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Air Quality and Land Use in Urban Region of Petaling Jaya, Shah Alam and Klang, Malaysia.

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Abstract

In line with the global trend of urbanisation, large population are staying in urban areas as compared to rural. However, urban area /region is always related to higher air pollution level as compared to less developed area/region. The major contributors of air pollution are mobile sources (transportation) and stationary sources (*e.g.* industry and power plant). Thus, the issue of air pollution is potentially caused by human choices and activities, and potentially affecting the human health. Therefore, the relationship between the urban activities (land use coverage/distribution) and air quality level should be well understood. It helps the urban managers, planners and all parties in constructing healthier urban policies. A study of air quality and the relationship with urban land uses was carried out in Malaysia's urban growth region of Klang-Shah Alam-Petaling Jaya. Air quality data was analysed in Air Pollution Index (API) with the classification of good, moderate, unhealthy, very unhealthy and hazardous levels. The urban land uses were mainly divided into two categories, *i.e.* pollution-prone land uses (transportation, industrial, and infrastructure), and green land uses. This study found that urban area with higher coverage of transportation, industrial and infrastructure land uses are potentially unhealthier in term of the air quality than the area with less coverage of these land uses. Strategic proposal was discussed in line with the findings.

Keywords: Air Pollution Index (API); green; industrial; relationship; transportation

1. Introduction

An increasing concentration of people and economic activities as well as growing vehicle fleet has contributed to high level of air pollution in the large cities of developing countries. Besides, rapid urbanization may cause various environment problems, such as air pollution, acid rain, water pollution and land pollution (*i.e.* solid wastes, toxic wastes, deforestation) (Farhad, 2007).

Urban ambient air is more polluted than overall atmosphere. Due to high density of human population and their activities in urban areas, it produces air pollutants with higher rate as compared to less-developed areas and natural environment. Besides, the atmosphere has always been one of the most convenient spaces to dispose off unwanted materials, which includes the use of burning. In Malaysia's most urbanized area, there was a clear increasing trend in the number of unhealthy/hazardous days, which increased from 11 days in 2001 to 67 days in 2005 in Kuala Lumpur city (Ling *et al*., 2012). Furthermore, Siti Nurazlina (2011) mentioned that a number of states in the west coast of Peninsular Malaysia including the Klang Valley were attacked by haze phenomenon. People who live in the urban area are now facing the air pollution issue due to the excessive gases that produce by the vehicles in the urban area. This will turn the save safe city into a "toxic city" (Siti Nurazlina, 2011).

There are several cities in Malaysia that being detected having the air pollution phenomenon. The cities are Shah Alam, Putrajaya, Nilai, and Tanjung Malim (Siti Nurazlina, 2011). The three major sources of air pollution in Malaysia are mobile sources, stationary sources, and open burning sources. For the past five (5) years, emission from mobile sources (*e.g.* motor vehicles) has been the major sources of air pollution, contributing to at least 70-75% of the total air pollution. Emission from stationary sources (*e.g.* industrial, and power plants) generally have contributed to 20-25% of the air pollution, while open burning and forest fires have contributed approximately 3-5% (Rafia *et al*., 2003). Kuala Lumpur city as reference, study shows that increase of "shopping floor space", "office floor space" or "industrial units" in the city is positively related with the number of unhealthy/ hazardous days (as measured in Air Pollution Index, API) (Ling *et al*., 2010). Thus, air quality of an area is potentially related to the urban activities and land use.

However, there are limited numbers of studies that focus on the relationship between urban air quality and land uses in the Malaysia urban regional context. Therefore, this paper aims to examine the ambient air quality in Malaysia's urban region and the relationship with the city-wide and localized land uses.

2. Study area and Methods

The study areas are located in the Klang Valley, Malaysia. The Klang Valley is an urban growth region in Malaysia, which comprises Kuala Lumpur and its suburbs and adjoining cities, and towns in the state of Selangor. The Klang Valley is considered to be the heartland of Malaysia's industry and commerce and was recorded as having a total population of over four million in 2004. In the most recent census, the population in this area had expanded to 4.7 million (Siti Zawiyah *et al*., 2010). Due to the geographical location, and as the most developed urban region in Malaysia following rapid urbanization, population growth and industrial activities, the Klang Valley is constantly exposed to the problem of air quality (Siti Zawiyah *et al*., 2010). Klang Valley has been chosen as case study in this paper with the focus on the corridor of three (3) continuous cities, namely Shah Alam city, Petaling Jaya city, and Klang town.

