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Temporal Variation of Ambient PM_{10} Concentration within an Urban-Industrial Environment

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Abstract. PM10 concentration in the ambient air has been reported to be the main pollutant affecting human health, particularly in the urban areas. This research is conducted to study the variation of PM10 concentration at the three urban-industrial areas in Malaysia, namely Shah Alam, Kuala Terengganu and Melaka. In addition, the association and correlation between PM10 concentration and other air pollutants will be distinguished. Five years interval dataset (2008-2012) consisting of PM10, SOX, NOX and O3 concentrations and other weather parameters such as wind speed, humidity and temperature were obtained from Department of Environment, Malaysia. Shah Alam shows the highest average of PM10 concentration with the value of 62.76 µg/m³ in June, whereas for Kuala Terengganu was 59.29 µg/m³ in February and 46.61 µg/m³ in August for Melaka. Two peaks were observed from the time series plot using the averaged monthly PM10 concentration. First peak occurs when PM10 concentration rises from January to February and the second peak is reached in June and remain high for the next two consecutive months for Shah Alam and Kuala Terengganu. Meanwhile the second peak for Melaka is only achieved in August as a result of the transboundary of smoke from forest fires in the Sumatra region during dry season from May to September. Both of the pollutants can be sourced from rapid industrial activities at Shah Alam. PM10 concentration is strongly correlated with carbon monoxide concentration in Kuala Terengganu and Melaka with value of r2 = 0.1725 and 0.2744 respectively. High carbon monoxide and PM10 concentration are associated with burning of fossil fuel from increased number of vehicles at these areas.

1 Introduction

In Malaysia, PM_{10} is one of the major air pollutants and is decisive in the determination of Malaysian Air Pollution Index (API) [1]. It is believed to have an effect on the human respiratory system which in turn may result in chronic obstructive pulmonary disease and asthma. Located in the centre of South East Asia, Malaysia is experiencing rapid urban growth and is affected by local and regional air pollution [1]. The main sources of air

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pollutants in Malaysia are mobile sources particularly motor vehicles, stationary and transboundary emission.

Air pollution can only be controlled through the emission sources pathways. Alteration of both indoor and outdoor air quality may happens when chemical, biological or physical agents are present in the original air composition. In fact, particulate matter in air pollution has been reported to be the imperceptible health deteriorating issue in Malaysia among these environmental pollution problems as indication in the Air Pollution Index (API) [1]. About 6.5 million people were reported death due to deteriorate indoor and urban air quality in 2012 [2]. This research is conducted for the purpose to statistically describe characteristic of particulate matter, identifying correlation of PM_{10} with other air pollutants using Pearson Correlation. The areas of interest are within an urban-industrial environment that are Shah Alam, Kuala Terengganu and Melaka with the claim that urbanisation with industrial development can speeds up the rate of vehicle exhaust emission.

2 Methodology

2.1 Study Areas

Three urban-industrial areas were chosen in this study, namely Shah Alam, Kuala Terengganu and Melaka. Selangor is one of the 13 states that are well recognized to be the largest industrial region located at the west coast of Peninsular Malaysia. Air quality monitoring station of Shah Alam is geographically located at latitude N 03º 06' 17" and longitude E 101º 33' 22" at Sekolah Menengah Kebangsaan TTDI Jaya, Shah Alam. Second study area is Kuala Terengganu, which is the capital city of Terengganu that is located at the eastern coastal area of the peninsular Malaysia. The air quality monitoring station is situated at latitude N 05º 18' 455" and longitude E 103º 07' 213" at SK Pusat Chabang Tiga. Third air quality monitoring station is in Melaka which is geographically located at latitude N 02º 15'510" and longitude E 102º 10' 364" at Sekolah Menengah Kebangsaan Bukit Rambai, Melaka The capital city of Melaka covers a total area of 1664 km^2 and is bordered by Strait of Malacca. During the study period, the population has reached 842,500 in 2012 [3].

Besides PM_{10} concentration, other air pollutants (i.e. carbon monoxide, ground level ozone, nitrogen dioxide, sulfur dioxide, non-methane hydrocarbon concentration) and meteorological parameters (i.e. relative humidity, ambient temperature, wind speed, UVB) were also used for studying the variation of PM_{10} in these areas.

