PAPER • **OPEN ACCESS**

Determination of background indoor air pollutants and thermal comfort in faculty of earth science building

To cite this article: N R Awang *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **842** 012003

IOP Conf. Series: Earth and Environmental Science **842** (2021) 012003 doi:10.1088/1755-1315/842/1/012003

Determination of background indoor air pollutants and thermal comfort in faculty of earth science building

N R Awang[1,*], N A N M Radzi[1], T S Yong[1], M A Abas[1], N S Zainordin[2], N A Ramli[3], and N Ibrahim[4]

[1]Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Jeli, Malaysia
[2]Faculty of Forestry and Environment, Universiti Putra Malaysia, 43300, Serdang, Malaysia
[3]School of Civil Engineering, Universiti Sains Malaysia Engineering Campus, 14300, Nibong Tebal, Penang, Malaysia
[4]Department of Civil Engineering, Faculty of Engineering, Science & Technology, Infrastructure University Kuala Lumpur, 43000, Kajang, Malaysia
*Corresponding author: norrimi.a@umk.edu.my

Abstract. The focus of this study was to determine the most significant factors that influencing indoor air quality (IAQ) and thermal comfort of a mechanically ventilated lecturer office room in FSB new building. This study measured the concentrations of ozone (O_3), nitrogen dioxide (NO_2), total volatile organic compound (TVOC), carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM), temperature and relative humidity using seven set up conditions. The set-up condition for study room is based on temperatures that have been selected between 22ºC to 26ºC and window of the room being either close or open. The IAQ were analyzed by descriptive analysis to indicate the parameters variations. Furthermore, thermal comfort for the room of FSB new building has been determine by the CBE thermal comfort tool based on ASHRAE 55 standards. Result suggested that the IAQ of the studied room in FSB new building showed maximum reading during the window was opened condition. The setup of selected temperature air conditioner was minimizing the concentrations of IAQ because IAQ were increase during high temperature. Among of the selected IAQ parameters, particulate matter was the most significant indoor air pollutants in the studied room with the highest average concentration was 20.944 μg/m^3. The increment of particulate matter concentrations was due to the suspended dust in the room and additional movements of the occupants inside the room exaggerate the condition. Besides, results of this study suggested that a good IAQ inside an air conditioning room was achieved when the temperature is set at 26ºC.

1. Introduction

Indoor Air Quality (IAQ) is a common among human being but not well recognized thus people still not consider as a problem. It considered as apodictic cause many people spend most of their lifetime indoor. There were various aspects of the indoor environment affect their health and performance [1, 2]. Various studies elucidated that a human being spends about eighty percent of the life inside the workplace or in the house [3] Furthermore, the health risk cause by the exposure towards indoor pollution is more dangerous than outdoor air pollution [1]. The polluted indoor environment enhanced the chances of long-term and short-term health issues and degraded the environment and reduced the comfort productivity. Health issues were related to building disease and sick building syndrome (SBS). SBS is a clinical symptom with no identified their causes. The existence of SBS because of mucosal, skin, and general symptoms that related to working building such as the age of building, the flow rate of outdoor air, issues from dampness management, the presence of photocopiers or humidifiers and the lack of cleaning management. There are causes of indoor air pollution which the combination of physical, chemical, and biological factors effect. Besides, the acceptable of ventilation in the environment is one of the causes of Indoor Air Pollution [4].

Indoor Air Pollutant (IAP) is any pollutants from things such as gases and particles contaminate the indoor environment. The effect of smoke's cigarette, store and operational oven, particle board, cement and emissions from other building materials were frequently the most significant determine of IAQ. The common IAQ parameters are carbon dioxide, temperature, relative humidity, formaldehyde, particulate matter, total bacteria, and primary air pollutants such as sulphur dioxide, nitric oxide, and nitrogen dioxide [4]. Furthermore, the important factor that affecting indoor air quality which is the ways of building to be heated, ventilated, and air-conditioned which also main factors for indoor thermal comfort. Thermal comfort was an acceptable standard of indoor climates which need to consider every factors related to indoor air environment. Thermal comfort standards required to help building systems provide an indoor environment that comfortably towards building occupants.

The main aim of this study was to determine the indoor air pollutants concentrations in an unoccupied lecturer office room in FSB new building during seven predetermined room set-ups based on the room windows which either been opened or closed and the temperature of its mechanical ventilation. Result of this study will provide the information about the status of IAQ of the studied room. In addition, this study would also determine the best conditions among the predetermined set-up conditions based on ASHRAE 55: Thermal Environmental Conditions for Human Occupancy Standard.

2. Material and Method

2.1. Study Area

The study area for this study was in the FSB new building in Universiti Malaysia Kelantan Jeli Campus (UMK) with the coordinates of 5°44'44.7"N 101°52'08.1"E. Universiti Malaysia Kelantan Jeli Campus was in Jeli, Kelantan. Data was monitored at the new building of FSB which prior the usage of the building. The building fully depends on mechanical ventilation which is an air conditioner system.

