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Investigation of Particulate Matter (PM_{10}) Pollution in Ipoh City, Malaysia

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Abstract: Air pollution is one of the phenomena that adversely affect the environment and negatively impact human health. Air pollution occurs when there are excessive air pollutants in the atmosphere. This study aims to identify and discuss the sources of PM_{10} emissions according to land use around Ipoh using descriptive and boxplot analysis. There are five areas selected as a sampling location for this study: Ipoh, Lahat, Chemor, Tanjung Rambutan, and Simpang Pulai that located in Hulu Kinta and Sungai Raya district. This sampling location's primary focus is located around Ipoh city, concentrated in the industrial area. Ten land use-based sampling stations are selected to measure. PM_{10} data were recorded for one week during working and non-working days in July 2020 on 10 sampling stations around Ipoh. The result shows PM_{10} concentrations consist of industrial, infrastructure and utility, commercial, residential, and recreational areas, as shown PM_{10} values were recorded for one week during working days and non-working days on 10 observation stations using Portable Laser Aerosol Spectrometer and Dust Monitor Model 1.108. Based on the observations, two stations show the daily average mean of PM_{10} exceeding 100 $\mu g/m^3$ outlined in the Malaysian Ambient Air Quality Standard (MAAQS) at S6 (175.78 $\mu g/m^3$) and S10 (103.79 $\mu g/m^3$). This situation is driven by the presence of limestone-based industrial areas as well as quarrying activities. The findings also show that PM_{10} concentration is higher during working days rather than non-working days. Overall, PM_{10} concentrations that exceed the limit will have a detrimental effect on the environment and human health.

Keywords: Air pollution, Particulate matter, PM_{10}, MAAQS, Ipoh City, Malaysia

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1. Introduction

The emission of particulate matter (PM_{10}) is one reason that contributes to air pollution and negatively impacts the environment. Air pollution is mainly caused by several factors such as urbanization and rapid industrialization [1], [2]. World Health Organization (WHO) reported in 2019, 90 percent of the world's population live in low air quality areas, which does not meet the optimum standards. According to Valencia et al. [3], Nor Diana et al. [4] and Anis et al. [5], urban areas are one of the high contributors to the release of suspended particles. PM_{10} is one of the suspended particles classified as air pollutants [6], [7]. Excessive release of PM_{10} will lead to air pollution, which significantly influences the Air Quality Index (AQI) and gives complications to the human respiratory system [8], [9]. Murnira et al. [10] and Atash [11] also reported that industrial areas and vehicle smoke emissions are prime contributors to the increase in PM_{10} concentration.

In recent years, Malaysia is experiencing rapid economic growth and urbanization. There are various sectors developed in Malaysia, especially in major cities. However, continuous development without attention for nature will lead to a deterioration of the environmental quality, which is contributed by the excessive release of particulate matter. The increase in the number of vehicles in Malaysia also caused PM_{10} concentration to spike mainly from vehicle emissions [12], [13]. Mohd Asrul et al. [14] also reported that industrial areas and fossil fuel burning in the Klang Valley contribute to the release of PM_{10} suspended particles. Iskandar Malaysia development corridors in Johor also face air pollution due to anthropogenic factors [15].

2. Particulate Matter Pollution in Ipoh

Ipoh is experiencing rapid urbanization as the third-largest city in Malaysia. There are 20 limestone sources and three quarries with a volume of 726,600 metric tons around Ipoh [16]. Mohd Hairy et al. [17] also stated that there are small limestone hills about 160-meters high in the southern area of Ipoh. This situation signifies that Ipoh is rich in limestone resources. Thus, continuous development will exploit the limestone resources, especially for the cement and ceramic industry. The opening of cement factories and quarries around Ipoh City has undoubtedly increased the amount of PM_{10} in the atmospheric space excessively [18].

