© Universiti Tun Hussein Onn Malaysia Publisher's Office

JAESRR

http://publisher.uthm.edu.my/ojs/index.php/jaesrr

e-ISSN : 2821-2819

Journal of Advancement in Environmental Solution and Resource Recovery

The Measurement of PM_{10} and $PM_{2.5}$ Concentration for Outdoor and Indoor Surrounding Industrial Area

Nurhidayah Hamzah[1], Nor Amani Filzah Mohd Kamil[2,3*], Nurul Syafiqah Maznan[3]

[1]School of Civil Engineering, Faculty of Engineering,
Universiti Teknologi MARA, Shah Alam, 40450, MALAYSIA

[2]Micropollutant Research Centre,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

[3]Department of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jaesrr.2021.01.01.002
Received 11 October 2021; Accepted 01 December 2021; Available online 07 December 2021

Abstract: The industrial area located adjacent to UTHM main campus releases air pollutants to the surrounding area. In addition, high complaints were received from UTHM's residents and surrounding area due to air pollution from the industrial area. The main objective of this study is to measure PM_{10} and $PM_{2.5}$ concentration for indoor and outdoor building in UTHM main campus and surrounding industrial area in Parit Raja, Batu Pahat, Johor. Air sampling was conducted to determine the indoor and outdoor concentrations of PM_{10} and $PM_{2.5}$. The highest concentration (40.8 ug/m^3 and 29.1 ug/m^3 for PM_{10} and $PM_{2.5}$, respectively) was at Tun Dr Ismail Residential College for outdoor concentration. Whereas, Bestari Residential College shows the lowest concentration (14.2 ug/m^3 and 10 ug/m^3 for PM_{10} and $PM_{2.5}$, respectively). Results from this study found that outdoor air pollution did not affect the indoor air pollution. For further improvement, the number of sampling stations need to be increased especially high-rise buildings in UTHM main campus

Keywords: Particulate matter, indoor air quality, outdoor air quality, type of window

1. Introduction

In these modern days, air pollution is an unseen and deadly killer to humans. It can affect human health, cause disease and death. Roughly 7 million people died in 2012 and this is 1/8 of total global deaths due to exposure to air pollutants [1]. This result increases initial estimates and recognizes that air pollution is now the highest single threat to environmental health in the world. Thus, by reducing air pollution, millions of lives can be saved.

Air pollutants can be classified as gaseous or particulate matter which contains suspensions of very small liquid or solid particles. Sulfate, ammonia, nitrates, black carbon, sodium chloride, mineral particles, and water are the main components of particulate matter [2], which focus in this study. This particulate matter consists of a

*Corresponding author: noramani@uthm.edu.my

complex mixture of inorganic and organic compounds suspended in the air with solid and liquid particles [2]. These particles pollution includes PM_{10} the breathable particles whereas the diameters are generally 10 micrometers and smaller.

Thus, this study was conducted to investigating on particulate matter indoor and outdoor building and assesses the significance of building characteristics which may contribute the levels of particle pollution inside buildings in surrounding industrial area in Parit Raja, Batu Pahat, Johor.

University Tun Hussein Onn Malaysia (UTHM) is an educational institution located in Parit Raja, Batu Pahat, Johor. Next to UTHM is an industrial area, which located nine factories. This factory produces fiber-board which release unpleasant smoke to the surrounding community especially to UTHM residents. In addition, the smoke emission from the factory is very active especially at night. Heavy vehicle movement such as trucks and trailers are also affected on air pollution because of the dusty condition when these big vehicles come and go from the factories.

There are numerous complaints from surrounding residents on air pollution caused by the industrial area but the factory is still operating at the same level of capacity every day. This industrial area has resulted in the reduction of air quality in Parit Raja as well as affecting the health of UTHM residents and the surrounding community. This air quality reduction gives health adverse impact on surrounding residents such as skin problem, pain in the nose and throat, migraine, dizziness and tiredness [3]. Most of the time, UTHM residents spend their time with indoor activities. Building characteristics play an important role in influencing environmental threat exposures such as air pollution. Indoor air pollution rates may be as high as those present outdoors or even higher for some contaminants.

