EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 11(2) (2018) 23-37
DOI 10.14456/ea.2018.20
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Preliminary Analysis of Traffic-Related Pollutants Measurements in Different Petaling Jaya Streets

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Received: November 29, 2017; Accepted: March 6, 2018

Abstract

This paper presents the preliminary analysis and trends of traffic pollutant released and assessment results in urban areas in Petaling Jaya, Selangor. The outcome indicates that road traffic and its infrastructure are the leading issues of air pollution problems in this study area. However, there exists a lack of research that has verified this assumption, considering real-world data of localized traffic flow. In this study, traffic pollutants data were collected at different street categories and investigated prior to traffic flow data. The concentration level were then compared with several guidelines and related previous studies where NO_2 and $PM_{2.5}$ show considerably high amount of concentration which exceed all of the guidelines provided. The final results reveal that most of the concentration of the traffic-related pollutants measured except for NO_2 and CO are significantly different at all type of streets where higher amount of concentration was found at highways and local streets rather than urban streets, attributable to the higher traffic volume associated with the former. The statistical analyses of both the traffic pollutants and its flow data was then conducted, and the spatial analysis using interpolation was finally demonstrated.

Keyword: Trends; Traffic pollutant; Localized; Interpolation

Introduction

Air pollution issues in urbanized areas of a city are often associated with increasing traffic volume. Undoubtedly, the yearly increment of vehicles on the road in Malaysia contributes the most to our air quality problem, where solutions and mitigation measures to overcome this issue remains hanging, especially in developing countries such as Malaysia. Despite all the recorded unhealthy conditions of air quality from the existing ambient monitoring stations, there is a lack of research on the mobile source at specific locations. Currently, there are no existing database in Malaysia for this particular reason. Therefore, the main goal of this study is to discover the extent pollution measurements are affected by the changes of the traffic volume, and by the influence of meteorological parameters. In this context, the spatial and temporal patterns of criteria pollutants, particularly for mobile sources, in urban areas of Petaling Jaya, Selangor were analyzed. The existing trends of traffic density, with the aim to improve current knowledge of the level of various air pollutants from vehicular emission, were also highlighted, which may prove to be useful in the management of air quality at critical urban areas in Selangor.

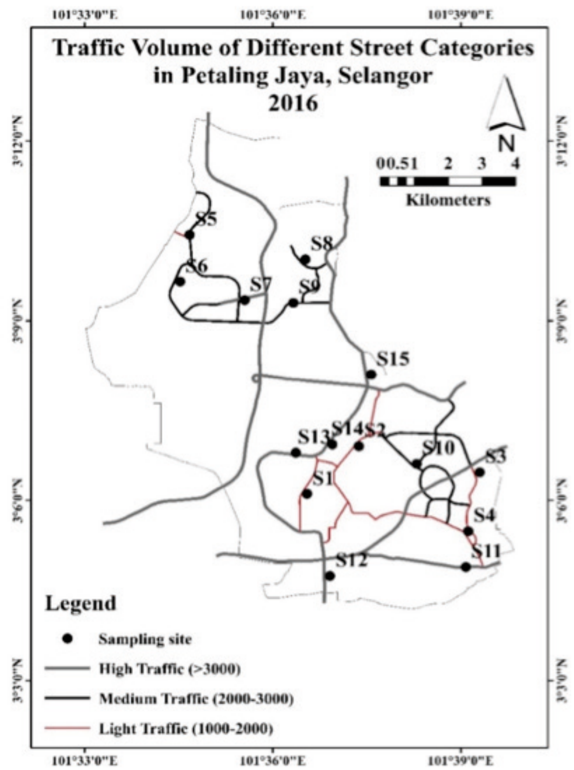

Figure 1. Sampling site location and traffic volume of different street categories in Petaling Jaya, Selangor

Methodology

Study area description

In Petaling Jaya, a densely populated area, total of fifteen sampling points were chosen to measure the on-site traffic-related pollutants, and its traffic density and flow. Despite the fact that the traffic and population density in this area is the highest in the country, the region is considered to be the most polluted area in Malaysia (Abas *et al.,* 2004). Besides, Ling *et al.* (2014) also reported that Petaling Jaya is among the most urbanized areas in Malaysia, with many consequential issues on unhealthy air quality records.