Data of ambient air quality, land uses and traffic volumes had been collected from various public authorities and documents. Ambient air quality data was recorded by air quality monitoring station of the Department of Environment Malaysia (DOE). Table 1 shows the location and surrounding land uses of the monitoring stations. The traffic volumes are based on the counts for both directions at the selected roads. The traffic data was recorded every hour manually by the Highway Planning Unit (Ministry of Works Malaysia) for 16 hours (06.00-22.00 hour) during sampling day.

Analysis of air quality has been presented in term of the number of good days and unhealthy days based on the Malaysian Air Pollution Index (API). The relationship study is discussed with the aid of tables. Correlation test is not being carried out due to the small amount of case studies (three areas of study only).

3. Results and Discussion

3.1. Trend of air quality

Throughout the year, air pollution is expected to be higher during the dry season (middle of year, June-September) due to the less precipitation process. During the wet season (November-March), the air quality is expected to be better. It is due to the fact that the wet season with more rainfall could reduce the concentration of air pollutants in the air through the washout and rainout effects (Ling *et al*., 2012). However, the ideal trend was not found in this study for the year 2010 and 2011.

For the period of year 2010 to 2012, in average, the number of good days (in API) was higher during wet season in Petaling Jaya (Fig. 4). Meanwhile, the average trend of number of unhealthy days (Fig. 5) showed two (2) peaks, which were in February (wet season) and June (dry season). However, the trend of unhealthy days in 2012 showed the peak in June which was during dry season (Fig. 5).

As for Shah Alam, the trend of API good days showed the peak during November-December, which was during the wet season (Fig. 6). Meanwhile, the average trend of API unhealthy days also showed the peak during the wet season, which was in February (Fig. 7). However, for the year 2012, the peak of unhealthy days was recorded in June, during the dry season.

Table 1: Air Quality Monitoring Stations in the study areas

Monitoring station	Location	Surrounding land uses
Petaling Jaya	located at Sri Petaling Primary School (N03° 06.612', E101° 42.274')	located in a housing area and beside the Jalan Utara (road) and light industrial area. It is surrounded by residential, commercial, light industrial and green areas (Fig. 1). It is the nearest to Kuala Lumpur city (among the three study areas).
Shah Alam	TTDI Jaya Primary School (Fig. 2) (N03° 06.287', E101° 33.368')	located in a residential area and surrounded by industrial, airport and ponds. Besides, it is located near to major roads, however, the traffic density is lower as compared to Petaling Jaya and usually, only significant during the morning and late afternoon rush hours (Siti Zawiyah *et al*., 2010).
Klang	Raja Zarina Girls School, Port Klang (Fig. 3) (N03° 00.620, E101° 24.484)	located in the residential area and just beside the major road of Port Klang (Persiaran Raja Muda Musa). It is surrounded by housing area (including villages) and industrial area too. Port Klang is one of the major industrial towns in Malaysia with high volume of heavy vehicle.

Figure 1. Location of Sri Petaling air monitoring station (marked with "A") and the surrounding area, Petaling Jaya. (Source: Google, 2013)

Figure 2. Location of TTDI Jaya Air Monitoring Station (marked with "A") and the surrounding area, Shah Alam. (Source: Google, 2013)