2.2 Association of PM_{10} concentration with the trace gases and weather parameters

Pearson correlation measures the degree of the linear relationship between two variables. By linear relationship, the relationship can be well-characterized by a straight line. Correlation ranges from -1.0 to +1.0, denoted by the letter r in Pearson correlation. There are three types of relationships: i) positive relationship (higher scores on other air pollutants concentration are associated with higher scores on PM_{10} concentration), negative (higher scores on other air pollutants concentration are associated with lower scores on PM_{10} concentration) and no relationship (there is no linear relationship between other air pollutants concentration and PM_{10} concentration).

3 Results and Discussions

3.1 Characterisation of PM_{10} Concentration

Fig. 1 illustrates the monthly concentration of PM_{10} in the study areas. The results show that there were two peaks observed in all the three study areas, which occurred in February and June (Shah Alam and Kuala Terengganu) while for Melaka, the second peak is in August. This is due to the southwest monsoon that occurred in Malaysia where the dry season started. In addition, the effect of transboundary particulate pollution from Sumatras will also make the peaks more significant [4]. The first peak is achieved in earlier month of the year at the three study areas where PM_{10} concentration rises from January to February as shown in Fig. 1 (a), (b) and (c). This happened due to minimum rainfall during the southwest monsoon. PM_{10} concentration for the three stations decreased in March before started to increase gradually to reach the second peak in June at Shah Alam, Kuala Terengganu and in August in Melaka. PM_{10} concentration remained high for the next two consecutive months as the ambient temperature rises during the dry monsoon (southwest monsoon) season [5]. Next, PM_{10} concentration decreased to the lowest concentration throughout the end of a year in November and increased slightly in December. The low PM_{10} concentration in November and December occurred due to high rainfall rate over the southwest and east coastal areas of peninsular Malaysia, where these areas experienced the northeast monsoon. The particulate matter that suspended in the atmosphere can be washed away by the rain precipitation and deposition [6].

The overall comparison of the average monthly PM_{10} concentration for Shah Alam, Kuala Terengganu and Melaka is indicated in Fig. 1(d). Overall, the highest PM_{10} concentrations were recorded in Shah Alam followed by Kuala Terengganu and Melaka. Most of the time, the concentration of PM_{10} in Shah Alam and Kuala Terengganu did not exceed the recommended value of Malaysia Ambient Air Quality Guideline (MAAQG) that is 150 $\mu g/m^3$. The PM_{10} concentration in Kuala Terengganu is the highest in February and in July due to high population with variety of commercial activities including airport station results in air pollution at this study area as the city center of Terengganu state. This situation can also be explained by the evaporation of seawater, which form salt particles in the atmosphere [7]. On the other hand, the PM_{10} concentration in Shah Alam recorded higher concentration than Kuala Terengganu from May until October. This may be due to the location of the station that is surrounded by the busy road in a mixed residential and commercial area. Besides that, the location of Shah Alam at the southwest coastal which near Indonesia also brought hot wind during southwest monsoon. Melaka shows the lowest PM_{10} concentration compared to the other two stations. The PM_{10} concentration exceeded Kuala Terengganu in the August and September due to southwest monsoon.

Table 1 indicates the tabulated values of the total number of unhealthy hours and unhealthy days recorded in Shah Alam, Kuala Terengganu and Melaka during the 5 years of the study period. The unhealthy hours and days were calculated based on the number of exceedances of PM_{10} concentration that were exceeded 150$\mu g/m^3$ according to Malaysia Ambient Air Quality Guidelines (MAAQG).

