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A Study of Outdoor Concentrations of Particulate Matter ($PM_{2.5}$) on Different Floors of a University Building

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Abstract: This study was conducted due to the verbal complained from residents at the Universiti Tun Hussein Onn (UTHM) buildings about dust released from nearby factories, buildings and heavy traffics which potentially impact human health Thus, this study compared $PM_{2.5}$ levels on different floors of a building to the New Malaysia Ambient Air Quality Guideline (NAAQG). Met One E-Sampler was used to measure $PM_{2.5}$ and the meteorological characteristics at different floor levels. Data was collected daily for 24 hours at each floor, except on public holidays, at two monitoring locations: FKAAB and FSKTM. On the ground level of FKAAB and the third floor of FSKTM, the average $PM_{2.5}$ concentration was 29 µg/m^3 and 31 µg/m^3, respectively. The 2nd floor FKAAB reveals similar levels as the ground floor, 28 µg/m^3. 2nd floor FKAAB was 3rd floor FSKTM. Both levels have the greatest $PM_{2.5}$ concentration in UTHM air. $PM_{2.5}$ concentrations were below the NAAQG (35 µg/m^3). The greatest $PM_{2.5}$ concentration was detected at 8:00 p.m. with 39 µg/m^3 on the bottom level of FKAAB. The highest $PM_{2.5}$ concentration on the third floor of FSKTM was 51 µg/m^3 at 8:00 a.m. and 11 µg/m^3 at 4:00 p.m. include the meteorological data. (Human activity such as nearby industries, buildings, and heavy traffic altered the concentrations)-this not discussed thoroughly in chapter 3, so suggested to discard. As conclusion, the $PM_{2.5}$ concentration to the occupant at the study area after 24 hrs exposure is negatively impact the health since all data comply to the $PM_{2.5}$ permissible limit. In future, human activities contribute to the most to UTHM air pollutants will be evaluated.

Keywords: particulate matter, outdoor air quality, different floors, environment, public health

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1. Introduction

Air pollution is defined as any physical, biological, or chemical contaminant that contaminates an indoor or outdoor environment and affects the inherent characteristics of the atmosphere [1]. It has the presence of one or more compounds in the air at a concentration or for a time that exceeds their natural levels and has the potential to cause harm. Outdoor air quality has emerged as a source of concern for people's overall well-being as clean air is seen as a fundamental requirement for human health. Outdoor air pollutants include particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), and sulfur dioxide (SO_2) [2].

The Malaysian processing industry continues to expand each year, and the surrounding area of Universiti Tun Hussein Onn (UTHM), Parit Raja, Batu Pahat, Johor is also no exception to this development. The main campus was near to the industrial areas that engaged in operations such as the production of electrical appliances, the processing of wood from plants, the production of corrugated cartons, and the packing of facilities. Various chemicals, such as adhesives, thinners, paints, and preservatives, were utilized in the wood-processing industry, which generated several polluting gases and dusts. Wood processing emissions may irritate the respiratory tracts and lungs and increase the risk of infection in the respiratory system.

The occupants of UTHM's buildings, including staff and students, lodged many complaints. This issue began because of UTHM's proximity to factories without a buffer zone. The air quality deteriorated due to the dusty environment generated by industrial activities. This issue also has a significant impact on the people of UTHM's health, as they have described staying in dusty places causing them headaches and coughing because of the pollution, particularly at a higher floor of a building. This is because the pollution producing sources are placed roughly at the same level as the higher floors of the building. Staff and students were compelled to get treatment in medical facilities for respiratory and skin problems.

Dust with a diameter of fewer than 10 micrometers, referred to as particulate matter PM_{10} and $PM_{2.5}$, is a significant health hazard due to its ability to be breathed deeply into the respiratory system [3]. This issue also has a significant impact on the people of UTHM's health, as they have described staying in dusty places causing them headaches and coughing because of pollution, particularly at an occupied higher floor. Staff and students were compelled to get treatment in medical facilities for respiratory and skin problems.