Increasing population leads to the expansion of residential areas. However, less strategic development of residential areas will lead to air pollution caused by anthropogenic activities such as open burning. Noor [19] stated that Seri Palma residents in Bandar Seri Botani, Ipoh, protested against housing projects developed nearby that cause dust and soot problems. This scenario occurs due to the high number of heavy vehicles passing through the road to the house's construction site regularly. Heavy vehicles that frequently commute to the construction site caused other areas to be dusty and dirty. Therefore, the dust that is blown away to the atmosphere will contribute to high PM_{10} concentration in a particular area.

Besides, quarrying activities carried out around Ipoh also cause problems not only to the environment but also cause air pollution. Mount Lanno, located in the Kinta Valley, is a limestone area with a unique limestone cave structure. However, there are several quarry sites operated around Mount Lanno. Muhammad Syafiq [20] reported that this area was affected by a rock explosion carried out at the quarry. Rock explosions carried out in quarry areas will cause an increase in PM_{10} as a result of dust being flown away and suspended in the air [21]. The increase of dust will affect the air quality around Ipoh City.

3. Data and Methodology

3.1 Sampling Stations

There are five areas selected as a sampling location for this study: Ipoh, Lahat, Chemor, Tanjung Rambutan, and Simpang Pulai that located in Hulu Kinta and Sungai Raya district. This sampling location's primary focus is located around Ipoh city, concentrated in the industrial area. Ten land use-based sampling stations are selected to measure PM_{10} concentrations consist of industrial, infrastructure and utility, commercial, residential, and recreational areas, as shown in Figure 1 and Table 1.