Many studies were conducted on indoor and outdoor air pollution. Most of studies just measure air quality indoor and outdoor, very limited conduct studies to measure particulate matter concentration indoor and outdoor that related with the building characteristics. Table 1 show the previous study of indoor and outdoor air pollution.

Table 1 - The previous study of indoor and outdoor air pollution

Author	Location	Objectives	Findings
[4]	Krakow, Poland	Investigate the correlation between concentrations of PM_{10} and $PM_{2.5}$ outdoors and indoors, and evaluates the significance of factors which influence levels of particle pollution inside house.	Increase of outdoor concentrations was accompanied by an increase of indoor concentrations
[5]	Hong Kong	Recognize the key factors affecting the indoor air quality	Indoor air quality depends on the contribution of both the indoor and outdoor environments.
[6]	Los Angeles and Beijing	Evaluate impacts of outdoor ventilation flow rates and filter efficiencies on indoor concentrations of $PM_{2.5}$ and ozone for office buildings in two mega-cities	For office buildings located in polluted cities, two-filter system was more resilient to outdoor $PM_{2.5}$ than the single filter system. The two-filter system is more effective for outdoor particle control.
[7]	Bhutan, South Asia	Measure concentrations of $PM_{2.5}$, PN and CO during cooking and heating in rural area.	High concentrations of pollutants detected when stoves were operated. Emission rates from biomass stoves significantly higher than gas and electric stoves

2. Materials and Methods

2.1 Sampling Location Selection

The average concentration of PM_{10} and $PM_{2.5}$ were recorded every 30 minutes for each sampling location from 10 am until 6 pm. Air sampling was carried out at ground level for outdoor and indoor of building.

The selected locations for the air sampling work were buildings in UTHM main campus and residential area which surrounding the industrial area in Parit Raja, Batu Pahat, Johor. There are five sampling stations that were selected for air sampling. In UTHM campus, Tun Dr Ismail residential college was selected as sampling locations. Whereas Bestari residential college, Taman Universiti, Taman Melewar and Parit Hj. Rais village were selected as samping locations which represented residential area surrounding industrial area in Parit Raja. These locations were selected based on the distance from emission sources as shown in Fig.1.

Fig. 1 - Location for sampling data

2.2 Measurement of PM_{10}, $PM_{2.5}$ and Meteorological Data

The concentration of PM_{10} and $PM_{2.5}$ was measured in unit microgram per meter cube ($\mu g/m^3$) at selected sampling locations by using Temtop Airing 1000 Detector System. The selection of devices was based on their on-site role and application which is easy to bring and measure. The device had been calibrated for data accuracy and quality control by the manufacturer. Moreover, data was compared with E-sampler and PM_{10} and $PM_{2.5}$ concentration error was less than 5%.

The wind direction and speed was recorded by using 100M Professional Weather Station. The wind direction and speed was recorded due to these factors affected the PM_{10} and $PM_{2.5}$ concentration as it blown away the air pollutants towards each location that were selected in this study. The sampling of meteorological data was conducted in every 30 minutes for 8 hour similar to measurement of PM_{10} and $PM_{2.5}$concentration.

2.3 Data Analysis

The relation of indoor and outdoor concentration was analyzed by using Microsoft Excel. The linear trend was developed based on indoor and outdoor PM_{10} and $PM_{2.5}$ concentration. The relation of indoor and outdoor air quality was based on value of R^2.

3. Results and Discussion

3.1 Measurement of Indoor and Outdoor PM_{10} and $PM_{2.5}$ Concentration

Fig. 2 shows the indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Tun Dr Ismail Residential College. This chart shows that the outdoor concentration starts to rise up from 17.4 ug/m^3 to 40.8 ug/m^3 between 5.00 pm to 6.00 pm for PM_{10}. This increasing may be due to the wind speed at that time was 2.6m/s and wind direction was heading from the industrial area to Tun Dr Ismail Residential College. Indoor concentration of PM_{10} was measured lower compared to the outdoor, which the lower concentration was between 9.4ug/m^3 – 10.9ug/m^3. For $PM_{2.5}$, the outcome reveals that the highest concentration for outdoor occur in evening which the concentration was increased from 8.9 ug/m^3 to 29.1ug/m^3 which occurred between 3.00 pm to 6.00 pm. On the other hand, during that time the concentration for indoor is lower compared to outdoor between 7.7 ug/m^3 to 7.9 ug/m^3.

