

Spatial and Temporal Characteristics of Air Pollutants Concentrations in Industrial Area in Malaysia

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Abstract. Quantification of the spatial and temporal variations of ambient air pollutant concentrations provides the information for epidemiological and other air-pollution studies and many have relied in the past on data from a single, centrally-located air pollution monitoring site. Particulate matter (PM₁₀), nitrogen oxides (NO), sulfur dioxide (SO₂), carbon monoxide (CO), ozone (O₃) were measured at 3 monitoring sites around a densely populated industrial zone which is at Nilai, Petaling Jaya and Seberang Perai. The observations were obtained over five year period from 2008 to 2012. The descriptive statistics show that the peak concentration of PM₁₀ occurs during the dry season; which is coincided with the southwest monsoon and also due to direct-influence of southwest winds and had caused a slightly moderate haze in Southeast Asia. From the Pearson correlation analysis, among the meteorological parameters, ambient temperature indicates the strongest positive correlation to the PM₁₀ concentration and proves that the ambient temperature tend to contribute significantly to higher PM₁₀ concentrations as high as in Southwest monsoon.

1. Introduction

Air pollution occurs when air is contaminated with natural and anthropogenic pollutants. Anthropogenic pollutants are contaminants associated with human activities, which include polluting residuals from consumption and production activity. Air pollution happens due to the presence of anthropogenic pollutants and non-point source pollutants in the air. Non-point source pollutants come from sources that cannot be accurately identified. These pollutants have diffusively and indirectly contributed towards the degradation of environment.

A study by Jacob (2010) [1] described that a full life cycle of a vehicle contributes to air pollution, which includes the process of manufacturing, refueling, emission and disposal of the car. Fuel refining and distribution cause additional pollutants. These pollutants can be further categorized into primary and secondary pollutants. Those considered primary pollutants are released straight to the air. Secondary pollutants on the other hand, are the by-products of chemical reactions that transpire between the pollutants and other minute particles in the atmosphere. From the previous studies, it can be assumed that most of the major pollutants come from manufacturing activities. It is important to note that the increase in the demand of vehicles and the many economic activities occur along population growth. However, the major concern of scientists as well as economists is the tremendous



impacts of the exposure to the air pollution. Urban population in particular may suffer adverse health effects with the combination of poor air quality and high temperatures.

In Malaysia, the air quality monitoring work was first carried out by the Department of Environment (DOE) Malaysia in 1977 but it consisted mainly of short surveys. These surveys produced limited data in which little analysis can be done. However, other interested bodies and individuals carried out related studies from time to time [2]. There are 52 air-monitoring stations throughout the country, which are at urban, sub-urban as well as industrial area. These monitoring stations are strategically located in both residential and industrial areas to detect any significant change in the air quality, which might be threatening to human health and the environment. Five criteria pollutants are being monitored continuously by DOE namely carbon monoxide (CO), nitrogen dioxide (NO₂), ozone (O₃), sulphur dioxide (SO₂), and particulate matter (PM₁₀). There are two types of monitoring which are Continuous Air Quality Monitoring Stations (CAQM) and Manual Air Quality Monitoring Station (MAQM). Alam Sekitar Malaysia (ASMA) Sdn. Bhd. is responsible to carry out air quality monitoring work for DOE. ASMA is awarded a 20-year concession to provide air quality monitoring data to DOE. To date, under the Concession, ASMA is acknowledged with the installation and management of 52 continuous air quality monitoring stations (CAQM). The establishments of the Malaysian Air Quality Guidelines in 1989, Air Pollution Index and Haze Action Plans in 1997 are among the important tools for air quality management that are endorsed and put into practice by the Malaysian Government.

In general, the overall air quality for Malaysia in was between good to moderate levels most of the time except for a number of unhealthy days recorded at various locations in the west and east coast of peninsular Malaysia. Particulate matter (PM₁₀) was the main pollutant that had caused unhealthy conditions in the late northeast monsoon (February until March) and southwest monsoon (May until September) especially during the dry season. The unhealthy days in Klang Valley during these periods were due to forest and peat land fires. The concentration of PM₁₀ in Klang, which is sited as the urban area was significantly higher compared to the suburban and rural areas. Hence, the major aim of this study is to presents the evaluation on trends of air pollutants and characterization of pollutants concentrations with respect to meteorological condition in the selected potential area.

