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IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

The behavior of Particulate Matter (PM_{10}) Concentrations at Industrial Sites in Malaysia

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DOI: https://doi.org/10.30880/ijie.2019.11.01.023
Received 30 June 2018; Accepted 10 December 2018; Available online 15 May 2019

Abstract: Particulate Matter (PM_{10}) is one of the atmospheric pollutants that can cause significant effect to human health. Meteorological factors such as wind speed (WS), relative humidity (RH) and temperature (T), and gaseous pollutants namely surface layer ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO) are reported as some of the main factors that influence the concentration of PM_{10}. Therefore, the aim of this study is to investigate the pattern and behaviour of PM_{10} concentration at three industrial sites which were Pasir Gudang in Johor, Perai in Penang and Nilai in Negeri Sembilan. In the current study, the descriptive statistics, correlation analysis and multiple linear regressions were used to analyse the hourly average data from 2010 to 2014. The maximum values of PM_{10} concentration recorded at Pasir Gudang, Nilai and Perai stations were 995 $\mu g/m^3$, 711 $\mu g/m^3$ and 232 $\mu g/m^3$, respectively. Positive correlation was found between PM10 concentration and all gaseous pollutants. While for meteorological parameters, only wind speed had negative relations at all monitoring stations. The values of R2 for Pasir Gudang, Perai and Nilai were 0.539, 0.628 and 0.634, respectively. Overall, this study proved that most of the selected meteorological parameters and gaseous pollutants positively influenced the concentration of PM_{10}.

Keywords: air quality, gaseous pollutant, meteorological parameters, particulate matter (PM_{10})

1. Introduction

Rapid urbanization and industrialization have increased atmospheric pollution and created significant challenges to the developing countries [1-2]. Five major atmospheric pollutants namely Particulate Matter (PM), surface layer ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) are emitted as primary pollutants or formed as secondary pollutants by chemical reactions. However, the PM becomes the most important component as compared to other atmospheric pollutants and has adverse effects to the human health [3-4]. The particulate matters sizing less than 10 µm and 2.5 µm in aerodynamic diameter are classified and referred as PM_{10} and $PM_{2.5}$, respectively. The exposures to high PM_{10} concentration lead to asthma, respiratory problems and cardiovascular disease [5]. The PM_{10} reportedly contributes about 0.8 million premature cases and 2.1 million deaths worldwide [6-7].

In Malaysia, the PM_{10} concentration is mostly influenced by industrial, power plants and transportation activities. While during haze events, the major regional source of PM_{10} is biomass burning during dry season from June to September each year [8-9]. Apart from emission sources, complex interactions in various processes such as emission itself, transport and transformation are the common factors that influence meteorological parameters in PM_{10}

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concentration [10]. The meteorological variables namely ambient temperature, wind speed and relative humidity affect the concentration of atmospheric pollutant in numerous ways as demonstrated by the previous studies [3, 11]. Apart from that, the gaseous pollutant which are formed as primary pollutant of SO_2, NO_2 and CO also reported to influence the PM_{10} concentrations distribution pattern [12]. Factory activities containing sulfur and petrol fueled vehicle motor emission are considered to be the major sources of SO_2, meanwhile the NO_2 and CO come from power plants and diesel fueled vehicle emission [13-14].

The objective of this study was to evaluate the characteristics and behaviour of PM_{10} concentration at three (3) different selected industrial monitoring stations in Malaysia. The evaluation of characteristics and behaviour provide an overview of the dispersion pattern in all selected sampling stations. Monthly and high episode of PM_{10} concentration were analyzed and referred to the Malaysia Ambient Air Quality Guideline (MAAQG) for comparison. Moreover, Pearson correlation and multivariate analyses using multiple regression (MLR) models were used to obtain the correlation values (r) and coefficient of determination (R^2) to examine the relationships between independent variables with PM_{10} concentration. Findings in this study can be useful to the concerned government agencies in order to take any preventive and protective measures if needed. The provided data can also be used as a guideline to improve the air quality level in the selected sampling areas.