Prior studies have been undertaken on the concentration of particulate matter on the different floors of a building. Most of the previous studies stated that the concentration of particulate matter decreased with increasing building height, which corresponded to an increase in floor levels. Meteorological conditions can contribute at least 16% to the reduction of $PM_{2.5}$ mass concentration [4]. As shown in the previous studies, P. Azimi et al. concluded that the height of the building was linked with temperature and humidity, but the wind direction correlated more [5]. R. Cichowicz and M. Dobrzanski found that the lighter fractions, $PM_{2.5}$ and $PM_{1.0}$, were more evenly distributed across the building, with no obvious concentration areas [4],[6]. X. Zhang et al. also found that particles under 1.0 μm tended to fall first, then rise in height. Meanwhile for 1.0-2.5 μm particles, the pattern was increasing then decreasing [7].

The Malaysian Department of Environment (DOE) also implemented the formulation of policy based on the Recommended Malaysian Air Quality Guidelines 1989 (RMAQG), which were replaced by the New Ambient Air Quality Standard. The DOE guideline states that the 24-hour monitoring limit for $PM_{2.5}$ must be less than 35 $\mu g/m^3$ [8]. The aim of this research is to investigate the $PM_{2.5}$ concentrations on different floors of a building and compare the $PM_{2.5}$ concentrations to the New Malaysia Ambient Air Quality Guideline (NAAQG). In addition to that, meteorological variables were also recorded.

2. Materials and Methods

2.1 Sampling Location Selection

This study was carried out at 10 and 4 sampling points respectively, which are FKAAB and FSKTM buildings as shown in Figure 1 and Figure 2. The pollution-producing sources are placed roughly at the same level as the higher floors of the building with the range of the stack's height from 33.5 m to 41.15 m. It was necessary to choose a building with at least four levels to conduct an analysis of the degree of pollution present on each floor of the structure. These buildings were also selected for the suitability of the instrument for placement at a particular sampling point.

Fig. 1 - Location of the sampling points at FKAAB

Fig. 2 - Location of the sampling points at FSKTM

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

The specified parameters were collected using Met One E-Sampler. In addition to measuring the concentration of particulate matter, this instrument can also record humidity, temperature, wind speed, and wind direction. This research involved a 24-hour data collection period with 10-minute sampling intervals at each sampling location. After the previous floor's readings were completed, the device was relocated to the next floor. Daily readings were taken, excluding public holidays. For this investigation, the air sampler was positioned in a corridor wherever possible. When there were no suitable passageways, nearby windows served as an alternative option.

2.3 Data Analysis

The research analysis has been assisted by software such as Met One Inc.'s COMET to retrieve the data and Microsoft EXCEL 2016 for data interpretation. A linear trend was created for the outdoor $PM_{2.5}$ concentration of a building's different floors. Also illustrated was the comparison of the two buildings at certain times.

3.0 Results and Discussion

3.1 $PM_{2.5}$ Concentrations on Different Floors

Figure 3 shows a summary of the $PM_{2.5}$ concentration in FKAAB, including the average, maximum, and minimum concentrations. The ground floor had the highest average concentration of $PM_{2.5}$, at 29 $\mu g/m^3$, while the eighth floor had the lowest average concentration, at 7 $\mu g/m^3$. The second floor had a nearly identical average concentration of 28 $\mu g/m^3$ to the ground floor. Even though the ground floor had the highest concentrations daily, the highest maximum concentration value obtained was 122 $\mu g/m^3$ on the second floor as opposed to 47 $\mu g/m^3$ on the ground floor. The lowest minimum concentration value of 1 $\mu g/m^3$ was recorded on the first and fourth floors. The average concentration of $PM_{2.5}$ fluctuated as the height increased [7].

Due to vehicle exhaust emissions entering and exiting the faculty building during working hours, the ground floor has the highest average concentration of particulate matter. Even though the mezzanine and first floor have a lower level than the second floor, the second floor had a higher average reading. This was because the particles were lighter and more easily dispersed by wind to the upper floor [9]. The concentrations continued to decrease gradually from the third to the eighth floor.

In the situation of the FKAAB building, particulate matter accumulated on the first four floors and then dispersed as the building got higher. As a result of the fact that the sources of pollution are situated almost at the same level as the higher floors of the structure, the air pollution that is produced tends to become concentrated on the first four levels of the building. Meanwhile on the third floor, the concentration of the particulate matter was higher than the mezzanine and the first floor even though the measurements were taken nearby an open two panel sliders window. This indicates that particle pollution exposure outside of a building is dependent on emissions from exterior sources [10].