2. Material and method

2.1. Study area

Three monitoring stations that were chosen in this study are located in the west coast of peninsular Malaysia. The three stations are Nilai, Petaling Jaya and Seberang Jaya. Nilai is a town located in Seremban District, Negeri Sembilan which is also a small state located about 50 km south of Kuala Lumpur (Figure 1(a)). According to the Department of Statistics (DoS, 2015) [3]. Climatically, Nilai shows a tropical monsoon climate, characterized with a significant amount of rainfall during the year and uniformly high daytime temperatures between 27 °C - 30 °C while 22 °C - 24 °C at night [4]. It is legitimately normal even for the driest month. The average precipitation in Nilai is 2223 mm. The driest month is June, with 119 mm of rain. With an average of 263 mm, the most precipitation falls in November whereas; April is the warmest month of the year.

Petaling Jaya is one of the wettest cities in Malaysia (Figure 1 (b)). It is warm with an average maximum of 30°C and receives heavy rainfall all year round, roughly more than 3,300 mm (130 in) of average rainfall annually. The city has no particular true dry season but June and July are the driest months. Mostly each month average rainfall receives more than 200 mm (7.9 in). Thunderstorm and extreme rainstorm weather is a common environment here and it is one of the highest lightning strike areas in the world. The average temperature in Petaling Jaya is 27.0 °C. About 2438 mm of precipitation falls annually. The least amount of rainfall occurs in July with the average of 126 mm. The most precipitation month falls in November with an average of 281 mm [3].

Seberang Perai, formerly Province Wellesley, is a narrow hinterland opposite Penang Island on the Malay Peninsula, which together with the island forms the Malaysian state of Penang (Figure 1 (c)). Its principal town is Butterworth. Seberang Perai has a population of 815,767, which is the second

Table 1.



Figure 1. Location of the three monitoring stations.

Table 1. The location of the study areas.

No.	Location	
1.	Taman Semarak (Phase 2), Nilai, Negeri Sembilan	N 2.8205°, E 101.8108°
2.	SK Bandar Utama, Petaling Jaya, Selangor	N 3.1314°, E 101.6082°
3.	Sampling station of SK Taman Inderawasih, Seberang Perai, Pulau Pinang	N 5.4°, E 100.4667°

2.2. Air quality data

In this study, air pollutants concentration and meteorology parameters in industrialized area (Petaling Jaya, Nilai and Seberang Perai) will be analyzed. Throughout this step, the air quality data which obtained from the Department of Environment (DOE) will be first analyzed. Then, the associations of the air pollutants concentration with its weather parameters will be justified by descriptive statistics. Later, the temporal and spatial characteristics and the correlations between the air pollutants

concentration and its meteorological conditions for the study area will be analyzed.

2.3. Statistical analysis

The descriptive statistics will be carried out to determine the shape, dispersion and the distributions of the data for the study area. The most important information needed to be collected from a set of data are the measure of central tendency and the measures of variability. These are the following measures of central tendency including; mean, median, mode and skewness. Besides, the measures of variability include the standard deviation, variance and range. In this study, the descriptive statistics for every set of data were analyzed by using SPSS Statistics 21. These are some of the summarized formulae for measuring the descriptive statistics. The Pearson correlation was conducted to determine the relationship between different air pollutants at each station as well as the connection between the pollutants and its meteorological parameters namely; humidity, wind speed and ambient temperature.

3. Results and analysis

3.1. Time series plot of air pollutants

The time series plots of the maximum daily average of air pollutants concentrations for five years of all the three-study area were plotted. Figure 2 and Figure 3 show the five years' time series plot for all three sites. PM₁₀ and O₃ concentrations were selected because both pollutants are the most prevalent gases concentrations recorded in the atmosphere at all stations. The reference line showing the Malaysian Ambient Air Quality Guideline (MAAQG) of PM₁₀ and O₃ concentrations for 24-hours averaging time also drawn to show the exceedances throughout the years which are 150 µgm⁻³ and 0.06 ppm respectively. It is to indicate which year and location exceeded the guideline.

Figure 2 illustrates the time series plot of particulate matter (PM₁₀) for Nilai, Petaling Jaya and Seberang Perai in 2008, 2009, 2010, 2011 and 2012. The highest hourly PM₁₀ concentration at all three stations was recorded throughout the five years period except for 2011, which was higher around October to November. The highest PM₁₀ concentration was during early May to late June, where it represent the dry season, which is coincided with the southwest monsoon and the lowest was in October 2008 (northeast monsoon). In Southwest Asia, the concentration of particulate matter (PM₁₀) is influenced by the occurrence of biomass burning in Sumatera Indonesia and the Southwest monsoon wind [5]. Besides, it was also due to the direct-influence of southwest winds and had caused a slightly moderate haze in Southeast Asia. Overall, PM₁₀ concentrations are seen to be the prior contributor of air pollutant in Seberang Perai throughout the year.