The site and traffic data

A pre-site visit was conducted beforehand in order to access suitable monitoring locations in Petaling Jaya that might experience high levels of air pollution, particularly major air pollutants emitted from exhaust vehicles. Based on the speed and function of the street, the street categories were classified into three major groups, namely, highways, urban streets and local streets. To define each street in this study, highways are considered as toll expressways while urban streets are described as main urban streets (basic network roads within the city). In the meantime, local streets are explained as basic road network within a neighborhood or residential area.

The pollutants were measured using different time-series equipment involving nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2) and particulate matter less than 2.5 ($PM_{2.5}$) and 10 micrometers (PM_{10}). Meteorological parameters including wind speed (WS), temperature (Temp), relative humidity (RH), pressure (P), altitude (Alt), and rainfall, were also measured using a portable weather meter. The pollutants were measured for one-day sampling of 12-hour period, during both rush and non-rush hours during weekdays. The rush-hour period lies within two timeframes, namely, from 7:00 am until 10:00 am (during which people usually go to work), and from 4:00 pm until 7:00 pm (during which people usually go back home from work). The non-rush hour period is considered to be the period from 10:00 am until 4:00 pm. Meanwhile, traffic counts was manually counted and estimated at different streets, according to five vehicle categories, namely, cars, light trucks (less than two axles), heavy trucks (more than two axles), buses and motorcycles. Details on the characteristics of sampling site are shown in Table 1; while Table 2 summarizes the types of equipment used to measure the pollutants and traffic parameters.

Table 1 Characteristics and coordinates of street categories in study area

Site	Category	Location	Longitude	Latitude
S1	Local	Jalan Majlis	101.60909	3.10186
S2	Local	Jalan SS2/24	101.62291	3.11517
S3	Local	Jalan Gasing	101.65501	3.10793
S4	Local	Jalan Templer	101.65196	3.09150
S5	Local	Persiaran Jati	101.57788	3.17392
S6	Urban	Persiaran Surian	101.57536	3.16089
S7	Urban	Persiaran Mahogani	101.59254	3.15576
S8	Urban	Jalan PJU 8/1	101.60866	3.16712
S9	Urban	Persiaran Surian (Pelangi Damansara)	101.60546	3.15500
S10	Urban	Jalan Semangat	101.63828	3.11028
S11	Highway	NPE–Taman Petaling Utama	101.65134	3.08156
S12	Highway	DPE–BHPetrol	101.61520	3.07909
S13	Highway	DPE–Kelana Jaya	101.60613	3.11337
S14	Highway	DPE–SS2	101.61581	3.11566
S15	Highway	DPE–Damansara Utama	101.62621	3.13511

NPE New Pantai Espressway; *DPE* Damansara Puchong Expressway

Table 2 Type of equipment used to measure air and traffic data

Data	Equipment used	Model
NO_2	Portable VOC Monitor	MiniRAE 3000
CO	Air Quality Monitor	TSI 7575 Q-Trak
CO_2	Air Quality Monitor	TSI 7575 Q-Trak
$PM_{2.5}$	Aerosol Monitor	Dust Trak II 8530
PM_{10}	Aerosol Monitor	Dust Trak II 8530
WS, Temp, RH, P, Alt	Weather Meter	Kestrel 4500
Rainfall	Rain Gauge	N/A
Vehicle count	Video camera	N/A

N/A Not applicable

Comparison to several guidelines and traffic-related studies

The hourly trends of the traffic air pollutants obtained from the real-time measurements were further analyzed by comparing the concentration values with standard guidelines, such as Malaysian Ambient Air Quality Guidelines (MAAQG), World Health Organization (WHO) guidelines and United States of Environmental Protection Agency (USEPA) of National Ambient Air Quality Guidelines (NAAQS). In spite of the guidelines referred, the comparison is made based on the ambient air pollutants limit, as there are no standard guidelines established from the line source. Therefore, a number of traffic-related studies were chosen as a reference to ensure that the results acquired are similar with studies carried out on other regions throughout the world.