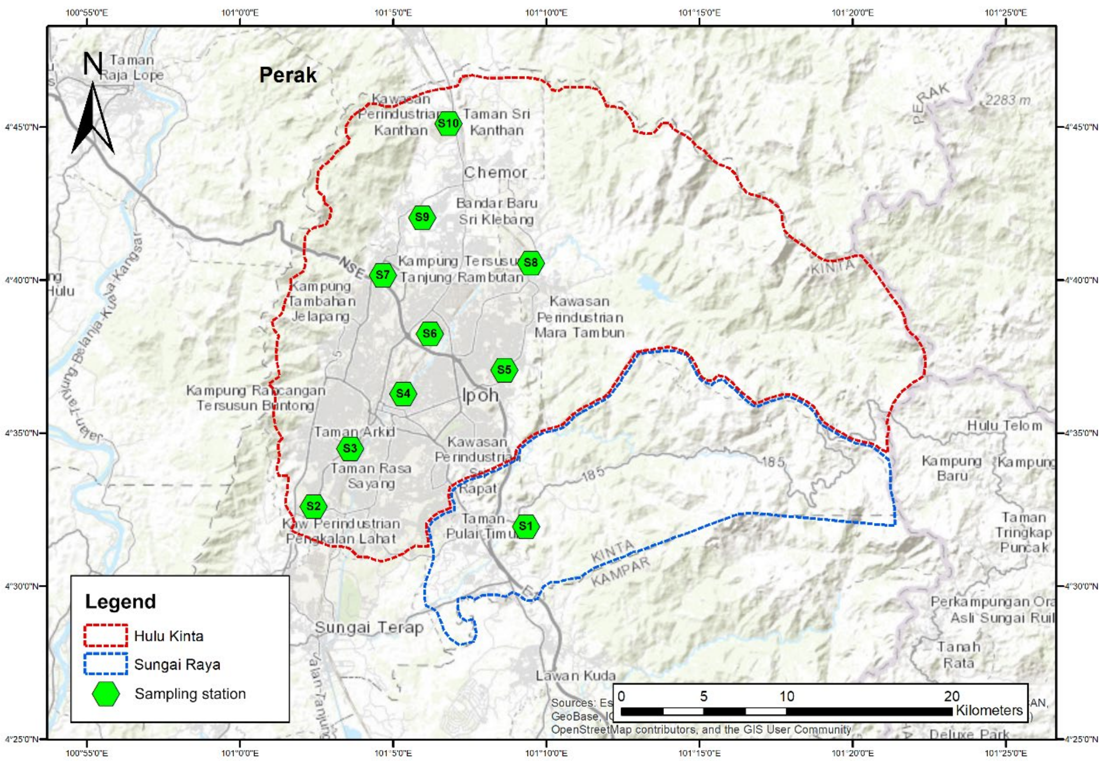

Table 1 - Sampling stations list

Station	Land use type	Location	Latitude	Longitude
Station 1 (S1)	Cement industrial and quarry	Simpang Pulai	4°32'1.644"N	101°9'14.086"E
Station 2 (S2)	Industrial	Lahat	4°32'38.57"N	101°2'25.731"E
Station 3 (S3)	Industrial	Menglembu	4°34'29.347"N	101°3'33.066"E
Station 4 (S4)	Infrastructure and utility	Bandar Ipoh	4°36'13.608"N	101°5'21.671"E
Station 5 (S5)	Recreation	Tambun	4°37'5.739"N	101°8'34.988"E
Station 6 (S6)	Cement and ceramic industrial, and quarry	Tasek	4°38'10.902"N	101°6'11.63"E
Station 7 (S7)	Commercial	Meru	4°40'14.711"N	101°4'38.229"E
Station 8 (S8)	Residential	Tanjung Rambutan	4°40'36.432"N	101°9'33.635"E
Station 9 (S9)	Ceramic industrial	Chemor	4°42'3.316"N	101°5'56.425"E
Station 10 (S10)	Cement industrial and quarry	Kanthan	4°45'5.773"N	101°6'55.072"E

3.2 Sampling Method

PM_{10} data were recorded for one week during working and non-working days in July 2020 on ten sampling stations around Ipoh. Land use is a primary factor in selecting sampling stations for this study, adapted from Muhammad Azahar et al. [15] and Ha et al. [22]. PM_{10} data collection started at peak hours at 8.00 am with high traffic flow proposed by Srimuruganandam and Shiva [23]. PM_{10} reading will be determined based on MAAQS (Table 2) outlined by the DOE. PM_{10} value was recorded using Portable Laser Aerosol Spectrometer and Dust Model Monitor 1.108. This device is an optical instrument that can measure the PM_{10} concentration directly by using an optical particle counter (OPC) that uses an optical instrument using the laser diode to determine the PM_{10} concentration.

Table 2 - Malaysian Ambient Air Quality Standard

Air Pollutant	Average Time	Ambient Air Quality Standard		
		IT-1 (2015)	IT-2 (2018)	Standard (2020)
		µg/m^3	µg/m^3	µg/m^3
PM_{10}	1 Year	50	45	40
	24 Hour	150	120	100

Source: Department of Environment [24]

4. Results and Discussion

4.1 Descriptive Analysis of PM_{10} Concentration

Table 3 shows descriptive statistics of daily PM_{10} concentration on each station. Based on Table 3, S1, S6, and S10 show a maximum value that is higher than the guidelines set in MAAQS, which is 100 µg/m^3. S6 showed the highest concentration of 273.60 µg/m^3, followed by S1 (160.67 µg/m^3) and S10 (143.57 µg/m^3). This situation occurs because S1, S6, and S10 are limestone-based industrial areas that release particulate matter. These particulate matters are classified as coarse particles with a diameter of between 2.5 and 10 micrometers [25], [26]. The World Health Organization (WHO) stated that coarse particles contain dust flown away from roads, quarrying and mining activities, and industrial areas. The high concentration of PM_{10} at stations S1, S6, and S10 indicates that the area releases dust excessively from the operation of cement factories and quarries.