The time series records of O₃ concentration from 2008 to 2012 are shown in Figure 3. The concentration of O₃ was found to be higher during certain months in that particular year due to the haze episode in August–September [6], where the concentration was far above the guideline particularly during early February. Other than being affected by the emission of industrial activities, the high O₃ concentration at all stations being affected by the vehicles emission. In general, each year, most of the O₃ concentrations exceeded the MAAQG of 1-hr averaging time.

3.2. The monthly trend of air pollutants

Figure 4 shows the monthly plots air pollutants concentrations for five years of all the three study areas. The pollutants concentration was compared to Malaysian Ambient Air Quality Guideline (MAAQG) for 24-hours averaging time. Figure 4 shows the averaged of monthly plot of PM₁₀ concentration of all the study area from 2008 to 2012. The monthly trends of all the three areas were consistently increased during the month of June until August where the highest PM₁₀ concentrations were recorded on June. The highest concentrations of PM₁₀ were recorded at the value of 68.326 µgm⁻³, 59.432 µgm⁻³ and 51.13 µgm⁻³ in June, July and August respectively, which might be due to the southeast monsoon. However, the concentrations seem decreased starting from September to November because of the time changes of season or called as transition. After all, the averaged concentration of all gases is still under the threshold limit by the Recommended Malaysian Air Quality Guideline (RMAAQG).

The highest O₃ concentration was recorded in Seberang Perai on February (0.02179 ppm). The local source that contributed higher O₃ concentration is that this station is located at the industrial areas. According to Department of Environment (2012) [7], the prevailing pollutants concern in Seberang Perai were O₃ and PM₁₀ due to the intensive industrial activity in this area. Figure 4 also shows that similar pattern was observed in Nilai and Petaling Jaya, as February recorded the highest O₃ concentration with the value of 0.01995 ppm and 0.01805 ppm respectively. Besides being affected by the motor vehicle emissions, the O₃ concentrations in the study area were high because of industrial activities and open burning [8].

The monthly trend of Sulphur Dioxide (SO₂) was showing a remarkably fluctuation in comparison with the three stations. The highest monthly average of SO₂ concentration was recorded in Petaling Jaya during May until July with the values of 0.00434 ppm, 0.00432 ppm and 0.00398 ppm respectively. While at Nilai and Seberang Perai, the highest monthly average of SO₂ concentration was recorded in September (0.00411 ppm) and June (0.002476 ppm) respectively. But somehow the average concentration was still under the threshold limit stipulated in the Recommended Malaysian Air Quality Guideline (RMAAQG).

Among the twelve month, June recorded the highest monthly concentration of NO₂ in Seberang Perai, Petaling Jaya and Nilai with the value of 0.01528 ppm, 0.03275 ppm and 0.0130 ppm respectively. None of these concentrations exceeded the RMAAQG suggested value that is 0.17 ppm for 1-hour averaging time. However, according to Department of Environment (2008) [9], the highest value of NO₂ concentration might due to the atmospheric conditions and emission from the motor vehicles in urban areas that enhance its formation.

3.3. Correlation between air pollutants and meteorological factors

The correlations between atmospheric pollutants and meteorological parameters at the three stations were investigated by using Pearson Correlation (Table 2). In Nilai, positive relationships between pollutant-pollutant and pollutant-weather parameter were observed. Nevertheless, the significant relation between pollutant-pollutant (for significant level of 0.01) were observed between PM₁₀ and NO₂ ($r=0.594$); PM₁₀ and SO₂ ($r=0.414$); PM₁₀ and CO ($r=0.466$); NO₂ and CO ($r=0.538$); SO₂ and NO₂ ($r=0.516$). Other than that, the significant relationships between pollutants-weather parameters at $p<0.01$ were observed between O₃ and wind speed ($r=0.521$); CO and temperature ($r=0.363$) and NO₂ and humidity ($r=0.351$).