An overview of the $PM_{2.5}$ concentration in FSKTM is also presented in Figure 3. This summary includes the average concentration as well as the greatest and minimum values. The average $PM_{2.5}$ concentration on the third floor was the highest in the building, coming in at 31 µg/m^3, while the $PM_{2.5}$ concentration on the second floor was the lowest, coming in at 7 µg/m^3. After the third floor, the first floor had the second lowest average concentration, which was 21 µg/m^3, and it was also the floor with the highest concentration maximum.

The maximum reading of concentration was also the greatest on the third floor, coming in at 59 µg/m^3, while the value on the first floor was the lowest, coming in at 37 µg/m^3. On the first and third floors, the minimum concentration value that was measured was found to be at its highest, 10 µg/m^3, while on the second level, it was found to be at its lowest, 4 µg/m^3. The average concentration of $PM_{2.5}$ also fluctuated as the height increases [5]. During the data collection at the second floor, the temperature at that time ranged from 25.2 – 30.8 °C which was lower than the other floors. This inhibited the photochemical reaction between precursors as the temperature can affect the formation of particles [11].

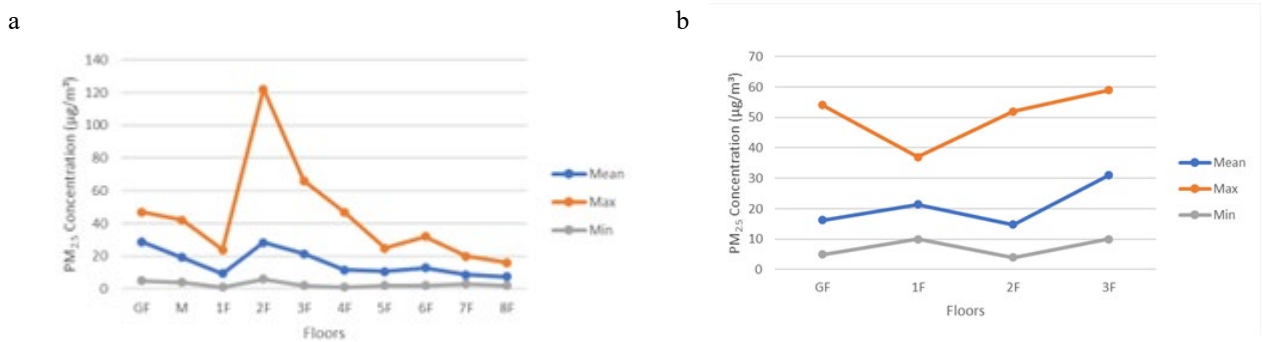

Fig. 3 – (a) $PM_{2.5}$ concentrations at FKAAB; (b) $PM_{2.5}$ concentrations at FSKTM

3.2 $PM_{2.5}$ Concentrations at Different Times

Figure 4 shows the $PM_{2.5}$ concentration on the highest average floor of both buildings in relation to the time. The times chosen for this section are at 8 a.m., 10 a.m., 1 p.m., 4 p.m., and 8 p.m.

At the FKAAB ground floor, the concentration of $PM_{2.5}$ was the highest at 8.00 p.m. with 39 µg/m^3 meanwhile the lowest was at 1 p.m. with 13 µg/m^3. Meanwhile, on the FSKTM third floor, the concentration of $PM_{2.5}$ was the highest at 8.00 a.m. with 51 µg/m^3 meanwhile the lowest was at 4 p.m. with 11 µg/m^3.

After 12 p.m., the $PM_{2.5}$ concentration on the ground level of the FKAAB increased. However, the pattern exhibits an opposite result on the third floor of FSKTM. At precisely 4:00 p.m., the temperature on the ground floor of FKAAB was lower than on the third floor of FSKTM, causing particles to accumulate there. Even though the wind speed was higher on the ground level of FKAAB, at 4 m/s, than on the third floor of FSKTM, at 2 m/s, it did not aid in the dispersion of the particles. This is because there were adjacent obstructions, such as trees, as well as sources from human activity at the university [12].