2. Material and Method

2.1 Study Area

This study focused at three different locations of industrial monitoring sites classified by the Department of Environment (DOE), Malaysia [20]. The selected monitoring locations were Pasir Gudang in Johor, Perai in Penang and Nilai in Negeri Sembilan, situated in Peninsular Malaysia. Pasir Gudang station is located in Johor, the southern region of Peninsular Malaysia. The area has dense industrial activities such as petrochemical, transportation and logistics, palm oil storage and distribution, shipbuilding and other heavy industries. Perai is situated in Penang, northern region of Peninsular Malaysia. The population is approximately 818, 917 and located at the northeastern tip of Penang Island. The area was developed from a mangrove swamp into an industrial area, which is the largest industrial area in northern Peninsular Malaysia. Nilai is situated in Negeri Sembilan, the southern region of Peninsular Malaysia. Recently, Nilai has undergone a development process especially in Bandar Baru Nilai. The details of the study area are illustrated in Table 1.

Table 1 - Location and description of selected monitoring stations

Station ID	Air Quality Monitoring station	Area	Coordinates
CA0001	Sek. Keb. Pasir Gudang 2, Pasir Gudang	Pasir Gudang	N 01º 28.225’ E 103º 53.637’
CA0003	Sek. Keb. Cederawasih, Taman Inderawasih, Perai	Perai	N05º 23.470’ E100º 23.197’
CA0010	Tmn. Semarak (Phase II), Nilai	Nilai	N 02º 49.246’ E 101º 48.877’

2.2 Air Quality and Meteorological Data

The actual monitoring records for air pollutants and meteorological parameters were retrieved from the Department of Environment (DOE), Malaysia. The recorded data was collected by subsidiary company of Alam Sekitar Sdn. Bhd (ASMA) and continuously monitored, 24 hours a day from the automatic air quality remote stations [15]. The hourly average of air pollutant concentration and meteorological parameters such as wind speed, relative humidity and ambient temperature were used in this study from January 2010 to December 2014. The pollutant concentrations at all monitoring stations were collected by ASMA using instrument called Beta Attenuation Mass Monitor (BAM-1020), Teledyne O_3 Analyser Model 400A UV Absorption, Teledyne Model 200A and Teledyne Model 300 for monitoring air pollutant concentration of PM_{10}, surface layer ozone (O_3), nitrogen oxides and carbon monoxide, respectively [16-17]. Meanwhile, for meteorological parameters measurement, a different set of specific instruments namely Met One 020C, Met One 062 and Met One 083D sensor were used. The reliability and quality of all recorded data is guaranteed since it has undergone the quality control established by the standard provided by DOE Malaysia.

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2.3 Statistical Approach

The descriptive statistics is widely used to describe and determine the characteristics of dispersion of air pollutant data. This study used the descriptive statistics in order to compare the characteristics of air pollutant data at each monitoring station. The dispersion pattern of air pollution of PM_{10} concentration was also determined including its behaviour at daytime and nighttime. Awang and Ramli [18] suggested that the collection of data during daytime was from 7.00 am to 7.00 pm, while for nighttime, from 7.00 pm to 7.00 am. The relationship of meteorological parameters (i.e. wind speed, temperature, and relative humidity) with other gaseous pollutants (i.e. O_3, SO_2, NO_2 and CO) and their significant relationship as well as the influence to PM_{10} concentration were analyzed using Pearson correlation and multivariate methods. Equation 1 shows the Pearson correlation coefficient in order to determine *r* value [19]. The method of multiple linear regressions was used as multivariate method to investigate the influence of several variables on the PM_{10} concentration.

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{\left[N\sum x^2 - (\sum x)^2\right]\left[N\sum y^2 - (\sum y)^2\right]}} \tag{1}$$

where, N = Number of data, $\sum xy$ = Sum of the multiply x and y data, $\sum x$ = Sum of x data, $\sum y$ = Sum of y data, $\sum x^2$ = Sum of squared x data, and $\sum y^2$ = Sum of squared y data.