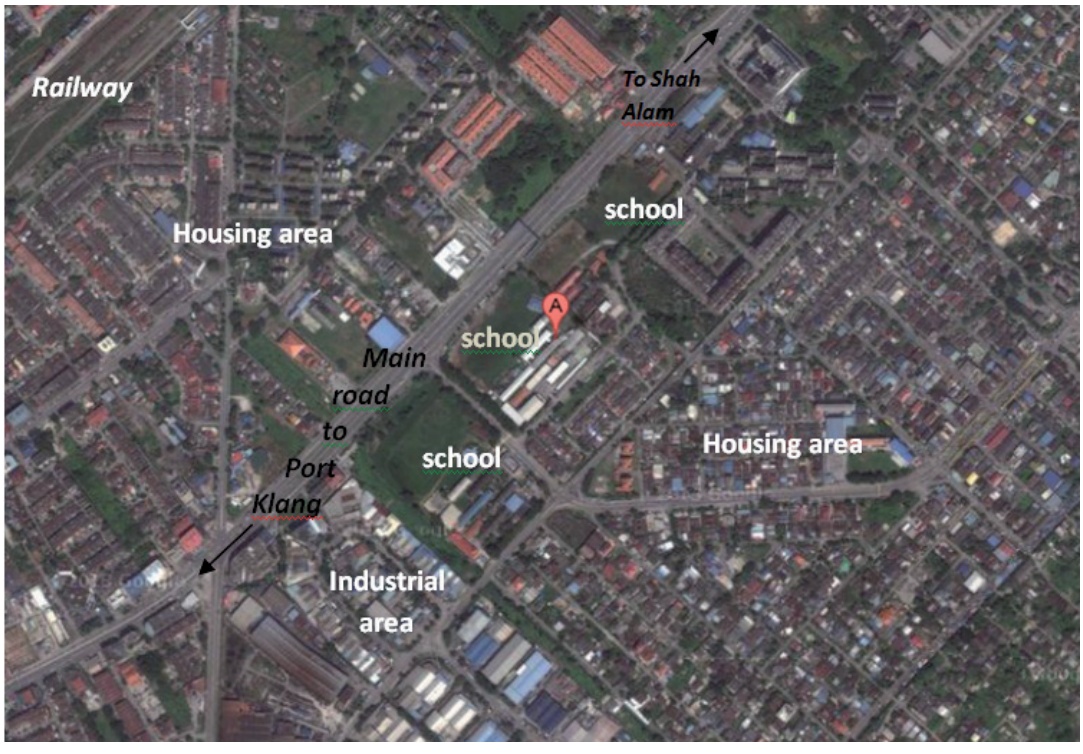

Figure 3. Location of Raja Zarina Girls School Air Monitoring Station (marked with "A") and the surrounding area, Port Klang. (Source: Google, 2013)