In Petaling Jaya itself, the location that is close to industrial area, which would lead to the existence of atmospheric pollutants from various sources in comparison to Seberang Perai, which is more influenced by the movement of motor vehicles. The most significant correlation in Petaling Jaya are between PM₁₀ and temperature ($R^2=0.2577$, $p<0.01$), PM₁₀ and wind speed ($R^2=0.1731$, $p<0.01$) and between CO and NO₂ ($R^2=0.2301$, $p<0.01$). The correlation between PM₁₀ and temperature indicates a strongest positive correlation when the value of PM₁₀ increases as the temperature rises. A study from Azmi et al. (2010) [6] proves that a high temperature increases the number of biomass burning as well as the evaporation of soil dust from the earth's surface. Hence justify that the variables moves along together.

Moreover, in Seberang Perai, particulate matter (PM₁₀) were also found to be correlated to one of a meteorological parameter which is ambient temperature ($R^2=0.1595$, $p<0.01$). A study from Azmi et al. (2010) [6] proves that a high temperature increases the number of biomass burning as well as the evaporation of soil dust from the earth's surface. Hence justify that the variables moves along together. There were only two variables that were correlated to each other in Seberang Perai. However, the strongest positive correlation happened in this area is between O₃ and SO₂ ($R^2=0.2924$, $p<0.01$). The result is expected to be negatively correlated since SO₂ and NO₂ are known as precursors of ozone (O₃) and indicates that a rise in O₃ concentration will associate with the decline in the levels of both pollutants.

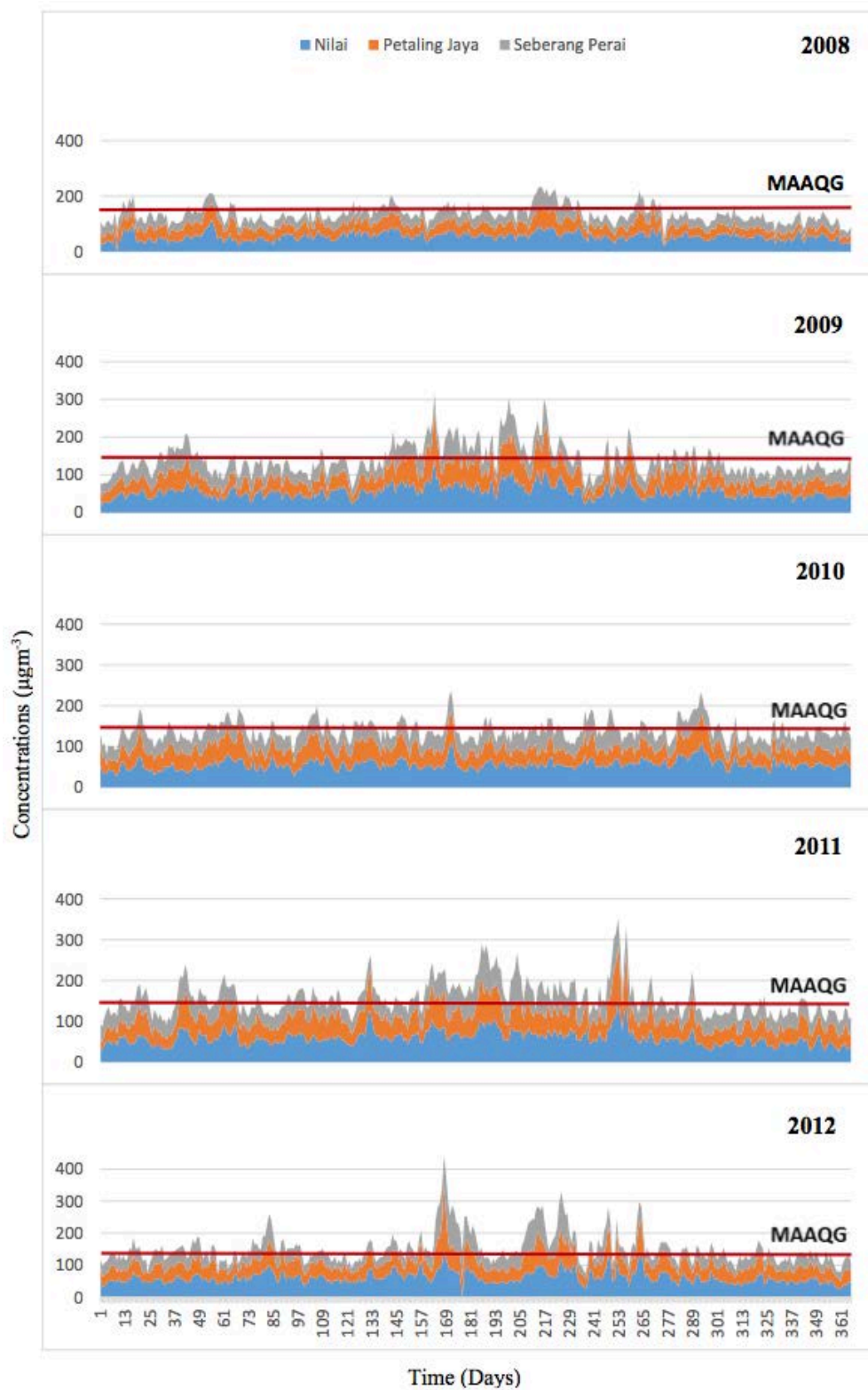


Figure 2. Time series plot of PM₁₀ concentration for the three study areas.