3. Results and Discussion

3.1 Descriptive statistics

Figure 1 and Table 2 show the box plot and descriptive statistics for each selected monitoring station for 2013. The outliers represent extreme values that deviate significantly from the rest of sampling data. The median line within the box is not equidistant from the hinges and the box is also shifted significantly to the lower side which indicates that the PM_{10} data is positively skewed. All monitoring stations exceeded the maximum limit of Malaysian Ambient Air Quality Guideline (MAAQG) for hourly average concentrations of 150 μg/m³. The highest hourly average of PM_{10} was recorded at Pasir Gudang station with 995 μg/m³ whereas Perai station recorded the lowest maximum hourly average with 232 μg/m³. Nilai station recorded the highest mean concentration of 57.99 μg/m³ followed by Pasir Gudang and Perai stations with 50.99 μg/m³ and 38.30 μg/m³, respectively. From the analysis, the standard deviation, skewness and kurtosis recorded the highest concentration at Pasir Gudang station with 45.76 μg/m³, 7.97 μg/m³ and 111.58 μg/m³, respectively. While Perai station consistently recorded the lowest concentration as compared to other two stations. Malaysia experienced high particulate event in 2013 in Johor (Johor Bharu) and Negeri Sembilan (Nilai) due to trans-boundary haze pollution from Indonesia [20], hence affect the results.