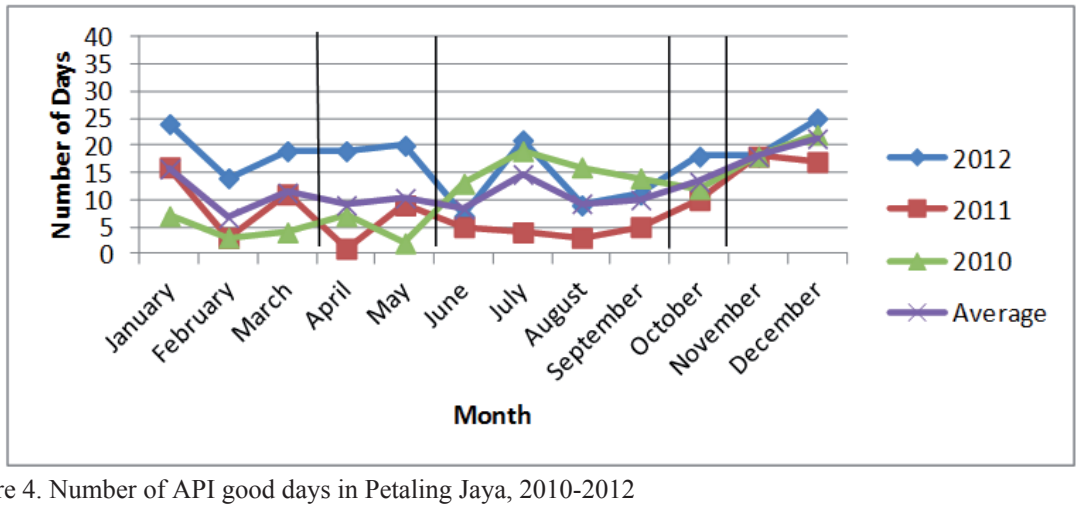

Figure 4. Number of API good days in Petaling Jaya, 2010-2012

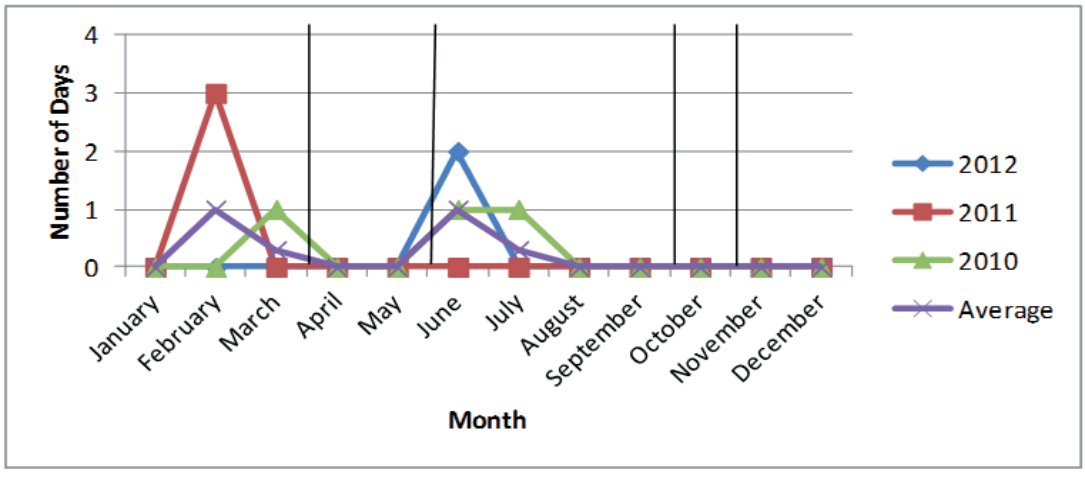

Figure 5. Number of API unhealthy days in Petaling Jaya, 2010-2012

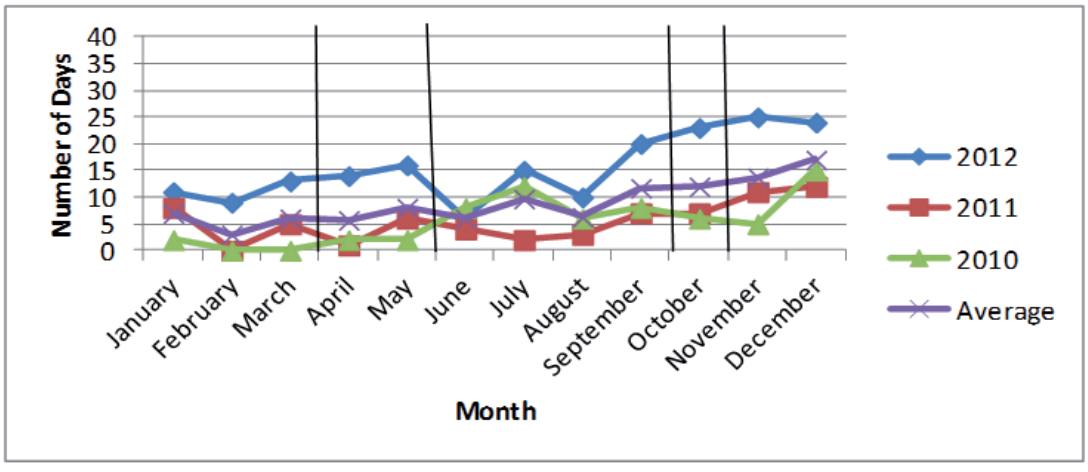

Figure 6. Number of API good days in Shah Alam, 2010-2012

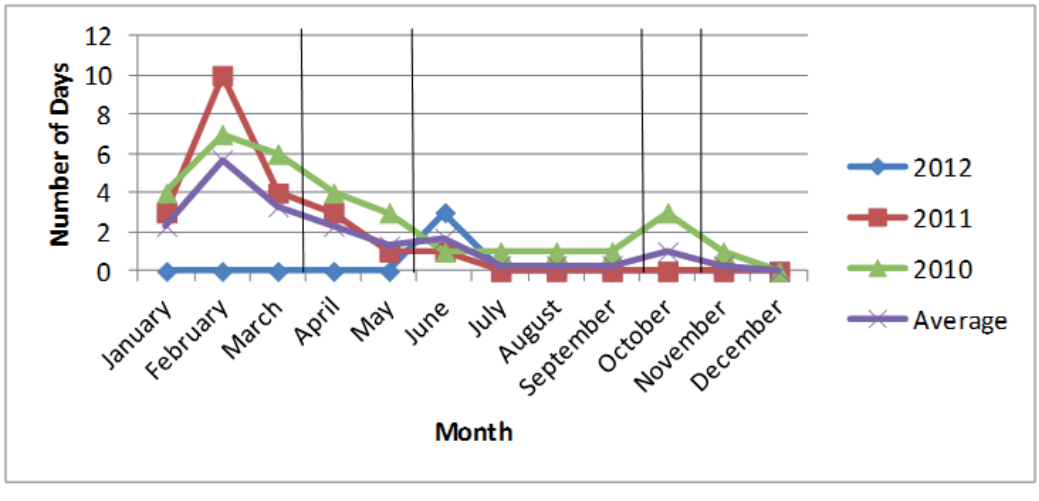

Figure 7. Number of API unhealthy days in Shah Alam, 2010-2012

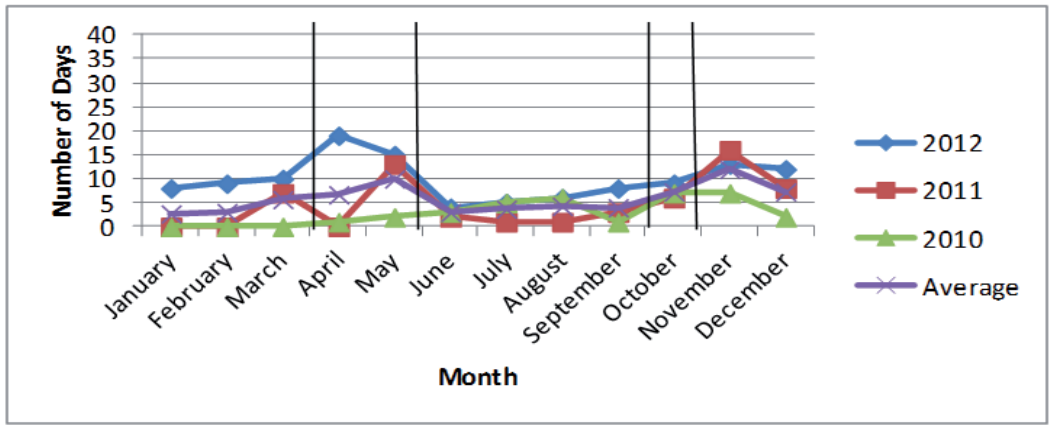

Figure 8. Number of API good days in Klang, 2010-2012

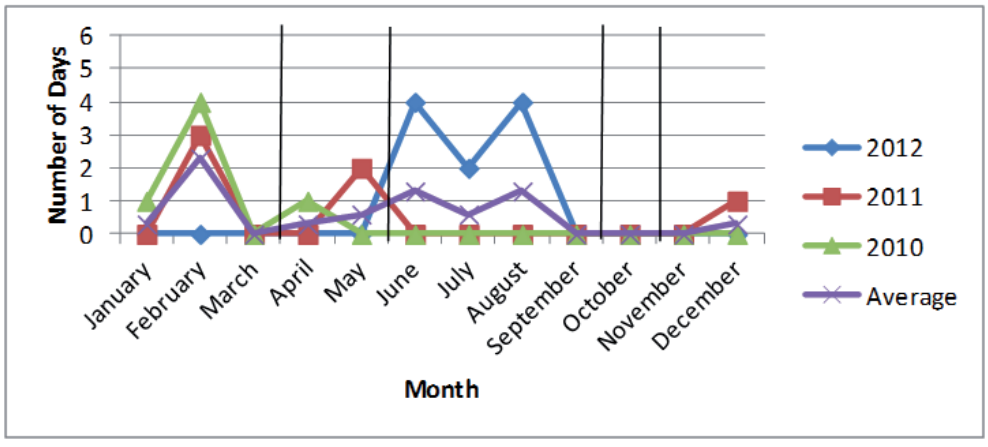

Figure 9. Number of API unhealthy days in Klang, 2010-2012

In Klang, Fig. 8 shows a clear trend of higher number of API good days during the wet season and transactional periods, and lower during the dry season. For the trend of unhealthy days, the data showed higher number during wet season for the year 2010 and 2011 (Fig. 9). However, in 2012, there was a clear trend of higher number of unhealthy days during the dry season and lower during the wet season.

To conclude, the study areas did not show a clear trend of higher number of unhealthy days during the dry season except year 2012. However, in general, the numbers of good days were higher during the wet season for the period of 2010-2012. From the observation, it might due to the situation of no clear trend of typical dry weather during the dry season (June-September) for the year 2010 and 2011. Thus, there was not clear increase in the number of unhealthy days during the dry season as compared to the wet season (November-March).