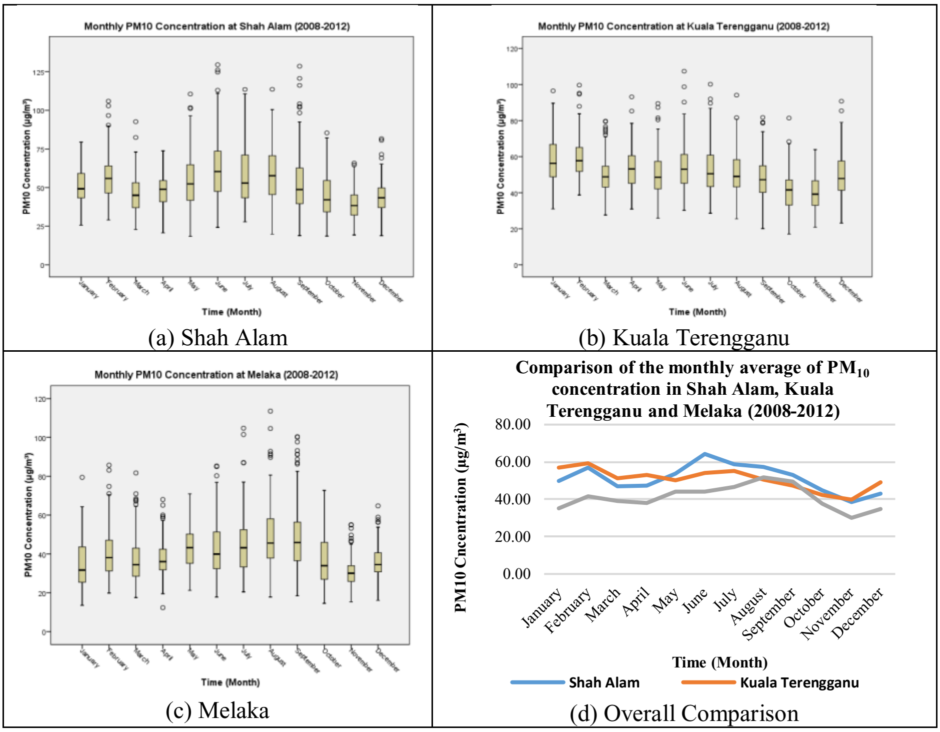

Fig. 1. Monthly concentration of PM_{10} in the study areas.

Table 1. Exceedances of PM_{10} Concentration.

Stations	Exceedance									
	Total Number of Hours*					Total Number of Days**				
	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
Shah Alam	24	57	3	34	78	22	23	3	11	14
Kuala Terengganu	32	59	25	34	19	21	34	18	23	16
Melaka	11	116	75	33	15	10	54	44	22	12

Remark :
* represents number of hours that the PM_{10} concentration exceeds 150 µg/m³ according to Malaysia Ambient Air Quality Standard
** represents number of days account for at least 1-hour PM_{10} concentration exceeds 150 µg/m³ according to Malaysia Ambient Air Quality Standard

The highest numbers of unhealthy hours due to high PM_{10} concentration for Shah Alam is 78 hours in 2012 as haze attributed mostly due to the transboundary air pollution caused by the fire burning on the Indonesia island of Sumatras, where the strong wind brings the fumes across the Melaka Strait to Malaysia during the dry monsoon season [8]. For Kuala Terengganu and Melaka, both recorded the highest numbers of unhealthy hours for 59 hours and 116 hours in 2009. On the other hand, the highest numbers of unhealthy day are observed to be in 2009 for 23 days, 34 days and 54 days at the three study areas respectively. During that year, all the three studied areas recorded the highest number of unhealthy days that were 54 µg/m³, 34 µg/m³ and 23 µg/m³ in Melaka, Kuala Terengganu and Shah Alam respectively. This situation happens due to the effect of El Nino that occurred in June 2009 until May 2010. This is a periodical occurrence where the sea surface temperatures in the central and eastern Pacific Ocean become warmer than usual.

The consequence is significant throughout Malaysia especially in Melaka, which situated near the Pacific Ocean [9].

3.2 Correlation of PM_{10} concentration with the trace gases and meteorological parameters

Table 2 shows the result of Pearson analysis for Shah Alam, Kuala Terengganu and Melaka. The correlation between the dependent (PM_{10}) and the independent variables (CO, O_3, NO_2, SO_2, relative humidity, ambient temperature and wind speed) is as bolded. There is a significant positive relationship between the non-methane hydrocarbon (NmHc) concentration and PM_{10} concentration at Shah Alam with r = 0.534. High PM_{10} concentration associated with non-methane hydrocarbon because of the emission of acetylene, alkenes from combustion of fossil fuel, release of i-butane and i-pentane from paint and solvent utilization and volatilization of benzene and toluene from chemical cleaning process [10].