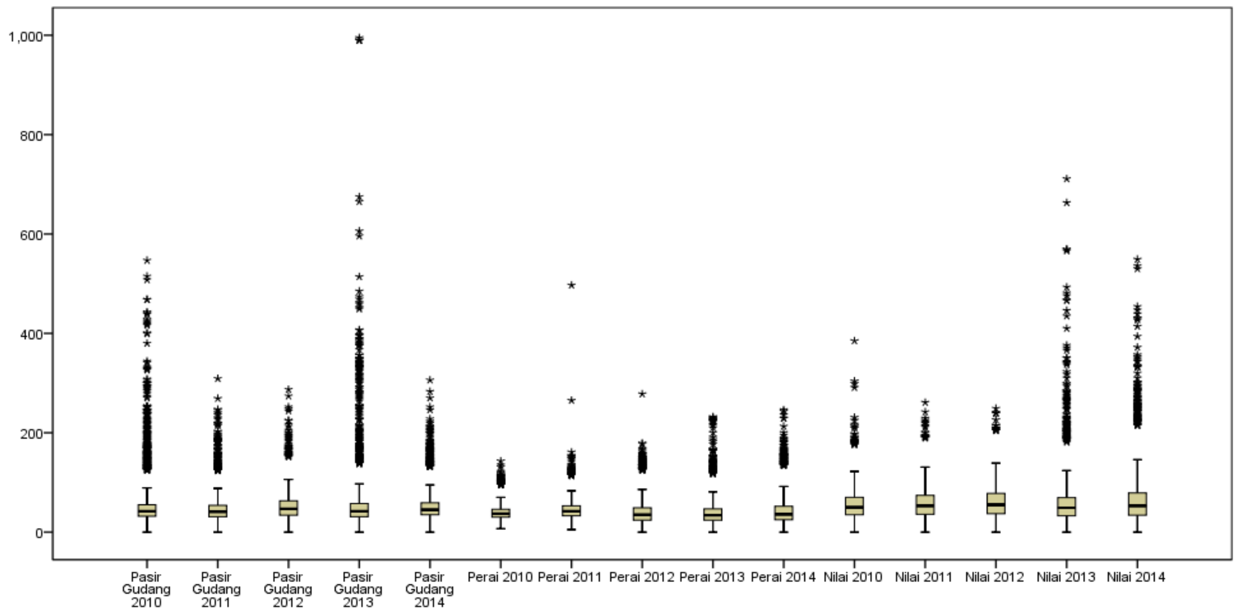

Fig. 1 - Box plot analysis for each monitoring station

3.2 Behavior of PM_{10} concentration

The average hourly behavior of PM_{10} dispersion pattern is shown in Figure 2. For all monitoring stations, it is clearly shown that there are two peaks of PM_{10} concentrations in a day. The first peak was recorded in daytime and another peak was observed in the nighttime. Nilai monitoring station consistently recorded the highest hourly average of PM_{10} concentration, followed by Pasir Gudang monitoring station. Meanwhile Perai recorded the lowest hourly average concentration of PM_{10} for all hours. The anthropogenic activities and motor vehicle emission caused the high concentration of PM_{10} in the daytime meanwhile at nighttime it was due to the unfavorable meteorological conditions

[21-23]. Since Pasir Gudang, Perai and Nilai stations are categorized as industrial stations, the main cause of PM_{10} concentration was due to the industrial discharged into the atmosphere and traffic emission from motor vehicles. More air pollution discharged from industrial area to atmosphere caused high level of PM_{10} concentration as claimed by previous researchers in [24]. The 34% of PM_{10} concentration is emitted from motor vehicles estimated from brakes and tyres [25], while 27.5% to 35% is estimated from exhaust [26]. The sea breeze and land breeze as well as the strong stability of atmosphere, usually from late afternoon to late morning contribute to the level of PM_{10} concentration [27]. This was similar to the behavior analysis for Pasir Gudang monitoring station. In this study, the PM_{10} concentration recorded at nighttime was higher as compared to daytime which shows similar outcome as claimed in Vecchi et al. [28] and Rodríguez et al. [29].

Table 2 - The descriptive statistics for each monitoring station from 2010 to 2014

Year	2010 (*μg/m³*)	2011 (*μg/m³*)	2012 (*μg/m³*)	2013 (*μg/m³*)	2014 (*μg/m³*)
Pasir Gudang station					
Mean	49.39	45.69	51.93	50.99	49.83
Standard Deviation	33.68	22.45	24.67	45.76	24.11
Median	42	41	48	43	45
Mode	35	37	38	42	40
Minimum	8	5	5	5	5
Maximum	547	309	287	995	306
Skewness	5.38	2.56	1.71	7.97	2.39
Kurtosis	48.29	13.63	6.49	111.58	11.06
Perai station					
Mean	39.26	45.65	41.26	38.30	42.37
Standard Deviation	13.677	18.135	24.142	21.594	25.578
Median	37	42	36	34	36
Mode	33	35	39	30	35
Minimum	5	5	5	5	5
Maximum	143	497	278	232	246
Skewness	1.365	3.110	1.772	2.375	1.948
Kurtosis	3.744	48.274	4.482	11.955	6.147
Nilai station					
Mean	55.80	58.82	61.08	57.99	63.78
Standard Deviation	27.848	29.511	30.816	39.234	43.727
Median	50.00	54.00	56.00	51.00	54.00
Mode	38	36	46	52	33
Minimum	5	6	5	5	5
Maximum	385	261	249	711	549
Skewness	1.528	1.078	1.107	4.399	2.723
Kurtosis	6.152	1.909	1.997	41.436	14.749

The total hours and days, and maximum values of PM_{10} concentration for all monitoring stations are tabulated in Table 3. Pasir Gudang station recorded the highest maximum limit of PM_{10} concentration for three years with were in 2010, 2012 and 2013. Meanwhile, Nilai and Perai stations recorded the highest maximum limit of PM_{10} occurred in 2014 and 2011, respectively. Even though Pasir Gudang monitoring station recorded the highest maximum limit, Nilai monitoring station observed the highest cumulative average hourly exceed of the Malaysia ambient air quality guideline (MAAQG). At Nilai station, from 2010 to 2014, a total of 776 hours exceeded the MAAQG followed by Pasir Gudang and Nilai monitoring stations with 468 hours and 92 hours, respectively. The highest recorded maximum limit of PM_{10} concentration was 995 μg/m³ at Pasir Gudang station in 2013. In 2013, Malaysia had experienced severe pollution from Sumatra and Kalimantan, Indonesia, from 15 to 27 June 2013 which severely affected Johor and Negeri Sembilan [20]. This trans-boundary haze caused the highest maximum limit recorded in 2013 at Pasir Gudang and Nilai stations.