Statistical analysis

To compare whether there is any significant difference among the mean concentration for all types of street categories, one-way analysis of variance (ANOVA) and post hoc test analysis of Tukey-Kramer procedure was conducted to see which type of streets differ to one another. The Pearson Correlation Test was used to determine the relationship between the traffic-related air pollutants and the meteorological parameters, as the data were normally distributed using IBM SPSS statistical software version 22. The strength of the relationship of the subgroups was based on Guilford's principle correlation coefficient, where an r-value of 0.00 to 0.49 is considered a low correlation, 0.50 to 0.69 as a medium correlation, and 0.70 to 1.00 as a high correlation (Guilford and Fruchter, 1973).

Interpolation using Geographical Information System (GIS)

The interpolation approach was employed in this study to assess the spatial distribution of air traffic-related data in the Petaling Jaya area as a whole. The application of geostatistical analysis in this study is useful to visualize the air pollution transportation, as well as to assess the relationship between high concentration levels and the potential sources of pollution. The analysis was performed using ArcGIS 10.2.1, where the inverse distance weight (IDW) was chosen as the interpolation method. The concept of IDW can be concluded in a manner that estimates the cell values by averaging sample data points values in the neighborhood of each processing cell. The averaging values estimated at the end of the process are highly influenced by the nearest point location. Based on certain aspects and criteria taken into account, the IDW was the best spatial interpolation method used, as it offers a low root mean square error (RMSE) value in comparison to other interpolation techniques such as kriging and spline (Lu and Wong, 2008).

Results and discussion

Hourly trends of traffic air pollutants in different street categories and comparison to several guidelines and related previous studies

Figure 2a, 2b, 2c, 2d and 2e illustrates the hourly trends of NO_2, CO_2, CO, $PM_{2.5}$ and PM_{10}, respectively, during both rush and non-rush hour periods, at various street categories in Petaling Jaya, Selangor. The average hourly number of vehicles running on the main streets in the city ranges from 1000 to more than 3000 vehicles/day, as shown in Table 3. Generally, most of the vehicles passing through all of the streets are dominated by passenger cars (77.2%), followed by motorcycles (18.3%), light trucks (3.3%), heavy trucks (0.7%) and buses (0.4%). To ensure a comprehensive study, all of the total mean concentrations of traffic-related pollutants are compared to several guidelines, as tabulated in Table 4. Generally, the study revealed that most of the streets in Petaling Jaya suffer from high concentrations of gaseous pollutants, primarily from traffic-related emissions that exceed the maximum limit, according to a number of guidelines.

In the meantime, results of one-way ANOVA analysis disclosed that there was a statistically significant difference between each type of street categories, with a $p\text{-value} < 0.05$ for all type of pollutants. And the Tukey-Kramer procedure output indicate that almost all traf fic-related pollutants have significant differences between each type of street categories except for NO_2 showing no significant difference in their mean concentration for urban street and highways, while CO displayed no significant difference for local street and highways.

Overall, the majority of the pollutants show almost the same hourly trends during a 12-hour period, at all types of streets. Theoretically, this assumes that the concentration of pollutants occurred twice a day, which spike during rush-hour periods (morning rush hour and evening rush hour). The concentration of most of the pollutants (e.g. NO_2, CO, $PM_{2.5}$ and PM_{10}) started to peak at 7:00 to 10:00 am; gradually decreased during the non-rush hour period (10:00 am to 4:00 pm); and then increased once again during the evening rush hour (4:00 pm to 7:00 pm). These observations can be explained by the fact that people commute the most during these periods, where morning rush hour and evening rush hour involved people traveling to and from the workplace. There was a relatively high traffic volume of vehicles at most of the streets during these times, where traffic tended to moved slowly, consequently resulting high smoke, particulate and emission of carbon monoxide.