Fig. 3(a) shows the x-axis and y-axis for indoor and outdoor concentration of PM10 and PM2.5 at Tun Dr Ismail Residential College, respectively. It is a positive relationship and weakly correlated with the regression analysis value for this graph is 0.7. Therefore, the outdoor air did affect the indoor air quality. The types of window was casement window as shown in Fig. 3(b). This window act as a good ventilation since the opening of the window is wide whereas it allows the light and air into the building. Other than that, casement window is a fixed panel window thus when the window is closed, the window pushes to the frame and construct an air tight seal preventing leaks. Based on interview, resident always open the window during day. Thus, the concentration was almost similar for indoor and outdoor. After 5 pm, residents start to close windown and indoor concentration was maintain. However, outdoor concentration start to increase.

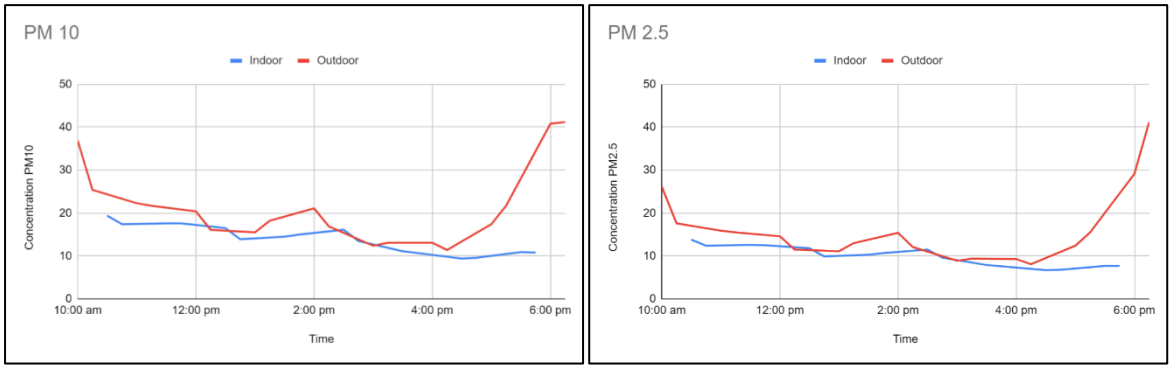
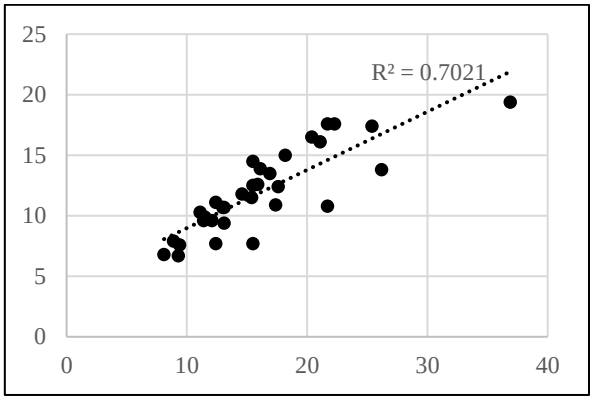


Fig. 2 - Indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Tun Dr Ismail Residential College

a



b

Fig. 3 - Outdoor vs indoor concentration and casement window at Tun Dr Ismail Residential College

Fig. 4 shows the concentration of PM_{10} and $PM_{2.5}$ at Taman Universiti Apartment. At 1.30 pm, the highest concentration of PM_{10} was recorded, which was 18.4 ug/m^3. Then, the concentration was decreased and started to increased again at 5.00pm from 12.7 ug/m^3 to 14.2 ug/m^3. For $PM_{2.5}$, the outdoor concentration slightly increased at 10.00am (7.2ug/m^3) compared to the indoor concentration (6.7ug/m^3). The outdoor concentration for $PM_{2.5}$ was increased between 1 pm to 2.00 pm (11.5 to 13.4 ug/m^3) due to smoke emissions from the nearby factory. In addition, the high concentration due to low wind speed at that hour 5.3 m/s.