The monthly distribution of PM_{10} concentration exceeded the MAAQG limit is shown in Table 4. This table shows the monthly exceeding of PM_{10} concentration in total hour. The analyses found two high episodes of PM_{10} at Pasir Gudang and Nilai stations occurred in June 2013 with a total of 149 and 131 hours, respectively. While in Perai monitoring station, the highest monthly PM_{10} exceeding MAAQG was observed in July 2014 with 26 hours. The recurrence of trans-boundary haze pollution causes the deterioration of air quality and usually occurs during the southwest monsoon where the number of hotspots recorded in Sumatra and Kalimantan, Indonesia escalates during haze event period. In Malaysia, the south west monsoon period starts from May and ends in September each year. The significant amount of particulate matter is transported by the south westerly winds from a neighboring country. Besides land clearing and forest fires in Indonesia, the localized source of PM_{10} from industrial activity, traffic emission and open burning also contribute to high PM_{10} episodes. During the dry period in 2014 between February and March, moderate haze episodes were reported due to local forest and peat land fires which resulted in high values of PM_{10} concentration episodes at Nilai station [30].

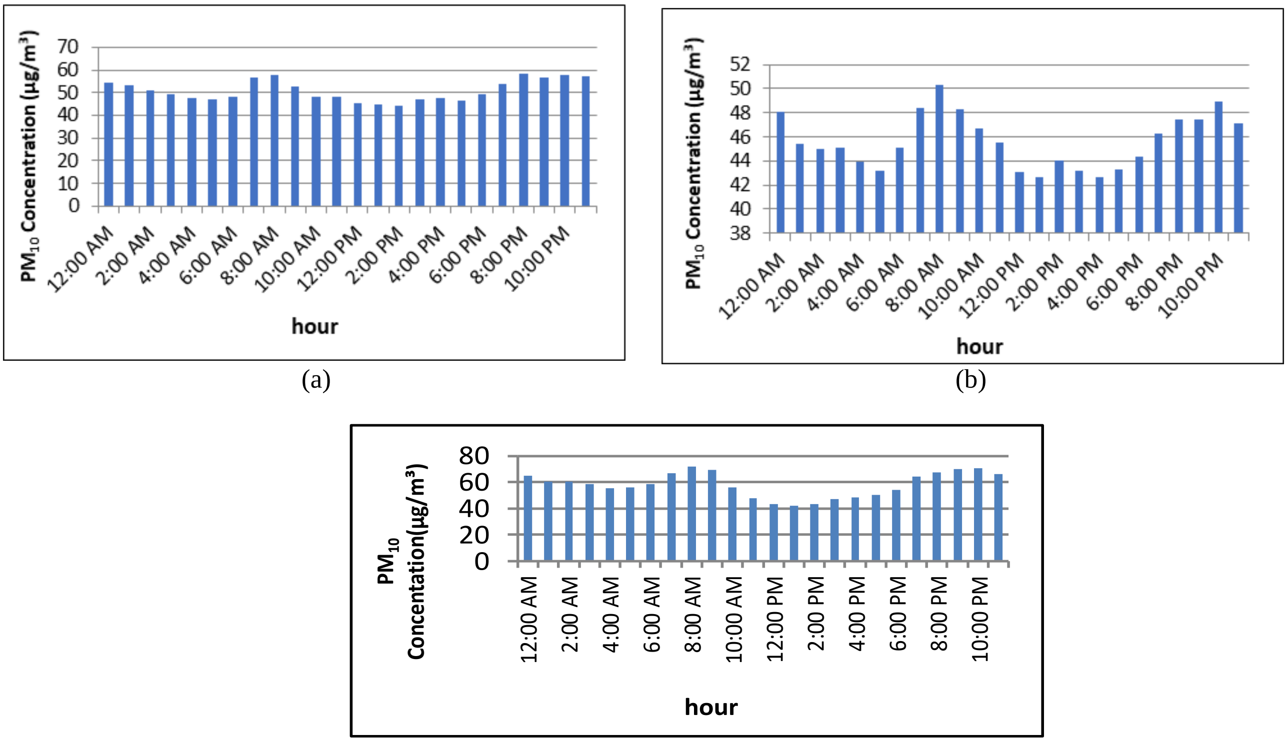

Fig. 2 - Hourly average of PM_{10} concentration from 2010 to 2014 for (a) Pasir Gudang, (b) Perai and (c) Nilai monitoring stations

Table 3 - Summary of total hours and days, and max values of PM_{10} concentration exceeding the Malaysia Ambient Air Quality Guideline (MAAQG) (150 µg/m³) for all monitoring stations from 2010 to 2014.

Year		Pasir Gudang	Perai	Nilai
2010	Total hours	141	0	61
	Total days	55	0	45
	Max PM_{10}	547	143	385
2011	Total hours	47	5	76
	Total days	24	4	31
	Max PM_{10}	309	497	261
2012	Total hours	36	14	118
	Total days	22	7	45
	Max PM_{10}	287	278	249
2013	Total hours	168	29	186
	Total days	26	5	31
	Max PM_{10}	995	232	711
2014	Total hours	60	54	330
	Total days	33	17	80
	Max PM_{10}	306	247	549