Figure 2a visualizes a clear pattern for temporal variations of NO_2 pollutants at highways, urban streets and local streets. The variations show a similar pattern across all types of streets, where highways represent a slightly higher concentration when compared to urban and local streets. This is due to its high traffic volume, as shown in Fig. 1 and Table 3. The NO_2 concentration measured ranges in between 5.45 and 9.97 ppm, where it peaks at 8:00-10:00 am, and then decreases gradually before it rises once again 4:00-7:00 pm; which exceeds MAAQS, WHO guidelines and USEPA NAAQS Standards (> 0.5 ppm). The reason for this is because the guidelines used are designed specifically for ambient air quality, whilst the focus of the

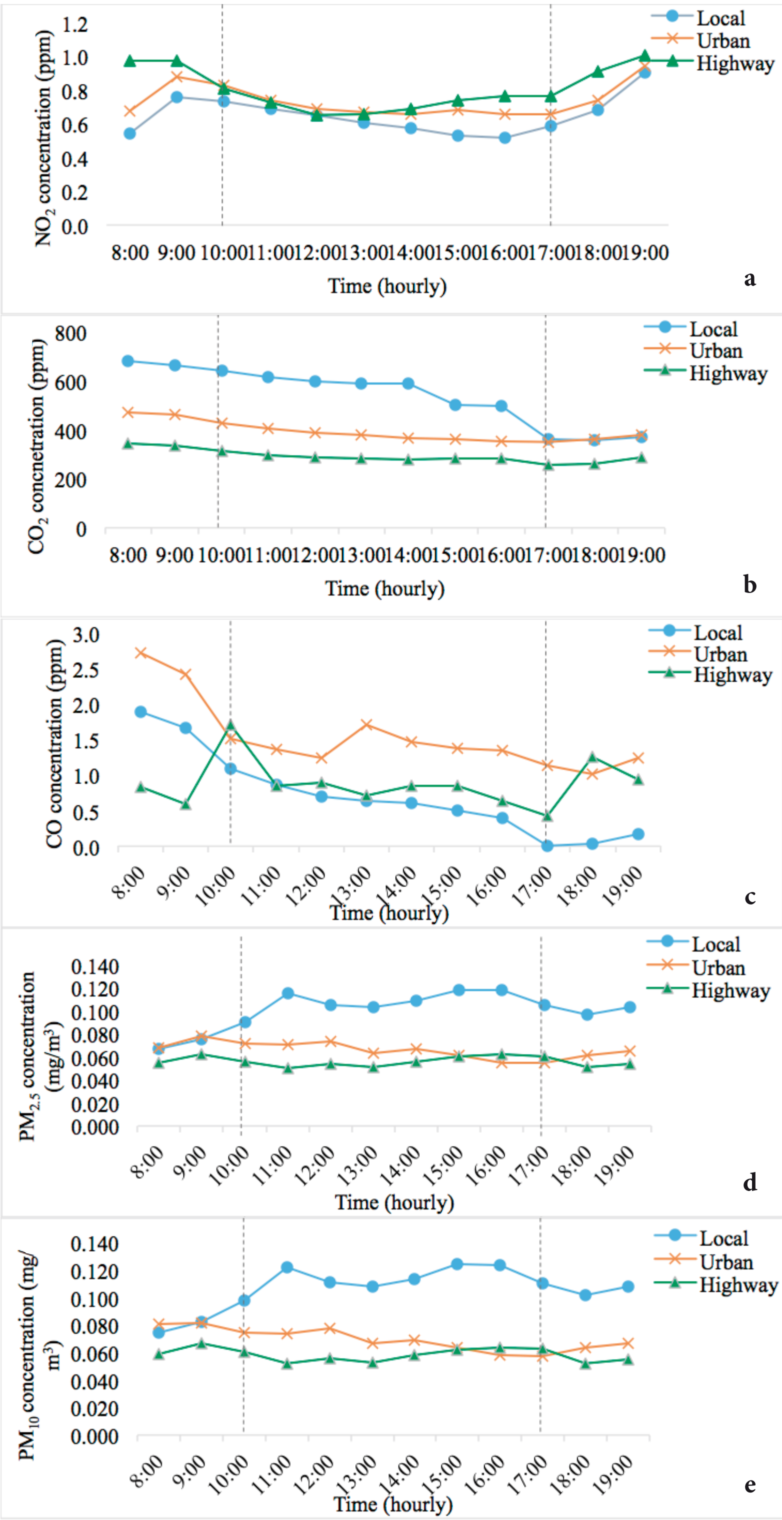

Figure. 2a, 2b, 2c, 2d, 2e Hourly concentration of NO_2, CO_2, CO, $PM_{2.5}$ and PM_{10} in different street categories in Petaling Jaya, Selangor respectively research is directly measured from the traffic line sources. Therefore, the level of concentration is expected to be high at localized sources compared to the ambient ones. Other than the conditions of vehicles in terms of poor maintenance, fuel types may also play a significant contribution to the traffic emission.