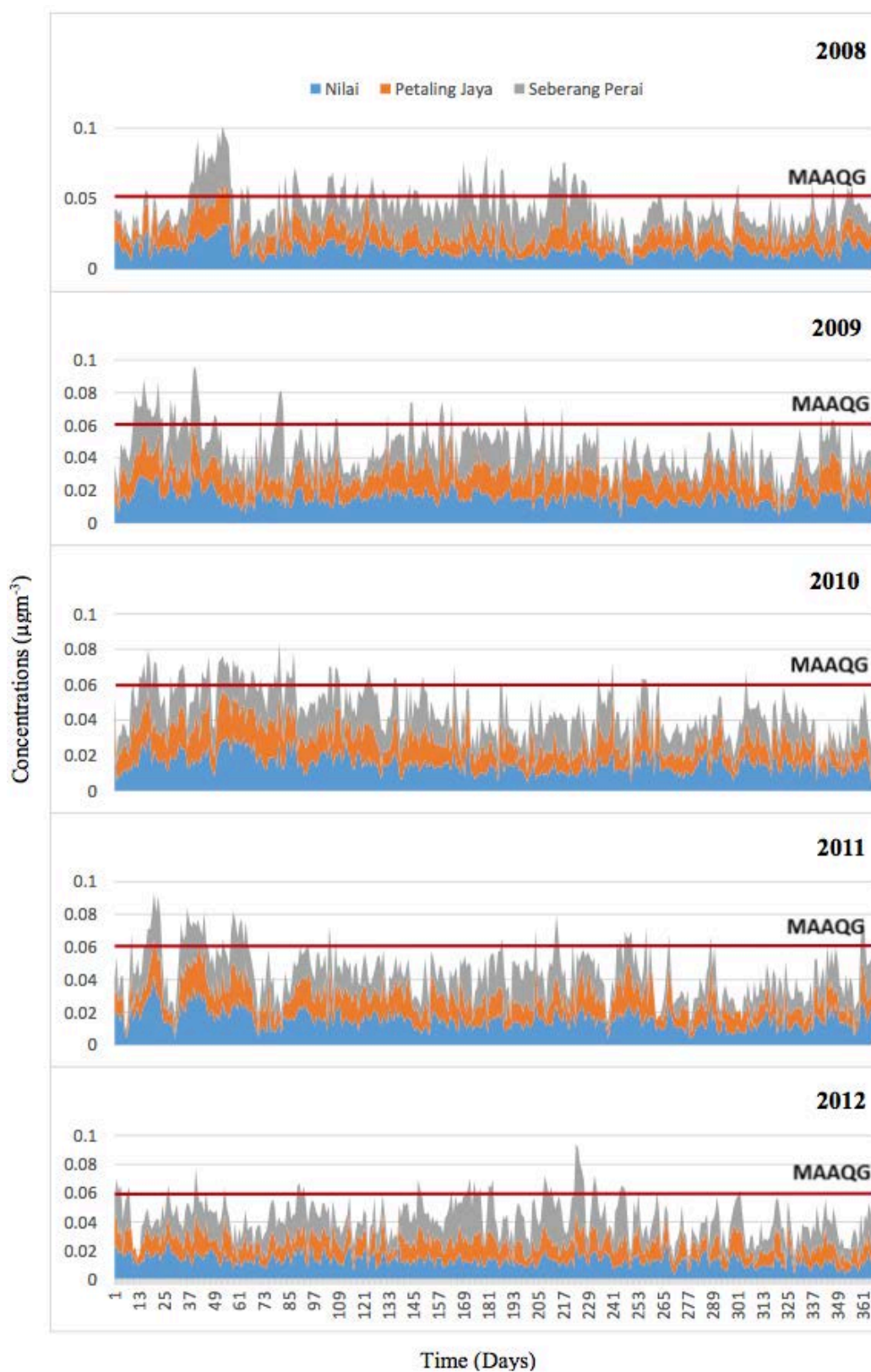


Figure 3. Time series plot of O₃ concentration for the three study areas.