Table 4 - Summary of PM_{10} concentration exceeding Malaysia Ambient Air Quality Guideline (MAAQG) in monthly distribution (total hours) from 2010 to 2014

Station	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Pasir Gudang	2010	0	4	3	3	7	32	25	20	5	40	1	1	
	2011	0	0	0	0	5	13	16	2	7	4	0	0	
	2012	0	0	1	4	4	6	5	1	13	4	0	0	
	2013	0	3	0	1	2	149	0	0	7	3	3	0	
	2014	1	0	11	0	3	22	12	0	5	4	2	0	
	Total	1	7	15	8	21	222	58	37	37	55	6	1	468
Perai	2010	0	0	0	0	0	0	0	0	0	0	0	0	
	2011	0	1	0	0	0	0	2	1	1	0	0	0	
	2012	0	0	0	0	0	10	0	3	0	0	1	0	
	2013	0	0	0	0	0	19	9	1	0	0	0	0	
	2014	0	1	10	0	0	5	26	0	0	10	0	2	
	Total	0	2	10	0	0	24	37	5	1	10	1	2	92
Nilai	2010	0	0	9	3	3	11	2	4	4	17	6	2	
	2011	2	0	4	2	14	6	16	1	32	0	0	0	
	2012	2	0	6	0	14	23	2	30	50	0	1	1	
	2013	2	1	30	2	1	131	14	1	0	3	1	0	
	2014	0	27	121	6	0	25	16	0	34	72	19	5	
	Total	6	28	170	13	32	196	50	34	120	92	27	8	776

3.3 Correlation Analysis

The relationship between PM_{10}, meteorological parameter (i.e. wind speed, relative humidy and temperature) and gaseous pollutants (i.e. NO_2, SO_2 and CO and O_3) were statistically analyzed using Pearson correlation method and the results are presented in Table 5. Pasir Gudang showed that the PM_{10} concentration was positively significant to CO, O_3, NO_2, SO_2, and T. While WS and RH provided different results, which demonstrated significant negative correlation. This result was slightly different as compared to Nilai and Perai stations. All meteorological parameters namely RH, T and WS contributed significant negative correlation to PM_{10} concentration. The magnitude value near to 1 denoted almost similar in temporal behaviour between variables [31]. For that reason, based on the magnitude values, the strong relations were observed between PM_{10} and T, O_3 and CO at Pasir Gudang, Perai and Nilai stations respectively. Moderate relations were observed at Pasir Gudang and Perai stations between PM_{10} and CO. Additionally, Pasir Gudang also observed moderate relation between PM_{10} and O_3, and NO_2. While the rest of the variables showed weak relations to PM_{10} at all three stations.