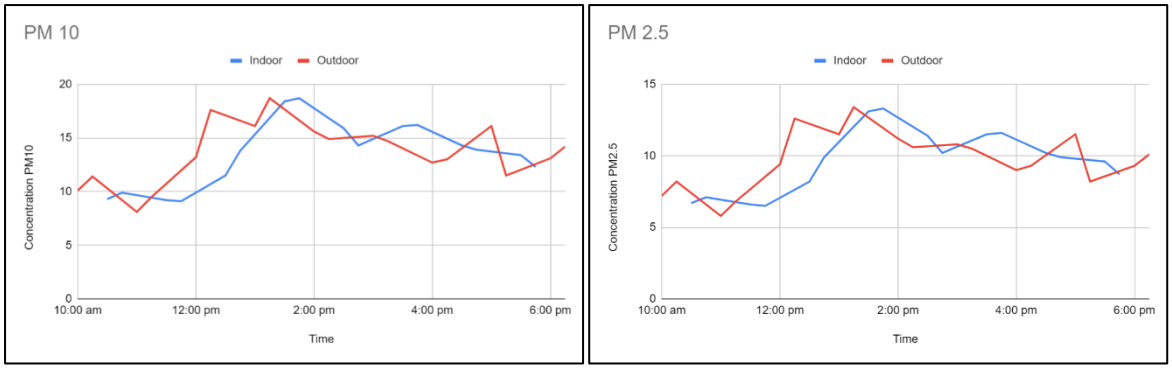
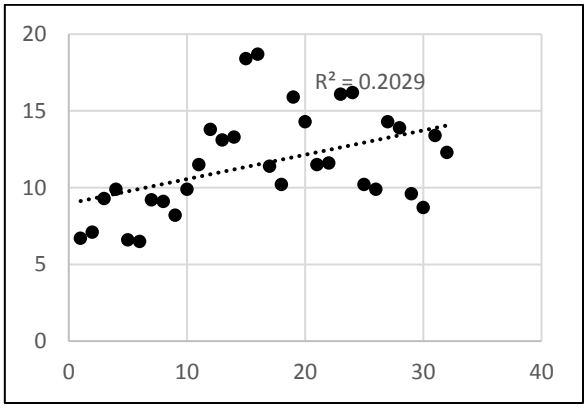


Fig. 4 - Indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Taman Universiti Apartment

Fig. 5(a) shows the x-axis and y-axis for outdoor and indoor concentration of PM_{10} and $PM_{2.5}$, respectively. It is a positive linear relationship but not correlated with the regression analysis value for this graph is 0.2. Therefore, the outdoor air did not affect the indoor air quality which maybe depends on the types of window. Types of window found in the apartment at Taman Universiti is three panel sliders [Fig. 5(b)]. This apartment has only 4 windows in each room and a kitchen. The living room in this apartment did not had windows and this causes poor ventilation in the house. Besides that, three panel sliders window did not seal tightly like casement window. As a result, the reading for both particulate matters did not give any significant result.

a



b

Fig. 5 - Outdoor vs indoor concentration and three panel slider at Taman Universiti Apartment

Fig. 6 shows the concentration of PM_{10} and $PM_{2.5}$ at Bestari Residential College. Based on the figure, PM_{10} outdoor concentration was increased from 9.4 ug/m^3 at 3.00 pm until 10.7 ug/m^3 at 6.00 pm. PM_{10} indoor concentration was highest at 12.30 pm (14.2 ug/m^3) and decreased at 1.30pm (7.6 ug/m^3). The $PM_{2.5}$ indoor concentration was increased at 12.30 pm (10 ug/m^3) and decreased with rate of 5.4 ug/m^3 at 1.30 pm. Different from the outdoor concentration, whereas it started to increase at 3.00 pm (6.7 ug/m^3) and head to the top at 6.00 pm (7.7 ug/m^3).