Figure 2b does not mark much variation of CO_2 concentration levels (269 – 946 ppm), except during the evening rush hour period, where the concentration decreases gradually during this period. According to the European (EU) reports, the CO_2 emissions from road transport contributes to around 10% of the total global, and 20% of the European, atmospheric CO_2 emissions (Metz, 2001; Nejadkoorki *et al.*, 2008). These emissions remain to rise, probably due to the increasing number of road freight traffic.

Hourly-averaged CO concentrations shown in Fig. 2c for the sampling sites varied within the range of 0.0 – 2.6 ppm, which was way below the level of concentration when compared to any of the guidelines provided in Table 4. When compared with all types of streets, urban streets seem to have a higher concentration of CO compared to highways and urban streets. This is expected, because highways are engaged with more lanes compared to local and urban streets, which occupy more than 3000 vehicles per day. Frequent traffic jams and low speeds were exhibited, despite of a very low concentration of pollutants, within allowable limits.

Conversely, noticeably higher measured particulate matter concentrations were found at the streets in the study area. Figure 2d and 2e illustrates almost the same trends of concentration levels, where the rush hour period evolved at almost the same time as mentioned above. However, local streets accumulated pollutants the most compared to urban streets and highways, which is probably due to its location being nearby the traffic junction of traffic lights or other contributing factors such as from non-exhaust emission which is from the abrasion of tyres and brakes, as well as road suspension wear or re-suspension of road dust. This consequently triggers the concentration level of pollutants, as the motion of vehicles at this current state are mostly in idling and deceleration driving modes. Based on the monitoring results in Table 4, the concentration of $PM_{2.5}$ was detected to vary in between 48 and 121 $\mu g/m_3$; while the concentration of PM_{10} was observed to be 49–128 $\mu g/m_3$. The results were found to be within the allowable limits of 150 $\mu g/m_3$; when compared to the 24-hour MAAQG and USEPA NAAQS limits. Nevertheless, WHO guidelines strictly limit the concentration down to 50 $\mu g/m_3$ for the uncompromising health risks such as reduced lung capacity, respiratory infection and premature death.

Table 3 Characteristics of selected sampling sites/street in the study area

Site	Category	Configuration	Traffic volume (vehicle/day)	
			Rush hour	Non-rush hour
S1	Local	2-lane (both ways), residential, school	1380	960
S2	Local	2-lane (both ways), residential, commercial and school	1320	1200
S3	Local	2-lane (both ways), residential, commercial and school	1680	2220
S4	Local	2-lane (both ways), residential	1140	1260
S5	Local	2-lane (both ways), residential	1140	660
S6	Urban	2-lane (both ways), commercial	2100	1320
S7	Urban	3-lane (both ways), commercial	1380	1260
S8	Urban	2-lane (both ways), commercial	1800	1800
S9	Urban	2-lane (both ways), commercial	3300	2220
S10	Urban	3-lane (both ways), commercial	1680	1920
S11	Highway	5-lane (both ways), commercial	3660	3780
S12	Highway	4-lane (both ways), commercial	2100	2100
S13	Highway	4-lane (both ways), commercial	1740	2220
S14	Highway	4-lane (both ways), commercial	5400	4680
S15	Highway	4-lane (both ways), residential, commercial and school	4800	4980

Table 4 Total mean concentration of traffic-related pollutants in Petaling Jaya in comparison with several guidelines and related previous studies