Aside from weather, the position of sensor placement at monitoring locations has an impact on concentration since there were a few locations at FKAAB where measurements were taken from windows rather than a hallway. Particulate matter dispersion may have been restricted by the walls surrounding the windows. Both monitoring sites were close to an obstruction, such as a building, and were surrounded by more human activities, such as construction and major roadways. According to the data obtained, the concentration of $PM_{2.5}$ at the third floor of FSKTM is higher than the ground floor of FKAAB. Even so, both floors are still below the standard limit which is 35 µg/m^3.

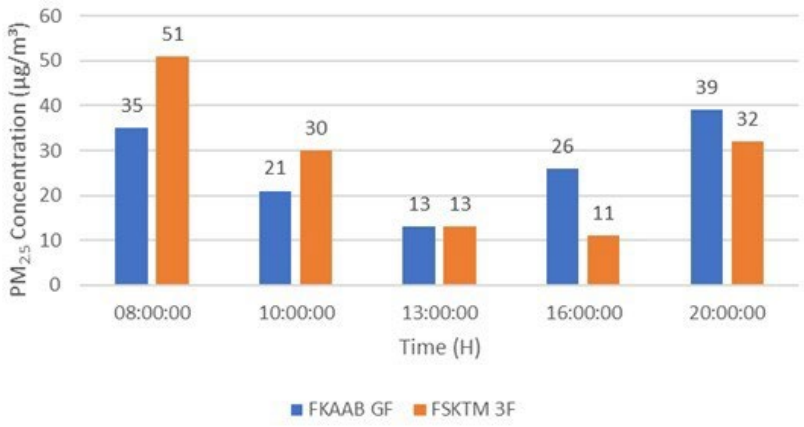

Fig. 4 - The concentration of $PM_{2.5}$ with the time given for both buildings

3.2.1 The Floors with the Highest Average PM2.5 Levels for Both Buildings

The floors selected with the highest average of $PM_{2.5}$ concentrations were the ground floor of FKAAB and the third floor of FSKTM, both with the readings of 29 µg/m^3 and 31 µg/m^3 respectively. The concentration of $PM_{2.5}$ for both floors was found to nearly exceed the daily guideline.

Figure 5 shows the $PM_{2.5}$ concentrations versus time (hours) at FKAAB ground floor. The maximum concentration of PM2.5 was 47 µg/m^3 between 2:50 and 3:00 a.m. and at 6:30 a.m., while the lowest concentration was 5 µg/m^3 at 11:20 a.m. The figure indicates that the reading appeared to increase steadily between morning and night. These times have a lower temperature to be compared than other times, such as in the evening. In the morning, however, the readings are higher because human activities around the campus and industrial activity began operating as contrasted to the night-time.

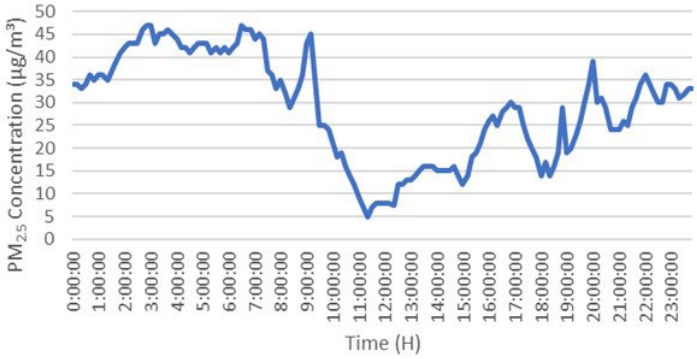

Fig. 5 - $PM_{2.5}$ Concentration versus Time (hours) at FKAAB Ground Floor

$PM_{2.5}$ concentration on the second floor of the FKAAB building was plotted against time in the form of hours in Figure 6. The second level has an almost identical average concentration to the ground floor, which is 28 µg/m^3. At 12:40 a.m., the $PM_{2.5}$ concentration was at its maximum of 122 µg/m^3, and it was at its lowest of 5 µg/m^3 at 10:10 a.m.

As shown in the graph, the curve started to decline noticeably somewhere between 2:00 a.m. and 3:10 a.m. The concentration started to increase at 7:10 a.m. and then started to fall at 8:40 a.m. After a brief increase, the concentration reading started to decrease once more. This is because it was raining at the time, which caused the relative humidity to be higher than 80% [13]. Wang, J., and Ogawa, S., (2015) found that precipitation was able to reduce $PM_{2.5}$ mass concentrations through wet deposition, which was in line with the current results [14].