3.2. Air quality among the three study areas

By comparing the three (3) study areas, the air quality of Petaling Jaya is the best. The overall air quality level in Petaling Jaya for the period of Nov. 2011 - Oct. 2012 was at a good level. The percentage of good days was 54.12% followed by 45.33% in the moderate air quality level and 0.55% for unhealthy days (Table 2). However, in the year 2010 and 2011 (Tables 3 and 4), Petaling Jaya was recorded with higher unhealthy days (3 days in both years as compared to two (2) days only in the year 2012). Besides, the good API days were recorded lower in the year 2010 and 2011 as compared to 2012. It shows that air quality in Petaling Jaya has been improved in the year 2012 as compared to the previous years.

For Shah Alam, high numbers of unhealthy days were recorded in the year 2010 and 2011, which were 32

Table 2. Air quality in Petaling Jaya, Shah Alam and Klang, Nov. 2011 to Oct. 2012

	Number of days (percentage)		
	Good API	Moderate API	Unhealthy API
Petaling Jaya (Sri Petaling)	197 (54.12%)	165 (45.33%)	2 (0.55%)
Shah Alam (TTDI Jaya)	160 (44.20%)	199 (54.97%)	3 (0.83%)
Klang (Port Klang)	117 (31.97%)	238 (65.03%)	11 (3.00%)

Adapted from: Department of Environment (2012)