Site	Location	Averaging time	NO_2 ppm	CO_2 ppm	CO ppm	$PM_{2.5}$ µg/m^3	PM_{10} µg/m^3
S1			0.56	921	0.2	112	118
S2			0.55	946	2.6	121	128
S3			0.70	397	0.1	88	94
S4			0.60	379	1.2	82	87
S5			0.78	412	0.0	104	110
S6			0.67	429	1.6	67	69
S7			0.63	418	1.7	64	66
S8			0.70	396	1.7	52	56
S9			0.77	349	1.2	71	78
S10			0.91	364	1.6	73	78
S11			0.63	283	1.9	48	49
S12			0.73	269	0.2	49	55
S13			0.82	321	0.0	64	65
S14			0.85	279	1.8	59	60
S15			1.00	306	0.5	62	63
Min			0.55	269	0.0	48	49
Max			1.00	946	2.6	121	128
Mean			0.73	431	1.1	74	78
S.D			0.13	211	0.8	23	24
MAAQG		1-hr	0.17		30		
(2016)		24-hr	0.04		9 (8-hr)		150
WHO		1-hr	0.10		25		
(2006)		24-hr	N/A		10 (8-hr)	25	50
NAAQS		1-hr	0.10		35		
(2016)		24-hr	N/A		9 (8-hr)	35	150
Leong et al. (2002)	Bangkok	1-hr	0.02-0.09		8.4-18.0		78.53-157.18
Adedeji et al. (2016)	Nigeria	1-hr	0.10-0.66		4.8-13.7		
Riediker et al. (2003)	Raleigh, NC, US		0.05		1.1	31.7	
Chan et al. (2000)	Hong Kong	24-hr					25.56-337.4

[d]*MAAQG* Malaysian Ambient Air Quality Guidelines; *WHO* World Health Organization; *USEPA* United States of Environmental Protection Agency; *NAAQS* National Ambient Air Quality Standards

The correlation between air pollutants and meteorological factors

The relationship between air pollutants and meteorological factor was analyzed using a Pearson product-moment correlation coefficient. Referring to Table 5, most of the pollutants have both significant positive and negative correlations with each other. Only one strong positive correlation was found, which is between $PM_{2.5}$ and PM_{10} ($r = 0.995$, $p < 0.01$). This indicates that the correlations is significant. This is commonly associated with PM_{10} concentration contributed by $PM_{2.5}$ readings. However, the resulting output of correlation between air pollutant concentrations and meteorological parameters show they have a weak relationship with each other. The results shown were rather negative, or had no significant correlation with air pollutant concentration, except among the meteorological parameters themselves. There is no significant temperature that affects the traffic-related pollutant concentrations, as the temperature during the sampling period was rather stable. The reported average temperatures during the monitoring period were recorded to be between 26 °C and 34 °C. Therefore, it can be concluded that meteorological parameters did not have a great impact on the air pollutant's concentration, except for $PM_{2.5}$ and PM_{10}, which have a moderate positive correlation with altitude parameter ($r = 0.651$, $p < 0.01$; $r = 0.636$, $p < 0.01$, respectively). This is because particulate matter demonstrates different behaviour with altitude (Zainab *et al.*, 2015). In this context, a higher altitude results in a high concentration of air pollutants.

Table 5 Correlation between air pollutants and meteorological parameters

NO_2	CO_2	CO	$PM_{2.5}$	PM_{10}	WS	Temp	RH	P	Alt	
NO_2	1									
CO_2	-0.396*	1								
CO	0.102	0.207	1							
$PM_{2.5}$	-0.436**	0.639**	-0.390*	1						
PM_{10}	-0.423*	0.668**	-0.344*	0.995**	1					
WS	-0.140	-0.656**	-0.472**	-0.228	-0.273	1				
Temp	-0.436**	-0.315	-0.456**	0.053	0.006	0.722**	1			
RH	0.373*	0.387*	0.409*	0.057	0.105	-0.734**	-0.982**	1		
P	-0.177	0.415*	-0.096	0.311	0.310	-0.080	0.173	-0.157	1	
Alt	-0.375*	0.360*	-0.365*	0.651**	0.636**	-0.160	-0.009	0.138	-0.004	1
Rain	-0.080	-0.268	-0.393*	0.037	0.021	0.234	-0.037	0.087	-0.195	0.399*