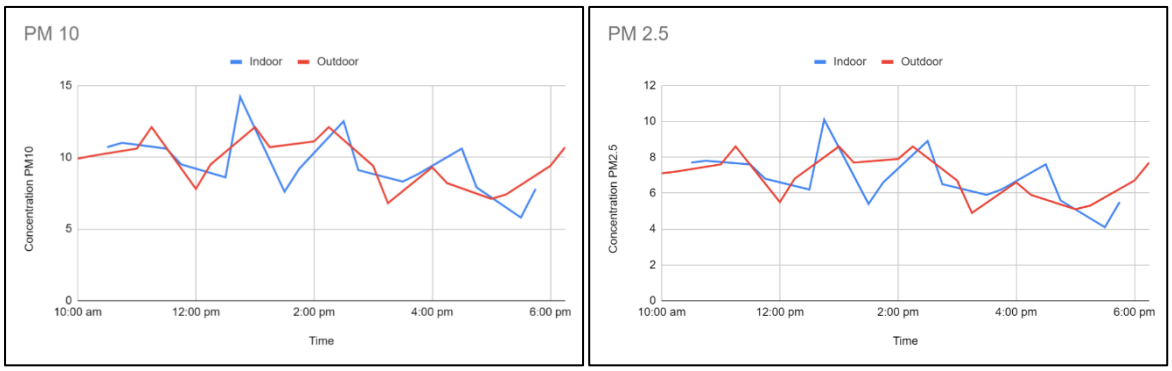
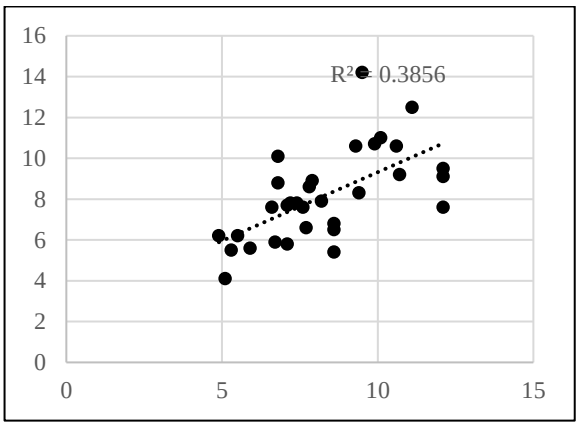


Fig. 6 - Indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Bestari Residential College

Fig. 7(a) shows the x-axis and y-axis for outdoor and indoor concentration of PM_{10} and $PM_{2.5}$, respectively. It is a positive linear relationship but very poor correlated with the regression analysis value for this graph is 0.3. Therefore, the outdoor air did not affect the indoor air quality which maybe depends on the types of window. Bestari Residential College have the same types of windows as Tun Dr Ismail Residential College which is casement window [Fig. 7(b)]. Even though, the type of window for both were similar, R^2 value for Bestari Residential College was much lower compare to Tun Dr Ismail Residential College. This study focus on design of window to evaluate the difference of outdoor and indoor concentration. From finding in this study, there were other factors that may influence the relation of outdoor and indoor concentration.

The line graph illustrates the results for PM_{10} and $PM_{2.5}$ concentration at Taman Melewar (was shown in Fig. 8). For $PM_{10,}$ the outdoor concentration was increased at 10.00am (16.9 ug/m^3) and head to the top at 11.00 am (26.6 ug/m^3). Then, the indoor concentration also hit the highest reading at 11.30 am (23.9 ug/m^3). Indoor air concentration was increased at that time due to the resident was cooking during air sampling. Next, the concentration of PM_{10} was consisten before it started to rise up at 4.30pm (10.6 ug/m^3) until 15.6 ug/m^3 at 6.00pm. For $PM_{2.5}$, the outdoor concentration was increased at 10.00 am (12.1 ug/m^3) and head to the top at 11.00 am (19 ug/m^3). Then, the indoor concentration also hit the highest reading at 11.30 am (17 ug/m^3). It happens due to the resident is cooking during air sampling. Next, the reading of the particulate matter consistency low before it started to rise up at 4.30 pm (9.6 ug/m^3) until 11.1 ug/m^3 at 6.00 pm.

a



b

Fig. 7 - Outdoor vs indoor concentration and casement window at Bestari Residential College