Table 5 - Correlation coefficient (*r*) matrix between PM_{10}, meteorological parameter with gaseous pollutants for all monitoring stations

	PM_{10}	CO	O_3	NO_2	SO_2	RH	T	WS
				Pasir Gudang				
PM_{10}	**1**							
CO	0.534**	**1**						
O_3	0.201*	-0.54*	**1**					
NO_2	0.500**	0.482**	-0.299**	**1**				
SO_2	0.446**	0.389**	-0.333**	0.838**	**1**			
RH	-0.050*	0.323**	0.005*	0.264**	0.166*	**1**		
T	0.132*	0.127*	0.141*	0.109*	0.133*	0.297**	**1**	
WS	-0.700*	-0.292**	0.476**	-0.516**	-0.395**	0.253**	0.133*	**1**
				Perai				
PM_{10}	**1**							
CO	0.514**	**1**						
O_3	0.619**	0.376**	**1**					
NO_2	0.308**	0.746**	0.464**	**1**				
SO_2	0.300**	0.629**	0.350**	0.741**	**1**			
RH	-0.359**	-0.146*	-0.181*	-0.146*	-0.011*	**1**		
T	-0.235**	0.171*	0.205*	0.238**	0.115*	-0.162*	**1**	
WS	-0.202*	0.008*	-0.070*	-0.097	-0.190*	-0.124*	-0.064*	**1**

	Nilai							
PM_{10}	**1**							
CO	0.759**	**1**						
O_3	0.257**	0.221*	**1**					
NO_2	0.316**	0.361**	-0.319**	**1**				
SO_2	0.118*	0.227**	-0.199*	0.450**	**1**			
RH	-0.177*	-0.166*	-0.474**	0.52*	-0.071*	**1**		
T	-0.252**	0.203*	0.093*	0.054*	-0.082*	-0.043*	**1**	
WS	-0.273**	-0.159*	0.488**	-0.538**	-0.244**	-0.305*	-0.093*	**1**

WS: wind speeds, T: temperature, RH: relative humidity, SO_2Sulphur dioxide, NO_2: nitrogen dioxide , CO**:** carbon monoxide
** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Positive correlation was found between PM_{10} concentration and all gaseous pollutants (i.e. SO_2, NO_2 and CO) as all stations are classified as industrial areas. SO_2 gas is generated from industrial processing activities as well as petrol fueled vehicles. While CO and NO_2 gases are mainly released by motor vehicle and machinery that uses diesel fuel [13]. This may contribute to this positive correlation results. On the contrary, the positive relation between PM_{10} and O_3 was unexpected. This was due to O_3 known as secondary formation by precursor of SO_2 and volatile organic compound (VOC). Decreased visibility during the photochemical smog in O_3 event may initiate this relation [32]. The strong wind speed may disperse and dilute PM_{10} concentration which causes negative correlations [33]. Temperature in Malaysia normally varies from 24ºC to 32ºC and there is no significant fluctuation in temperature [13]. Therefore, the results gave negative correlation to PM_{10} concentration. The aerosol removal occurred during the condition of wet deposition which is known as precipitation or wet removal mechanism [34]. This happens when it is at high RH condition and expected to give negative correlation to PM_{10}.