Table 3 - Descriptive statistics of daily PM_{10} concentration in each station

Station	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Mean	95.51	26.33	24.78	8.94	6.89	175.78	7.80	5.80	32.55	103.79
Median	112.70	29.50	31.80	8.30	6.87	218.10	5.60	6.83	34.23	111.17
Std. Deviation	60.13	9.23	14.62	3.97	1.08	94.33	5.03	2.23	19.22	33.46
Skewness	-.268	-1.899	-1.192	.653	-.764	-1.090	.560	-1.087	.687	-.703
Kurtosis	-2.168	3.636	-.819	.227	.592	.195	-1.417	.512	.285	-.897
Minimum	20.90	7.13	2.37	3.70	4.97	9.33	2.57	1.73	9.23	54.47
Maximum	160.67	33.73	35.90	15.67	8.10	273.60	15.60	7.87	66.03	143.57

Fig. 2 shows the PM_{10} daily concentration box plot on each station. The plot box aims to provide a brief overview to make comparisons ideally. Relatively, S1, S6, and S10 show maximum values that exceed the levels set in the MAAQS compared to the other stations. Two stations showed a daily average of PM_{10} below 10 µg/m^3 situated at S5 (8.10 µg/m^3) and S8 (7.87 µg/m^3). This situation occurs due to the lack of anthropological factors contributing to PM_{10} concentration because S5 is a recreational area and S8 is a residential area. The scenario is also supported by Mohamed et al. [27] and Ahmad et al. [28]. They stated that residential and recreational areas have low PM_{10} concentrations and do not exceed the limits set in the MAAQS. However, Borrego et al. [29] stated that residential areas located in four seasons country showed a significant amount of PM_{10} concentration due to wood burning during winter.

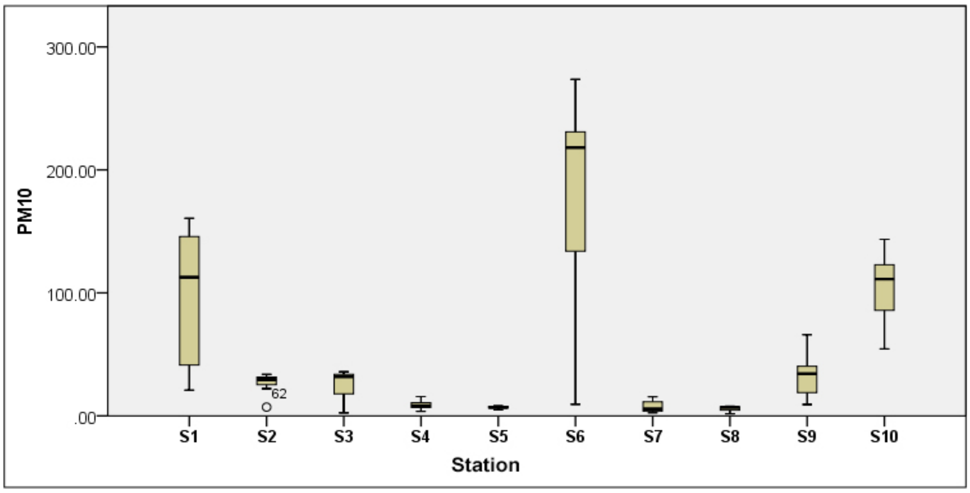

Fig. 2 - Daily concentration of PM_{10} box plot in each station

4.2 PM_{10} Concentration Trends in Ipoh

Fig. 3 shows the trend of daily PM_{10} concentration in Ipoh for one week. Several factors are considered during data collection: the type of land use, weather and climate factors, and the influence of working and non-working days. Based on Fig. 3, three stations showed the amount of PM_{10} that exceeds the limits outlined in the MAAQS, which are S1, S6, and S10. This situation is driven by the limestone-based industries that emit dust around the station. It is clearly can be concluded that dust emissions from cement factories and rock blasting carried out in quarries show high PM_{10} concentrations. Nevertheless, other stations did not show significant PM_{10} concentrations and did not exceed the limit in MAAQS. Other stations that show low PM_{10} concentrations are consist of residential, commercial, recreational areas, infrastructure, and utilities.