Figure 4. Monthly plot of air pollutants in Nilai, Petaling Jaya and Seberang Perai.

These meteorological conditions are typical for a tropical environment. Correlation between the most significant air pollutants (PM₁₀) and meteorological factors indicates that the PM₁₀ concentration has a significant positive correlation with humidity ($R^2=0.5491$, $p<0.01$). High humidity is commonly related to the number of rain occasions, and this reduces the number of particles due to the wash-out processes of the atmospheric aerosol in the atmosphere. Therefore, there is a positive correlation between humidity and PM₁₀ in ambient air. Other factors such as wind speed and temperature were found to slightly influence the concentration of particulate matter in the atmosphere in the study areas.

Table 2. Correlation between parameters at Nilai, Petaling Jaya and Seberang Perai.

Station	Parameter							
	Wind speed	Temp.	Humidity	SO ₂	NO ₂	O ₃	CO	PM ₁₀
Nilai	Wind speed	1						
	Temp.	0.068	1					
	Humidity	-0.068	0.0051	1				
	SO ₂	-0.353	0.307*	0.233	1			
	NO ₂	-0.449	0.277*	0.351**	0.516**	1		
	O ₃	0.521**	-0.06	-0.585	-0.23	-0.379	1	
	CO	-0.066	0.363**	0.061	0.116	0.538**	-0.174	1
	PM ₁₀	-0.412	0.162	-0.109	0.414**	0.594**	-0.094	0.466**
Petaling Jaya	Wind speed	1						
	Temp.	0.437**	1					
	Humidity	-0.666	-0.449	1				
	SO ₂	-0.087	-0.145	0.092	1			
	NO ₂	-0.0707	-0.234	-0.011	0.172	1		
	O ₃	-0.249	0.057	-0.163	0.174	0.115	1	
	CO	-0.413	-0.206	0.215	0.318*	0.480**	0.354**	1
	PM ₁₀	0.416**	0.5088**	-0.741	0.027	0.027	0.273	-0.052
Seberang Perai	Wind speed	1						
	Temp.	0.237	1					
	Humidity	-0.263	-0.631	1				
	SO ₂	-0.311	0.090	-0.009	1			
	NO ₂	-0.017	-0.153	0.086	-0.055	1		
	O ₃	-0.318	0.153	-0.355	0.541**	-0.208	1	
	CO	0.228	0.109	0.027	0.124	0.351	-0.266	1
	PM ₁₀	-0.129	0.400*	-0.352	-0.040	0.156	0.275	-0.064

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

4. Conclusions

The result from this study shows that practically all the averaged concentration of atmospheric pollutants recorded at Nilai, Petaling Jaya and Seberang Perai are under the permissible value recommended by the Malaysian Department of Environment (DoE).

It has been resulted that the highest average concentration of PM₁₀ recorded at Nilai was in 2012 with value of 60.48588 $\mu\text{g}/\text{m}^3$. While the maximum value is recorded in 2008 which is 315 $\mu\text{g}/\text{m}^3$. The mean average concentration of PM₁₀ recorded at the station throughout these 5 years was significantly differ and was found to be slightly above than the value suggested by the Malaysian Ambient Air Quality Guideline (MAAQG) for the 24-hr averaged concentration (50 $\mu\text{g}/\text{m}^3$). PM₁₀ and O₃ were more closely to be discussed because of its strong correlation with the transboundary sources, due to

photochemical processes, the averaged concentration of other parameters is influenced more by the number of motor vehicles and emission by industrial activities near the monitoring stations.

The correlation between the air pollutants recorded to be the most significant correlated in Nilai whereas for Petaling Jaya and Seberang Perai the correlation was significantly correlated between the air pollutants and some of the meteorological parameters. Moreover, the high concentration of ozone (O₃) concentration recorded at Nilai, Petaling Jaya and Seberang Perai are intriguing and needs further investigation. Meteorological factors particularly humidity and the ambient temperature are expected to be associated with the concentration of ozone and suspended particulate matter. In terms of monthly variation there has been an obvious temporal variation of all three area that were seen to be similarly increase during the month of June until August where the highest PM₁₀ concentration were recorded on June at value of 68.326 µgm³, 59.432 µgm⁻³ and 51.13 µgm⁻³ respectively which might be due to Southeast monsoon.

5. References

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