** Correlation is significant at the p<0.01; * Correlation is significant at the p<0.05

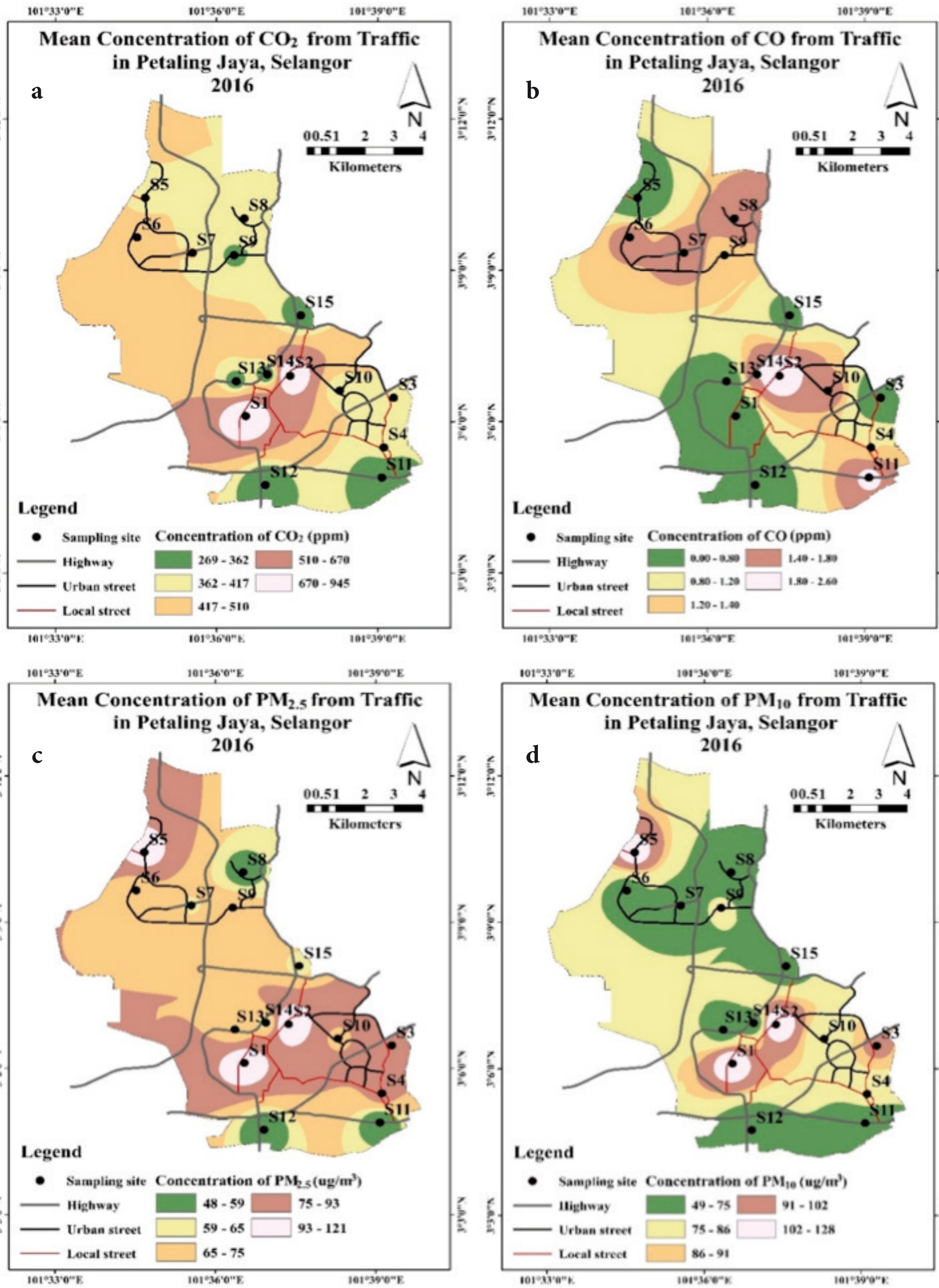

Figure 3a, 3b, 3c, 3d Mean concentration of CO_2, CO, $PM_{2.5}$ and PM_{10} in different street categories in Petaling Jaya, Selangor respectively