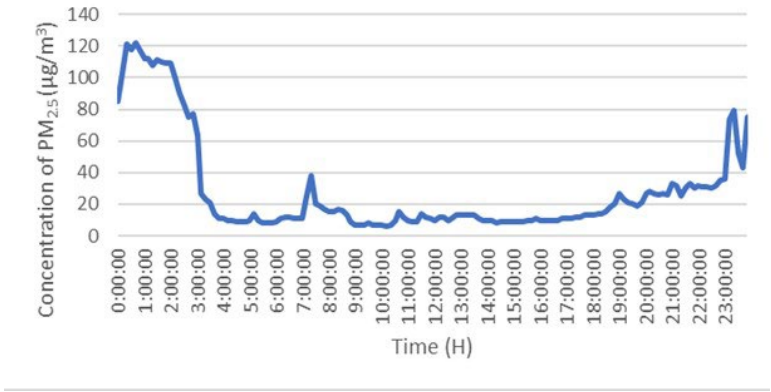

Fig. 6 - $PM_{2.5}$ Concentration versus Time (hours) at FKAAB Second Floor

Figure 7 shows the $PM_{2.5}$ concentration versus time (hours) at FSKTM third floor. The maximum concentration of PM2.5 was 59 µg/m^3 at 9:00 a.m. while the lowest concentration was 10 µg/m^3 at 3:50 p.m., 4:20-5:10 p.m. and 5:30 p.m.

The graph below indicates that the reading appeared to increase gradually in the morning, from 12:00 a.m. until 9.40 a.m. Other than that, the reading in the night-time also increases gradually starting from around 5:30 p.m. to 11:50 p.m. The presence of both people and industry around the university contributed to the readings in the morning to be higher than the night.

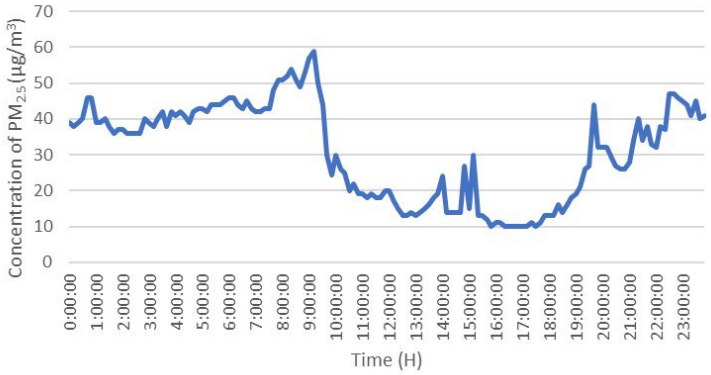

Fig. 7 - $PM_{2.5}$ Concentration versus Time (hours) at FSKTM Third Floor

4. Conclusion

According to the collected data, the average particle concentrations were highest on the bottom floor of FKAAB and the third floor of FSKTM. Comparing the collected data to the New Ambient Air Quality Guideline (NAAQG). According to the data, the lowest average $PM_{2.5}$ concentration was at the eighth floor of FKAAB and the second floor of FSKTM, with the reading of 16 µg/m^3 and 15 µg/m^3 respectively. Additionally, the ground floor of FKAAB has the highest average $PM_{2.5}$ concentration at 29 µg/m^3. The third floor of FSKTM has the highest average $PM_{2.5}$ concentration at 31 µg/m^3. The $PM_{2.5}$ concentrations reported on both floors are still below the NAAQG 24-hour monitoring limit which is less than 35 µg/m^3. Therefore, the previously discussed floors do not constitute a harm to the health of the occupants of the building after 24 hours of exposure.

Other than that, the $PM_{2.5}$ concentration was highest at 8:00 p.m. with 39 µg/m^3 and lowest at 1:00 p.m. with 13 µg/m^3 on the ground level of FKAAB. On the third floor of FSKTM, the $PM_{2.5}$ concentration was highest at 8:00 a.m. with 51 µg/m^3 and lowest at 4:00 p.m. with 11 µg/m^3. Both floors recorded the $PM_{2.5}$ concentration of 13 µg/m^3 at 12 p.m. Overall, the results indicated that outdoor particle matter concentration reduced as building floor levels increased.

Acknowledgment

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