Table 3. Air quality in Petaling Jaya, Shah Alam and Klang, 2011

	Number of days (percentage)		
	Good API	Moderate API	Unhealthy API
Petaling Jaya (Sri Petaling)	102 (27.95%)	260 (71.23%)	3 (0.82%)
Shah Alam (TTDI Jaya)	67 (18.31%)	277 (75.68%)	22 (6.01%)
Klang (Port Klang)	57 (15.61%)	302 (82.74%)	6 (1.64%)

Adapted from: Department of Environment (2012)

Table 4. Air quality in Petaling Jaya, Shah Alam and Klang, 2010

	Number of days (percentage)		
	Good API	Moderate API	Unhealthy API
Petaling Jaya (Sri Petaling)	137 (37.53%)	225 (61.64%)	3 (0.82%)
Shah Alam (TTDI Jaya)	66 (18.08%)	267 (73.15%)	32 (8.77%)
Klang (Port Klang)	34 (9.32%)	325 (89.04%)	6 (1.64%)

Adapted from: Department of Environment (2012)

and 22 days respectively (Tables 3 and 4). These figures make Shah Alam as the most polluted/unhealthy area among the three (3) study areas. However, in 2012, the number of unhealthy days was dropped to three (3) days only, which is lower than Klang (11 days) (Table 2). The number of good API days was moderate in Shah Alam among the 3 study areas for the year 2010 to 2012. Based on the previous record, Shah Alam was experiencing high number of unhealthy days, perhaps, generally was the highest in Klang Valley during the period of 2002 to 2008 (Department of Environment, 2009; Ling *et al*., 2011).

Meanwhile, the unhealthiest area in 2012 (Klang with 11 unhealthy days, Table 2) was much cleaner in the previous years (6 unhealthy days for both 2010 and 2011, Tables 3 and 4). However, Klang was always being recorded with smallest number of good API days from 2010 to 2012 (Tables 2, 3, 4).

To conclude the air quality data for the study areas for the period of 2010 to 2012, Petaling Jaya was the cleanest area, and Shah Alam and Port Klang were the unhealthier areas. In general, Shah Alam and Port Klang are the two (2) major industrial cities in Malaysia. Meanwhile, the Petaling Jaya as the satellite city of Kuala Lumpur is more urbanized with commercial and residential development. Some of the headquarters of private corporate company and government department have been located in Petaling Jaya instead of Kuala Lumpur. For instance, the headquarters of Hong Leong Assurance Bhd. and Kurnia Insurance Bhd. had been moved from Kuala Lumpur to Petaling Jaya. Meanwhile, headquarter of Department of Meteorology is located in Petaling Jaya.

3.3. Land Use and Traffic

Land use pattern and traffic volume for the study areas are being discussed due to these potential impacts on the air quality based on the findings of previous studies (as discussed in the "Introduction"). In general, Petaling Jaya city and Shah Alam city were covered with higher percentage of industrial, transportation and infrastructure land uses among the three study areas with 25.88% and 34.11% respectively (column III in Table 5). Meanwhile, Klang was only consisting of 16.23% of these land uses. However, in term of the acreage, Shah Alam and Klang showed larger coverage of industrial, transportation and infrastructure land uses as compared to the Petaling Jaya, which are 9,906 hectare for Shah Alam, 9,277 hectare for Klang, and 1,956 hectare for Petaling Jaya (Tables 6, 7, 8). These land uses are related to the potential impact on the air pollution of the areas. Besides, Petaling Jaya and Shah Alam were recorded with higher traffic volume (column II in Table 5) as compared to Klang which is potentially increasing the air pollution levels of Petaling Jaya and Shah Alam.

For the green coverage (open space, forest, agriculture, and undeveloped land), Petaling Jaya and Shah Alam showed lower percentage as well as acreage as compared to Klang. For the Klang town area, it showed a high percentage and large acreage of green coverage (80%, Tables 5 to 8).

Based on the observation on the localised land use (land use coverage in adjacent to the air monitoring stations), Sri Petaling showed most greens and no major pollution-prone land use or activity (Fig. 1, column IV in Table 5). Meanwhile, the air monitoring station of Port Klang was located just besides the major road connecting between Klang town and Port Klang, with industrial areas located adjacent to the station (Fig. 2, column IV in Table 5). For TTDI Jaya, Shah Alam, it showed large coverage of industrial area as well as green area (Fig. 3, column IV in Table 5). Thus, the land use coverage for the localised area is different from the overall city/town land use pattern for the study area.