Spatial analysis of traffic air pollutants in different street categories

The IDW model in the ArcGIS spatial analysis module version 10.2.1 was utilized to interpolate the spatial air pollutant mapping. Figure 3a, 3b, 3c, and 3d visualize clearly the spatial dispersion of air pollutants mapping in the study area. According to Greiner (1995), the outdoor concentration level of CO_2 lies within 300 ppm. In this context, the alarming level of CO_2 is dominated within local streets area as in S1 and S2 (> 670 ppm) due to the fact that these areas are situated close to the traffic junctions which are directly influenced by the motion of vehicles such as deceleration and acceleration processes that led to a great amount of direct product from the fossil fuel combustion.

Figure 3b illustrates the concentration of CO where it is higher at S14 and S15, which both involve busy highways that always have a high concentration of traffic. S2 is located nearby a highway in S14, thus explaining why the concentration level was also affected at this particular area, which may be due to the streets linked towards the direction of the highway. Similar with CO_2 characteristics, CO released is mainly caused by the incomplete combustion of the diesel, gasoline of natural gas in traffic engines (Han and Naeher, 2006). And since the highways are the main roads used for people to commute within large city centres in the Klang Valley area (i.e. from Klang to Kuala Lumpur, or from Kuala Lumpur to Bandar Sunway), it is noted that the concentration is contributed from high traffic volume of not only cars, but for buses and both light and heavy trucks as well, which all use diesel as fuel.

Concentration level of $PM_{2.5}$ and PM_{10} were found to be high at local streets (S1, S2 and S5) instead of high traffic volume areas (Figure 3c and 3d). Since that these areas are linked both ways towards and from the highways which is located nearby city centres, where most of the job opportunities take place, it is expected to have greater amount of particulates as they are all connected to each other. For instance, S1 and S2 are linked towards a highly industrialized area in Pelabuhan Klang and Shah Alam where light and heavy trucks that uses diesel as fuel are passing through the street in daily routine. Even though Malaysian Road Transport Act in 1987 have announced specific time and respected type of streets to be used by these diesel-type-vehicles, still, the act is hardly to be enforced. In the meantime, NO_2 dispersion of mapping was not included in this study, as it shows very little variance in its concentration level, and was almost uniform across all locations in the study area, ranging from 0.55 to 1.00 ppm.

Conclusions

Petaling Jaya recorded a normal hourly trend of traffic-related air pollutants that most previous studies investigated. The concentration of almost all of the pollutants peak during morning and evening rush hour periods, which are in the range of 7:00 to 10:00 am and 4:00 to 7:00 pm, respectively. This is due to the high traffic volume of vehicles, where their motion slows down, and could result in high particulate and emission of CO due to the incomplete combustion of hydrocarbons, especially during delaying-events such as idling, acceleration and deceleration driving modes. In addition, a huge warrant alert has also been triggered by this study, as most of the pollutants measured mostly exceeded the ambient air quality guidelines, which may result in severe health problems in both short and long term exposure effects. Due to the low number of localized studies carried out to comprehensively investigate the physical and chemical interactions among these pollutants, and their relationship with the traffic characteristics, a proper national establishment of fuel quality standards that are tightly supported by vehicle emission standards is recommended. In this context, continuous assessment of these traffic-related pollutants should be closely monitored in a bigger prospective at its specific localized sources. This attempt is limited for developing countries, as it requires great resources and efforts, including manpower, and financial and technical support. In this case, aid from the application of Geographical Information System such as interpolation is greatly beneficial in terms of practically visualizing the trends of pollution in the city. Subsequently, a collaborative effort on promoting alternative fuels and the use of non-motorized forms of transportation is highly encouraged. In addition, improvement in public transportation especially in city centres are hugely anticipated in contribution to lessen the amount of major traffic related pollutants in the country.

Acknowledgements

The authors gratefully acknowledge research grant provided by Universiti Putra Malaysia (UPM) under GP-IPM/2014/9435300. The authors would also like to thank Universiti Malaysia Terengganu (UMT) for their valuable advice, guidance and technical support throughout the whole journey of research.

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