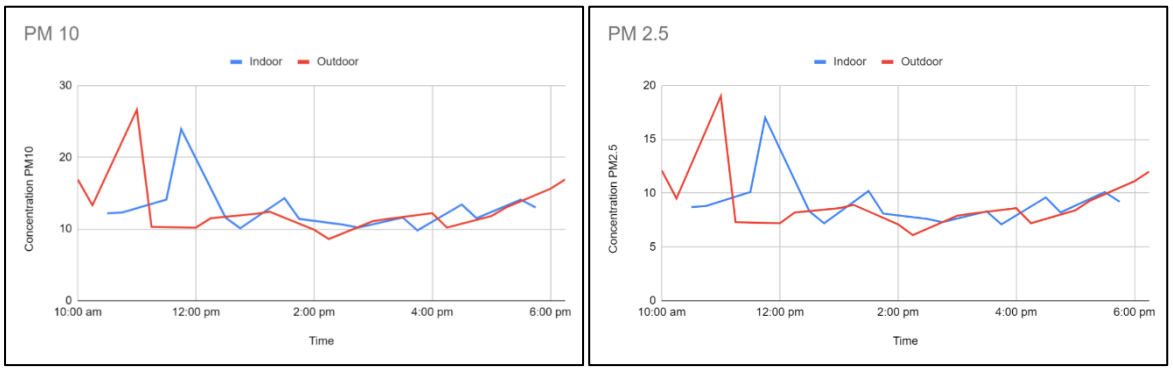
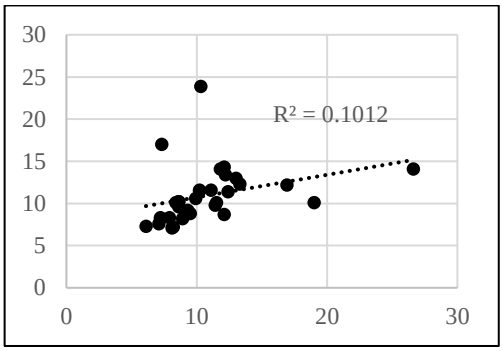


Fig. 8 - Indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Taman Melewar

Fig. 9 shows the x-axis and y-axis for outdoor and indoor concentration of PM_{10} and $PM_{2.5}$, respectively. It is a positive linear relationship and weakly correlated with the regression analysis value for this graph is 0.1. Therefore, the outdoor air did not affect the indoor air quality which maybe depends on the types of window. The design of the house in Taman Melewar is a single storey house. The houses use the casement windows and three panel sliding door. Taman Melewar, Tun Dr Ismail Residential College and Bestari Residential College share the same types of window. Yet, the plot center graph for Taman Melewar weakly correlated. Probably due to types of building which is residential college is a high-rise building while Taman Melewar is a landed house. Other than that, the house in Taman Melewar had both types of windows and door which is good in term of

ventilation. However, based on interview with the residents, both windows and door were always closed. Thus, this affect the correlation between outdoor and indoor concentration.

a



b

Fig 9 - Outdoor vs indoor concentration and casement window at Taman Melewar

Fig. 10 shows the indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Parit Haji Rais between 10.00 am and 6.00 pm. According to the figure, the levels of both indoor and outdoor formed a similar pattern during the same period. The indoor PM_{10} concentration was highest at 11.30am (39.3 ug/m^3) and decreased at 1.30 pm (15.3 ug/m^3). For the outdoor concentrations, at the same time as indoor, the readings at 11.30 am shows the highest concentration (36.8 ug/m^3) and reduced until 1pm (17.6 ug/m^3). After that, the result continues lower before it started to increase at 3.00pm (13.7 ug/m^3) till 6.00pm (17.6 ug/m^3). For $PM_{2.5,}$ based on the figure, the indoor concentrations was increased from 11.30 am (28.1 ug/m^3) and decreased at 1.30 pm (10.9 ug/m^3). For the outdoor concentrations, at the same time as indoor, the readings at 11.30 am increased (26.1 ug/m^3) and fall to the bottom at 1 pm (13.9 ug/m^3). Based on the result during that hour, the release of emission was due to the nearby villagers open burning of garbage. After that, the result continues low before it started to increase at 3.00pm (6.1 ug/m^3) till 6.00 pm (12.5 ug/m^3).