Table 2. Pearson correlation matrix of PM_{10} concentration with the trace gases and weather parameter

					Shah Alam					
	PM_{10}	CO	O_3	NO_2	SO_2	NmHC	H	UVB	T	WS
PM_{10}	1									
CO	.498**	1								
O_3	.206**	-.050*	1							
NO_2	.503**	.681**	.030	1						
SO_2	.303**	.192**	.084**	.273**	1					
NmHC	**.534****	.688**	-.020	.598**	.376**	1				
H	-.264**	.113**	-.355**	.094**	-.172**	.115**	1			
UVB	-.026	-.097	.285**	-.175**	.038	-.040	-.343**	1		
T	.303**	-.016	.405**	-.014	.205**	-.003	-.838**	-.382**	1	
WS	-.221**	-.509**	.109**	-.486**	-.115**	-.526**	-.377**	.251**	.281**	1
					Kuala Terengganu					
	PM_{10}	CO	O_3	NO_2	SO_2	H	T	WS		
PM_{10}	1									
CO	**.416****	1								
O_3	.308**	-.008	1							
NO_2	.364**	.351**	.144**	1						
SO_2	.109**	.085**	-.104**	.082**	1					
H	-.381**	.019	.303**	.038	-.090**	1				
T	.230**	.028	.094**	.031	.085**	-.603**	1			
WS	.041	-.241**	.455**	-.385**	-.166**	-.208**	-.082**	1		
					Melaka					
	PM_{10}	CO	O_3	NO_2	SO_2	H	T	WS		
PM_{10}	1	.547**	.375**	.444**	.283**	-.186**	.275**	.010		
CO	.547**	1	-.094**	.601**	.145**	.093**	.029	-.233**		
O_3	.375**	-.094**	1	-.054*	.216**	-.432**	.378**	.143**		
NO_2	.444**	.601**	-.054*	1	.352**	.245**	.071**	-.367**		
SO_2	.283**	.145**	.216**	.352**	1	-.081**	.223**	.047		
H	-.186**	.093**	-.432**	.245**	-.081**	1	-.684**	-.263**		
T	.275**	.029	.378**	.071**	.223**	-.684**	1	.088**		
WS	.010	-.233**	.143**	-.367**	.047	-.263**	.088**	1		

For Kuala Terengganu, the most significant positive relationship was found to be between PM_{10} concentration and carbon monoxide concentration that was released from the combustion of fossil fuel in automobiles with the r = 0.416 [11].

The air pollutant that has the most significant positive correlation with PM_{10} concentration in Melaka was carbon monoxide concentration with r = 0.547. Apart from transportation, a significant concentration of carbon monoxide are also due to combustion of paddy field in agricultural activities [1].

4 Conclusions

The variations of PM_{10} concentration in the three urban-industrial areas i.e. Shah Alam, Kuala Terengganu and Melaka were analysed in this study. From the monthly variation, two peaks were observed in February and June. The first peak started from November to March while the second peak occurred in June for Shah Alam and Kuala Terengganu and August for Melaka. This is due to the southwest monsoon that occurred in Malaysia where the dry season starts from June to September. Other external contributing factor is the effect of transboundary particulate by forest fires from Sumatras. The exceedances of the PM_{10} concentration according to Malaysia Ambient Air Quality Guidelines (MAAQG) at $150 \mu g/m^3$ were done to observe the total hours and total days of PM_{10} concentration exceeding the recommended value. The highest occurrence of unhealthy hours and unhealthy days are recorded in 2009. This can be explained that extreme high ambient temperature caused by El Nino effect, which leads to high particulate event in Shah Alam, Kuala Terengganu and Melaka. From Pearson correlation, the factor that has the most significant relationship with the PM_{10} concentration at Shah Alam is non-methane hydrocarbon (NmHc) whereas for Kuala Terengganu and Melaka, high concentration of PM_{10} is associated with the high carbon monoxide concentration. These relationships can be explained due to the surrounding of the monitoring stations that were located at the busy road and nearby the commercial areas.

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