2.2. Data Collection

The setup conditions of indoor monitoring of an unoccupied lecturer office rom in the FSB new building were regulated based on room temperature. Five different conditions tested based on either the window was open and closed, and mechanical ventilation were used in the room with the set-up temperature in between 22ºC to 26ºC. The IAQ parameters that were observed are ozone, nitrogen dioxide, total volatile organic compound, carbon dioxide, carbon monoxide, temperature, particulate matter, relative humidity. The Wolf Sense Indoor Air Quality apparatus was used to obtain parameters of ozone (O_3), nitrogen dioxide (NO_2), total volatile organic compound (VOC), carbon dioxide (CO_2), carbon monoxide (CO), temperature (T), and relative humidity (RH). Meanwhile, the measurement of particulate matter was used the Casella Microdust Pro. The monitoring periods was in between 8 a.m. to 6 p.m. incline with the normal periods when the room will be occupied. The monitoring equipment were placed at one meter high above the room floor in the middle of the room to ensure representativeness of the monitored data. Each set up conditions were monitored for two days and calculated for average values.

2.3. Data Analysis

The data obtained was analysed by statistical analysis for pattern identification and visualization using descriptive statistics. Meanwhile, the CBE Thermal Comfort ASHRAE 55 Standards using Predictive Mean Votes (PMV) model was used to determine thermal comfort in the studied room. The main aim to test the compliances of the standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to most of the occupants within the space/room. The compliances of ASHRAE 55 Standard during the set-up conditions was calculated using CBE Thermal Comforts Tool (https://comfort.cbe.berkeley.edu/) developed by University of California, Berkeley. The level of thermal comfort for each condition were calculated based on monitored studied room air temperature, mean radiant temperature, air velocity, relative humidity. Other than that, the model also considered the occupants activity rate and clothing insulation in its calculation of thermal comfort.

3. Results and Discussion

The average value of IAQ and thermal comforts parameters that were monitored in studied room during different conditions were shown in Table 1. Result suggested there were variations among the IAQ parameters during different conditions set up. Indoor O_3 showed the highest concentrations once the window is open with 0.027 ppm compared to when window is closed. This is because the concentrations of O_3 in window close condition are limited due decreased in photochemical reactions [5] as the reaction require sunlight to be completed [6].

Table 1. Descriptive statistic of indoor air quality parameters of unoccupied lecturer room in FSB New Building

Conditions	O_3 (ppm)	NO_2 (ppm)	TVOC (ppm)	CO_2 (ppm)	CO (ppm)	PM (μg/m^3)	T (°C)	RH (%)
Window Closed	0.000	0.042	0.360	355.840	1.316	20.944	29.633	64.200
Window Opened	0.027	0.047	0.228	487.406	1.225	20.027	30.449	59.826
Temperature 22°C	0.003	0.060	0.248	355.840	0.312	19.567	23.085	46.302
Temperature 23°C	0.001	0.062	0.188	356.040	0.068	20.027	24.000	48.900
Temperature 24°C	0.001	0.063	0.203	346.537	0.067	18.672	23.034	50.307
Temperature 25°C	0.001	0.061	0.188	345.664	0.235	18.857	23.118	51.795
Temperature 26°C	0.001	0.061	0.174	378.808	0.236	18.980	25.017	50.082

On contrary, NO_2 concentrations showed high concentration in air conditioning conditions with the highest concentration was recorded when temperature set to be 24°C. TVOC concentrations is highest during closed window concentration with 0.360 ppm and the usage of air conditioning seem to be capable to reduce its concentration to around 0.06 ppm as it is know that the high temperature of indoor has ability to add indoor exposure to TVOC [7]. The outdoor intrusion was identified as the main influenced of indoor CO_2 as the result showed that CO_2 concentrations during opened window is 487.406 ppm which around 100 ppm higher compared to other set-up conditions. Unlike CO_2, CO is significantly higher during closed window compared to opened window even study by Chithra & Shiva Nagendra [8] reported the indoor CO concentrations were found to be influenced by concentrations of ambient particles air which were emitted by traffic vehicle. Nevertheless, air conditioning conditions were able to control indoor CO at low concentration around 0.068 to 0.312 ppm. Similar trend was also depicted for indoor PM concentrations as lowest PM concentrations (18.672 μg/m^3) were recorded once temperature is set at 24°C. The indoor PM concentrations were varied significantly with occupants' activities [8] such as walking, sweeping or dusting which might induced turbulence and caused PM to be resuspension. Results suggested that temperature and relative humidity reflect the room conditions when high temperature with 30.449°C were observed once the window was opened and the room temperature were regulated according to the set-up temperature.

