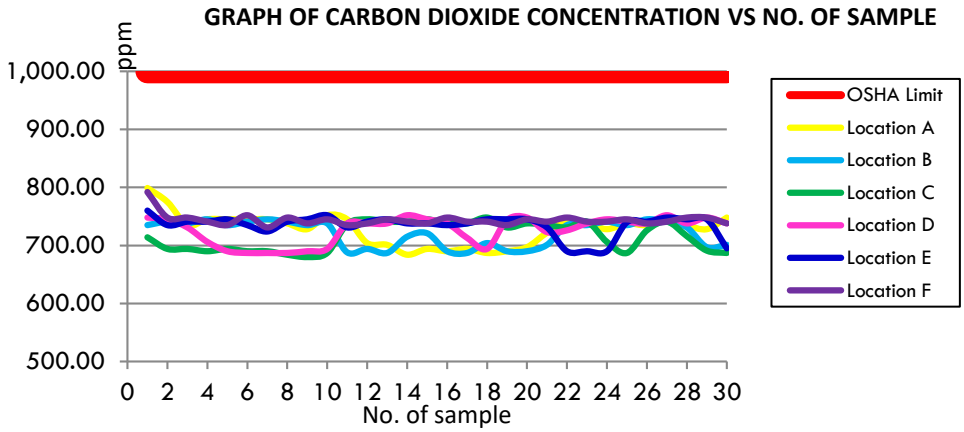


Fig. 5. Graph of carbon dioxide concentration versus the number of samples for six sampling points

Several methods can help to reduce the CO_2 concentration inside an office building. One of the methods prove by Yuefei Hou *et al.,* [19] indicated that natural ventilation by opening windows and doors can bring in adequate air from outdoor and decrease indoor CO_2 concentration to an acceptable level.

3.3 Carbon Monoxide (CO)

The concentration of carbon monoxide was conducted by field measurements. Table 2 below show the result of carbon monoxide concentration versus the number of samples for location A until F. The CO concentration values are considered together with the door and windows are closed. From the measurement data, the CO concentration is 0 ppm for all locations. The carbon monoxide concentration does not exceed the maximum limit of OSHA standard is 10ppm.

CO is a colorless, odorless and tasteless, and non-irritating gaseous pollutant that is emitted into the environment from natural sources and anthropogenic [20]. Motor vehicles and industries are recognized as the main sources of atmospheric CO pollution in urban areas [21].

The reading of carbon monoxide concentration obtained is 0 ppm because the indoor space in the office is not exposed to outdoor pollution. The doors and windows are closed while measurements are being taken. Then in the office, there are no sources of CO emissions such as gas stoves, tobacco smoke, wood-burning furnaces, fireplaces, and other fossil fuel burners.

Table 2
Carbon monoxide concentration versus the number of samples for six sampling points

No. of Sample	OSHA Limit	Location					
		A	B	C	D	E	F
1	10	0	0	0	0	0	0
2	10	0	0	0	0	0	0
3	10	0	0	0	0	0	0
4	10	0	0	0	0	0	0
5	10	0	0	0	0	0	0
6	10	0	0	0	0	0	0
7	10	0	0	0	0	0	0
8	10	0	0	0	0	0	0
9	10	0	0	0	0	0	0
10	10	0	0	0	0	0	0
11	10	0	0	0	0	0	0
12	10	0	0	0	0	0	0
13	10	0	0	0	0	0	0
14	10	0	0	0	0	0	0
15	10	0	0	0	0	0	0
16	10	0	0	0	0	0	0
17	10	0	0	0	0	0	0
18	10	0	0	0	0	0	0
19	10	0	0	0	0	0	0
20	10	0	0	0	0	0	0
21	10	0	0	0	0	0	0
22	10	0	0	0	0	0	0
23	10	0	0	0	0	0	0
24	10	0	0	0	0	0	0
25	10	0	0	0	0	0	0
26	10	0	0	0	0	0	0
27	10	0	0	0	0	0	0
28	10	0	0	0	0	0	0
29	10	0	0	0	0	0	0
30	10	0	0	0	0	0	0

3.4 Volatile Organic Compounds (VOCs)

The concentration of VOCs was conducted by field measurements. Measurements were taken at 6 locations inside the office. Every location consists of 30 samples for formaldehyde concentration measurements. Figure 6 below shows the graph of VOCs concentration versus the number of samples for location A until F. The volatile organic compounds concentration does not exceed the maximum limit of OSHA standard is 3ppm. The maximum value is about 3 ppm at location C which is the nearest between two air supply air conditioning units and the minimum value is about 1 ppm.

One of the major indoor air pollutant groupings is assumed to be volatile organic compounds (VOCs), including a variety of hydrocarbons with different functional groups. Among VOCs, some species have carcinogenic effects, and some are generally used in many consumer products. Variations in environmental parameters such as temperature, humidity, and air exchange rate cause variety in VOCs concentrations [22]. The volatile organic compounds concentration in an office is still under control.

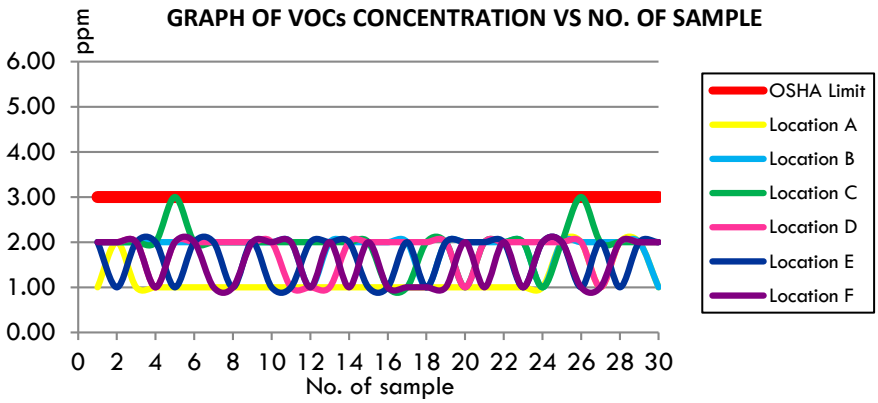


Fig. 6. Graph of volatile organic compounds concentration versus the number of samples for six sampling points

4. Conclusions

The purpose of the current study was to determine the condition administration office is healthy or not. The results showed that there was not much difference in readings between the six locations taken. This is due to the small size of the office room. This paper presented results of contaminants concentration in an office. The results of this investigation show that contaminants concentration in an office through field measurement has been shown only the formaldehyde concentration exceeds the maximum limit by OSHA standard. The results of this study indicate that the new office is not in a healthy condition because the formaldehyde concentration is exceeding the maximum limit by OSHA standard. It is recommended that further research be undertaken in the following areas. Further experimental investigations are needed to control the contaminant concentration and protect occupants in enclosed environments, the study of airflow and contaminant distribution is important.

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