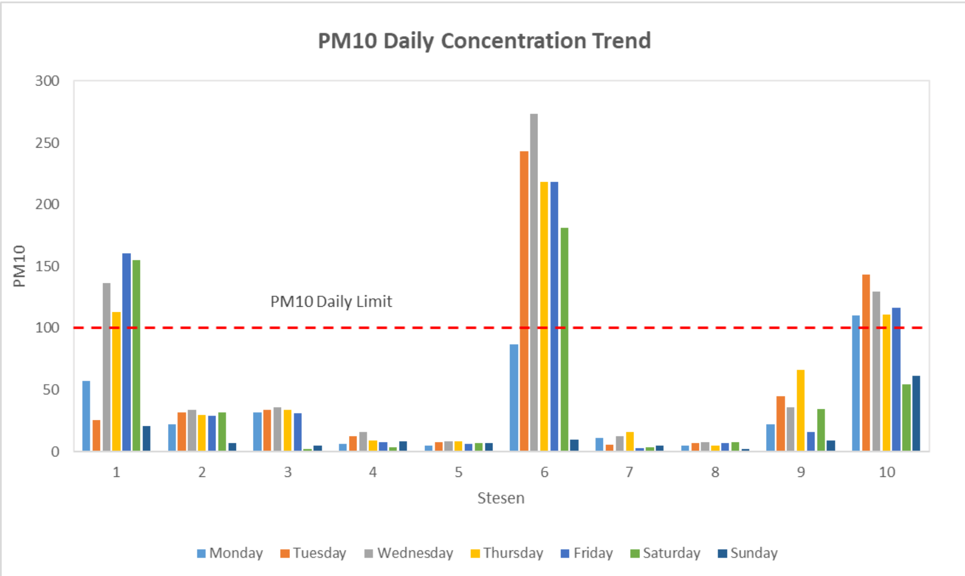

Fig. 3 - Daily concentration of PM_{10} boxplots in each station

Based on Figure 3, the trend of daily PM_{10} concentration showed a significant difference during working and non-working days. Figure 3 shows that the trend of daily PM_{10} concentration on Monday to Saturday is higher than Sunday. This situation is driven by the factor of working days on Monday to Saturday. Although Saturday is a weekend, some sectors were operating half-day. Nevertheless, Saturday showed daily concentrations of PM_{10} exceeded the limits in S1 (155.26 $\mu g/m^3$) and S6 (180.93 $\mu g/m^3$) even though factory operations and quarrying activities were carried out for half day [5]. Gour et al. [30] also reported a similar situation in Delhi, India, showed a higher concentration of suspended particles from Monday to Saturday than Sunday.

Even though S2 and S3 are industrial areas, the recorded daily concentration of PM_{10} does not exceed the DOE standard. The maximum value recorded in S2 was only 33.73 $\mu g/m^3$, while S3 showed a value of 35.90 $\mu g/m^3$. This condition suggests that the type of industrial activity influences the emission of suspended particles. S2 is metal and rubber-based industrial area, while S3 is a metal fabrication-based light industrial area. Relatively, S1, S6, and S10 showed high concentrations due to particulate matter released from cement processing plants and quarrying activities. Yang et al. [31] also agreed that cement plant is one of the causes of increased PM_{10} concentration in an area.

5. Conclusion

In conclusion, this study discusses the pollution of suspended particles focusing on PM_{10} around Ipoh City. Several stations show daily concentrations of PM_{10} above the standards set by the DOE. There is no denying that this situation will have adverse effects, especially on human health. As a result of the analysis, the limestone-based industrial areas, namely cement factories and quarrying activities carried out in S1, S6, and S10 recorded PM_{10} concentrations exceeding 100 $\mu g/m^3$, especially on working days. According to a statement released by the WHO [32], PM_{10} is a significant indicator of air pollution as it is often associated with respiratory and cardiovascular diseases. Therefore, the Environmental Quality Act 1974 must be reviewed so that the National Climate Change Policy can be fully realized.

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