3.4. Relationship between air quality, land use and traffic

Air quality data as recorded by the air monitoring stations was not showing clear relationship with the road traffic volume and city-wide land use (in percentage) of the cities/towns (column II and IV in Table 9). Klang town with highest percentage of green land use (80%, potentially improve the air quality) and lowest percentage of land use which was potentially pollution

Table 5: Traffic volume and land use in Petaling Jaya, Shah Alam and Klang

I Study area	II Road Traffic volume (16-hours)[1]	III City-wide land use of the city/town[2]	IV Localised land use of the study area
Petaling Jaya (Sri Petaling)	Higher traffic volume Apr. 2006 = 309,828 Sep. 2006 = 397,047 (Federal Highway, KL-PJ)	Higher % of land uses which potential to increase air pollution (25.88%): • Industrial - 3.58% • Transportation - 16.94 • Infrastructure & utilities - 5.36% Land uses which potential improve air quality (16.07%): • Open space & recreation - 9.83 • Undeveloped land - 0.08% • Forest - 6.16% Others : • Residential - 19.40% • Commercial & service- 3.46% • Institution - 13.64% • Water body - 2.02% • Under construction - 19.58% *Refer to Table 6*	With greens; no major pollution-prone land use/activity (Fig. 1). • Consist of large residential area. • Light industrial area located at the surrounding area. • A few spots of agriculture land use. • Commercial land use. • Open space and recreation land use were there too.
Shah Alam (TTDI Jaya)	Lower traffic volume Apr. 2006 = 55,582 Sep. 2006 = 64,460 (Road from Batu 3 to Damansara)	Higher % of land uses which potential to increase air pollution (34.11%): • Industrial - 12.79% • Transportation - 16.33% • Infrastructure & utilities - 4.99% Land uses which potential improve air quality (15.13%): • Open space and recreation - 7.62% • Agriculture - 0.32% • Forest - 7.19% Others: • Residential - 34.34% • Commercial & service - 3.92% • Mix development - 1.16% • Institution - 8.80% • Water body - 2.69% *Refer to Table 7*	Large industrial area (potential pollution) but also large green area (able to reduce pollution) (Fig. 2). • Residential area • Large area of industrial. • Large area of open space and recreation too. • Agriculture land use spotted there. • Commercial land use was nearby. • There was water body and airport near to the residential area.
Klang (Port Klang)	Lower traffic volume Apr. 2006 = 39,397 Sep. 2006 = 36,494 (Langat Road to Pandamaran)	Low % of land uses which potential to increase air pollution (16.23%): • Industrial - 4.73% • Infrastructure & utility - 0.52% • Transportation / water body - 10.98 High % of land uses which potential improve air quality (80.53%): • Open space & recreation - 0.71% • Undeveloped land - 6.94% • Forest - 34.33% • Agriculture - 38.55% Others • Residential - 8.32% • Commercial - 0.85% • Institution - 1.12% • Special use - 0.84% • Under construction - 2.09% *Refer to Table 8*	Clear air pollution sources (Fig. 3). • Beside the major road to Port Klang • Industrial land use situated not far from the study area. Other land uses: • Majority of the area covered with the residential (& villages). • Agriculture land use category involved too. • Commercial land use was nearby.

Source: 1. Adapted from Highway Planning Unit (2006).
2. Adapted from Petaling Jaya City Council (n.d.), Shah Alam City Council (2012) & Klang Municipal Council (2008).

Table 6. Land use coverage for Petaling Jaya city

	Hectare	%
Transportation	1,280.54	16.94
Industrial	270.30	3.58
Infrastructure & utility	405.43	5.36
Forest	465.97	6.16
Open space/recreational	742.90	9.83
Undeveloped land with grass	6.35	0.08
Residential	1,466.94	19.40
Commercial/services	261.90	3.46
Institution	1,031.32	13.64
Under construction	1,481.74	19.58
Water body	152.94	2.02
Total	7,566.33	100

Source: Petaling Jaya City Council (n.d.)

Table 7. Land use coverage for Shah Alam city

	Hectare	%
Transportation	4,741.84	16.33
Industrial	3,713.21	12.79
Infrastructure & utility	1,450.85	4.99
Open space/recreational	2,213.27	7.62
Forest	2,089.77	7.19
Agriculture	94.14	0.32
Residential	9,911.22	34.14
Commercial/services	1,140.36	3.92
Mixed use development	337.64	1.16
Institution / public facilities	2,555.36	8.80
Water body	782.34	2.69
Total	29,030.00	100.00

Source: Shah Alam City Council (2012)

Table 8. Land use coverage for Klang town

	Hectare	%
Transportation/Water body	6,303.10	10.98
Industrial	2,714.25	4.73
Infrastructure & utility	259.98	0.52
Open space/recreational	409.31	0.71
Undeveloped land	3,982.86	6.94
Forest	19,703.80	34.33
Agriculture	16,381.82	38.55
Residential	4,774.33	8.32
Commercial/services	486.97	0.85
Institution	585.76	1.12
Special usage	479.87	0.84
Under construction	1,198.95	2.09
Total	57,380.00	100

Source: Klang Municipal Council (2008)

Table 9. Relationship between air quality, road traffic volume and land use in Petaling Jaya, Shah Alam and Klang.