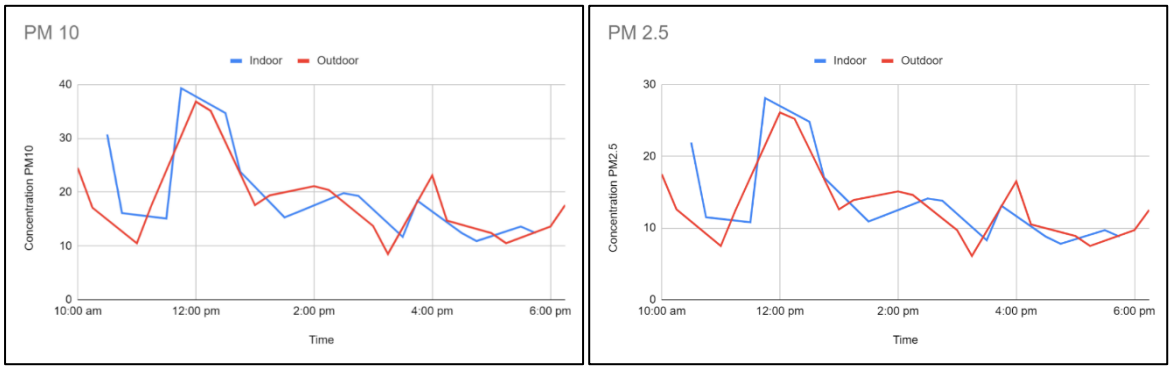
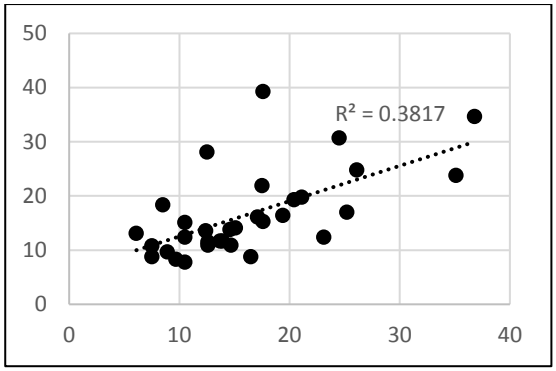


Fig. 10 - Indoor and outdoor concentration of PM_{10} and $PM_{2.5}$ at Parit Haji Rais

Fig. 11(a) shows the x-axis and y-axis for outdoor and indoor concentration of PM_{10} and $PM_{2.5}$, respectively. It is a positive linear relationship and weakly correlated with the regression analysis value for this graph is 0.4. Therefore, the outdoor air did not affect the indoor air quality which maybe depends on the types of window. Generally, a village house mostly used jalousie window with the airhole at the top of the window [Fig.11(b)]. This design provide a good ventilation and maintaining good airflow. Besides that, this window preventing rain from entering the house even when the slats are open for the air and light enter the house.

a



b

Fig. 11 - Outdoor vs indoor concentration and jalousie window at Parit Haji Rais

Air sampling that was carried out at ground level for outdoor and indoor, each location gave different outdoor concentration of PM_{10} and $PM_{2.5}$ due to the distance of each location from emission sources was different. Besides, wind speed and direction also give an effect to the result. Based on industrial production, the release of emission was constant for all times. There was no different between day and night. In addition, the result shows that the concentration start to rise up at 5.00 pm and above. This condition maybe due to meteorological factor, which temperature at night is relatively lower compare to at day. When the temperature is low, the humidity is high, which is the disadvantages for the air flow and diffusion [8].

3.2 Relation of Indoor and Outdoor PM_{10} and $PM_{2.5}$ Concentration

Outdoor air reaches the building and leaves the building through infiltration, mechanical ventilation and natural ventilation. Outdoor pollutants can enter building environments through holes, cracks, and joints. During natural ventilation, air passes through open windows and doors [9]. Table 2 shows the R^2 value for different type of windows. Based on this finding, type of window did not influence R^2 value eventhough the type of windows were similar. For example, Tun Dr Ismail Residential College and Bestari Residential College use similar type window but had different R^2 value. These sampling location were located surrounding industrial area which produce high concentration of air pollutants. This high concentration can affect the residents' health through air pollution related diseases such as asthma, headache, irritation, and tiredness. Luckly, the finding in this study shows that outdoor air pollution did not affect the indoor environment. Air movement related to infiltration and natural ventilation is caused by wind, indoor and outdoor air temperature difference and other factors [9]. In addition, there are numerous ventilation system devices that can enhance the ventilation. Ventilate fans constantly remove air from a single room such as kitchen and bathroom.