3.4 Multivariate analysis

The analysis was continued to identify the factors affecting PM_{10} concentration using multivariate analysis namely multiple linear regression (MLR). The multivariate analysis can be applied to extract the major influencing factor for dependent variables [12,35]. At this stage, all variables were considered as one part of analysis to examine the most significant variable that influence PM_{10} concentration. Table 6 shows the results of multivariate analysis. All variables influenced PM_{10} concentration at Perai station. However, only five variables (i.e. CO, O_3, NO_3, RH and WS) and three variables (i.e. CO, O_3 and WS) influenced PM_{10} concentration at Pasir Gudang and Nilai stations. Overall, the values of coefficient determination (R^2) demonstrated the significant influence by other variables to PM_{10} concentration. The R^2 values between 0 to 0.449 and 0.5 to 1 indicate the weak influence and strong influence respectively. The values of R^2 obtained for Pasir Gudang, The values obtained in this study established that all independent variables such as CO, O_3, NO_3, SO_2, RH, T and WS were strongly influenced the concentration of PM_{10} at Pasir Gudang, Perai and Nilai stations.

Table 6 - Factors affecting PM_{10} concentration using multivariate analysis

	CO	O_3	NO_2	SO_2	RH	T	WS	R^2
				Pasir Gudang				
B (Standardized Coefficient)	0.463	0.266	0.436	0.188	-0.334	0.020	0.320	
Significance	**<0.0001**	**<0.0001**	**0.001**	0.103	**<0.0001**	0.756	**0.010**	**0.539**
				Perai				
B (Standardized Coefficient)	0.520	0.548	-0.503	0.177	-0.213	0.112	0.201	
Significance	**<0.0001**	**<0.0001**	**<0.0001**	**0.036**	**<0.0001**	**0.048**	**<0.000**	**0.628**
				Nilai				
B (Standardized Coefficient)	0.216	0.648	0.025	-0.067	-0.059	0.064	-0.290	
Significance	**<0.003**	**<0.0001**	0.732	0.273	0.344	0.248	**<0.0001**	**0.634**

WS: wind speeds, T: temperature, RH: relative humidity, SO_2Sulphur dioxide, NO_2: nitrogen dioxide , CO**:** carbon monoxide

4. Conclusions

Results the hourly average data of PM_{10} concentration, gaseous pollutant of CO, O_3, SO_2 and NO2 as well as meteorological variables of wind speed, temperature and relative humidity from January 2010 to December 2014 were used to analyze the characteristics, behavior, relations and influence of PM_{10}. The characteristics analysis exhibited that the maximum and minimum PM_{10} concentration were observed at Pasir Gudang (995 μg/m³) and Perai (232 μg/m³) stations respectively. Similar behavior in patterns of PM_{10} dispersion was observed at all stations. PM_{10} concentrations started to increase early in the morning at 8.00 am and early afternoon at 6.00 pm. The high correlation of O_3 with PM_{10} in Perai station is unexpected result which can be justified, since; the O_3 is secondary oxidation formation from its precursor of SO_2 and volatile organic compound (VOC). The only variable that was observed to have a negative relation to PM_{10} at all stations was wind speed (WS). Overall, values of R^2 obtained from multivariate analysis emphasized that the all variables CO, O_3, SO_2, NO_2, WS, T and RH were strongly influenced by the PM_{10} concentration. The values of R^2 were 0.539, 0.628 and 0.634 for Pasir Gudang, Perai and Nilai stations, respectively. These values indicate that of independent variables of meteorological parameter (i.e. wind speed, relative humidity, temperature) and gaseous pollutant (O_3, SO_2, NO_2 and CO) is significance to dispersion of PM_{10} concentration. The finding in this study can be useful to other researchers as well as the related government agencies in order to develop a policy related to PM_{10} concentrations especially in industrial areas. It is recommended to increase the number of stations to cover other areas in Malaysia to obtain a more accurate outcome in the future

Acknowledgement

Authors would like to thank the Department of Environment, Malaysia (DOE) for providing air quality data and Universiti Tun Hussein Onn Malaysia (UTHM) by Research Management Center (RMC) under Graduate Incentive Scheme (GPPS-Vote U792) for providing financial support for this research. Also thank to Fundamental Research Grant Scheme (Vote 1523) for publication support.

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