The thermal comfort parameters were monitored to FSB new building and the assessment of the complied ASHRAE 55 Standard determined by using CBE Thermal Comfort Tool which has been detail in section 2.3. Thermal comfort compliance results can be used as an indicator to test the compliances of the standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to most of the occupants within the space/room. Table 2 shows the summary of thermal comfort compliance in studied room the results suggested that the most satisfying condition that complies with the thermal comfort ASHRAE 55 standard was setup of temperature 26˚C. Meanwhile, the setup of window closed shows the result of not complies with ASHRAE 55 standard from 8:00 a.m. to 17:00 p.m. due to closed space without any ventilations. Furthermore, the setup of opened window shows that on 8:00 am until 10:00 am the condition was complies with ASHRAE 55 standard but after time increment to the noon the conditions become not complies. The condition was slightly warm and to the evening the condition becomes warm. This condition is not satisfying the thermal comfort of ASHRAE 55 standard. The setups of temperature at 22°C, 23°C, 24°C and 26˚C have shown similar result which in earlier operational the conditions were complies with ASHRAE 55 standard but when time increment the conditions turn to cool and not complies the ASHRAE 55 standard.

Table 2. Summary of thermal comfort compliance in FSB new building

Hour / Conditions	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Window Closed	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb
Window Opened	C	C	NCc	NCc	NCd	NCd	NCd	NCd	NCd
Temperature 22°C	C	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb
Temperature 23°C	C	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb
Temperature 24°C	C	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb
Temperature 25°C	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb	NCb
Temperature 26°C	C	C	C	C	C	C	C	C	C

*Note: C is comply; NCa is cool; NCb is slightly cool; NCc is slightly warm; NCd is warm

4. Conclusion

This study determined the indoor air quality (IAQ) parameters and thermal comfort of an unoccupied lecturer room in FSB new building using different conditions which window closed or opened and temperature set up at 22˚C, 23˚C, 24˚C, 25˚C and 26˚C. The highest mean concentration of O_3, NO_2, TVOC, CO_2, CO, temperature, and relative humidity which are 0.027 ppm (window closed), 0.063 ppm (24ºC), 0.360 ppm (window closed), 487.406 ppm (window opened), 1.316 ppm (window closed), 20.944 mg/m^3 (window closed), 30.449ºC (window opened) and 64.20%, respectively. The maximum mean values seem to be achieved during either closed or opened window conditions according to different IAQ parameters. However, result showed that IAQ is much controlled in air conditioning system as the condition of the room is controlled by mechanical ventilation. In addition, result suggested the best conditions of thermal comfort to satisfy thermal environmental conditions acceptable to most of the occupants within the lecturer room was by using of air condition system at temperature of 26˚C.

Acknowledgement

The authors would like to thank the Universiti Malaysia Kelantan thanks Universiti Malaysia Kelantan for providing the best facilities for this research and Clean Air Research Group, Universiti Sains Malaysia for lend the monitoring equipments. The publication of this paper is funded by Rinsing Start Grant Scheme (R/STAR/A0800/01525A/003/2020/00793).

References

[1] Kamaruzzaman S N, Egbu C O, Zawawi E M A, Ali A S and Che-Ani A I 2011 The effect of indoor environmental quality on occupants' perception of performance: A case study of refurbished historic buildings in Malaysia, *Energy and Buildings*, **43** (2–3) 407–413.

[2] Sansaniwal S K, Mathur J and Mathur S 2020 Review of practices for human thermal comfort in buildings: present and future perspectives, *International Journal of Ambient Energy* 1-27.
[3] Norhidayah A, Lee C K, Azhar M K and Nurulwahida S 2013 Indoor air quality and sick building syndrome in three selected buildings, *Procedia Engineering*, **53** 93–98.
[4] Lee S and Chang M 2000 Indoor and outdoor air quality investigation at schools in Hong Kong, *Chemosphere*, **41**(1) 109–113.
[5] Awang N R, Elbayoumi M, Ramli, N A and Yahaya, A S 2016 The influence of spatial variability of Critical Conversion Point (CCP) in production of ground level ozone in the context of tropical climate, *Aerosol and Air Quality Research*, **16**(1) 153-165.
[6] Awang N R, Ramli N A, Shith S, Yusof N F F M, Zainordin N S, Sansuddin N and Ghazali N A 2018 Time effects of high particulate events on the critical conversion point of ground-level ozone, *Atmospheric Environment*, **187** 328-334.
[7] Tao H, Fan Y, Li X, Zhang Z and Hou W 2015 Xi'an, China: concentrations investigation of formaldehyde and TVOC in underground malls in, sources, and affecting factors, *Building and Environment*, **85** 85–93.
[8] Chithra V S and Shiva Nagendra S M 2012 Indoor air quality investigations in a naturally ventilated school building located close to an urban roadway in Chennai, India, *Building and Environment*, **54** 159–167.