Table 2 - R^2 value for different type of window

Location	Types of window	R^2
Tun Dr Ismail Residential College	casement	0.7
Taman Universiti Apartment	three panel sliders	0.2
Bestari Residential College	casement	0.4
Taman Melewar	Casement *sliding door	0.1
Parit Haji Rais	jalousie window with the airhole at the top	0.4

4. Conclusion

The aim of this study was measure PM_{10} and $PM_{2.5}$ concentration and analysis relation of indoor and outdoor air pollution. In conclusion, based on the information that had been gathered from five sampling locations, it is shows that the concentration of PM_{10} and $PM_{2.5}$ starts to increased starting at 5pm until night. This is may be due to the temperature was low which was 28℃ at 5.00pm to compared to 32℃ at noon. For this reason, the exposure to particle pollution inside and outside the building depends on emission from both indoor and outdoor sources. Next, this study aimed to determine the effect of building characteristic on PM_{10} and $PM_{2.5}$ for indoor and outdoor concentration. The building characteristic that had been focused on is the type of window, since it was an important role for the relation of indoor and outdoor concentration. Each sampling location had different types of windows thus the indoor concentration for each sampling location was different. There are three sampling station that have the same types of windows which is casement window. The relationship of indoor and outdoor concentration for these three-sampling locations give the same analysis which the outdoor air quality doesn't affected the indoor air quality.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Geran Kontrak (vot H614).

References

[1] Kuehn, B.M. (2014). WHO: 7 million premature deaths annually linked to air pollution. *The Journal of the American Medical Association*, 311(15), pp. 1486. Retrieved January 2, 2021, from https://doi.org//entity/mediacentre/news/releases/2014/air-pollution/en/index.html?

[2] WHO. (2018, May 2). Ambient (outdoor) air quality and health. *World Health Organization*. Retrieved January 5, 2021, from https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

[3] US EPA, OAR. (2019, January 18). Introduction to Indoor Air Quality. *US EPA.* Retrieved January 4, 2021, from https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

[4] Ścibor, M., Balcerzak, B., Galbarczyk, A., Targosz, N. & Jasienska, G. (2019). Are we safe inside? Indoor air quality in relation to outdoor concentration of PM10 and PM2. 5 and to characteristics of homes. *Sustainable Cities and Society*, 48(101537), pp. 1-33. Retrieved January 3, 2021, from https://doi.org/10.1016/j.scs.2019.101537

[5] Leung, D. Y. C. (2015). Outdoor-indoor air pollution in urban environment: challenges and opportunity. *Frontiers in Environmental Science*, *2*(69), pp. 1-7. Retrieved January 6, 2021 from https://doi.org/10.3389/fenvs.2014.00069

[6] Ruan, T. & Rim, D. (2019). Indoor air pollution in office buildings in mega-cities: Effects of filtration efficiency and outdoor air ventilation rates. *Sustainable Cities and Society*, *49*(101609), pp. 1-28. Retrieved from January 3, 2021, from https://doi.org/10.1016/j.scs.2019.101609

[7] Wangchuk, T. (2016). *Quantitative assessment of air quality in different indoor and outdoor environments in rural Bhutan*. Queensland University of Technology: Ph.D. Thesis

[8] Teixeira, P. R., de Freitas, S. R., Correia, F. W. & Manzi, A. O. (2018). MOVEIM v1. 0: Development of a bottom-up motor vehicular emission inventories for the urban area of manaus in central Amazon rainforest, *Geoscientific Model Development Discussions*, pp. 1–21. Retrieved January 1, 2021, from https://doi.org/10.5194/gmd-2018-81

[9] Liu, T. & Lee, W. L. (2019). Using response surface regression method to evaluate the influence of window types on ventilation performance of Hong Kong residential buildings. *Building and Environment*, *154*, pp. 167–181. Retrieved January 3, 2021 from https://doi.org/10.1016/j.buildenv.2019.02.043