I Study area	II Air quality	III Road traffic volume	IV City-wide land use	V Adjacent (localized) land use
Petaling Jaya (Sri Petaling)	Most healthy. Reported to have the highest number of good days in API and the lowest number of unhealthy days in API as compared to the another 2 stations, Nov. 2011- Oct. 2012.	In overall, it is the largest road traffic volume in both 16 hours and peak hours among the 3 areas, in 2006. However, the sampling point (Federal highway) is around 1km away.	Higher % of land uses which potential to increase air pollution (25.88%). But, smaller in coverage (1,956 hectare). Lower % and acreage of land uses which potential improve air quality (16.07%).	• Residential area. • Beside to light industrial area. • Near to small green area and recreation land. • A distance to Federal Highway. • No clear air pollution source located adjacent to the station.
Shah Alam (TTDI Jaya)	The air quality as moderate as compared to another 2 stations, Nov. 2011- Oct. 2012. But, it is the most unhealthy area in 2010 and 2011 with 32 and 22 unhealthy days respectively.	The overall road traffic volume in Shah Alam was the second large among the 3 study areas, in 2006.	Higher % and acreage of land uses which potential to increase air pollution (34.11%; 9,906 hectare). Lower % and coverage of land uses which potential improve air quality (15.13%).	• Residential area • Beside a light industrial area. • Near to water body & airport. • A distance to the large green space (golf) and recreation area. • A distance to highways. • 1 air pollution source (light industries located adjacent to the station), but large green space (golf) is located near to it.
Klang (Port Klang)	Most polluted. The good days (API) was reported as the lowest and the unhealthy days (API) was the highest as compared with another 2 stations, Nov. 2011- Oct. 2012.	The overall road traffic volume was the lowest among the 3 areas either in the 16 hours volume or peak hours volume, in 2006.	Low % of land uses which potential to increase air pollution (16.23%). But, higher in the coverage (9,277 hectare). High % and coverage of land uses which potential improve air quality (80.53%).	• Residential area (& village). • Beside the major road to Port Klang. • Adjacent to industrial area. • Small green area. • 2 air pollution sources (major road to seaport & industries located adjacent to the station).

the air (16%), was suffered with most unhealthy air quality level as compared to other study areas. Besides, the traffic volume was recorded with the lowest level in Klang as compared to other study areas (column III in Table 9).

However, the localised land uses condition as per observation showed positive relationship between land use and air quality (column II and V in Table 9). Sri Petaling (Petaling Jaya) with most healthy air quality showed no clear air pollution source / land use adjacent to the air monitoring station. Meanwhile, the Port Klang (Klang) and TTDI Jaya (Shah Alam) showed more unhealthy air quality level as compared to Sri Petaling. It can be related to the existence of some clear air pollution sources/land use in adjacent to the air monitoring stations (Port Klang and TTDI Jaya).

Furthermore, the positive relationship also had been found between the air quality level and city-wide land use coverage of the cities/town (in hectare but not the percentage). Petaling Jaya city with lowest coverage of pollution-prone land uses (1,956 hectare, column IV in Table 9) showed most healthy air

condition (column II in Table 9). Meanwhile, the Shah Alam city and Klang town with the higher coverage of pollution-prone land use (more than 9,000 hectare) showed more polluted air level among the three study areas (column II and IV in Table 9).

4. Conclusions

Urban air quality is not always about a standard trend or a typical relationship with the urban land use patterns. Theoretically, pollution-prone land uses such as transportation and industry, as well as traffic volume are potentially increasing the air pollution level. However, in this study, it was found out that the air quality was not clearly related to the traffic volume and percentage of pollution-prone land uses in the urban region (study areas). However, the air quality was clearly related to the size of pollution-prone land use coverage in both the city-wide land use coverage as well as localised land use coverage.

It showed that the size of pollution-prone land use coverage is potentially increasing the level of air pollution in study areas (an urban region). Area with large industrial, transportation and infrastructure land uses is potentially more polluted in term of air quality. Thus, all parties including the urban planner should manage or plan a city or area with less air pollution-prone land use in order to improve the air quality/ healthiness of an area. It did not refer to the reduction of the size of pollution-prone land use alone but also the more innovation ways to reduce the potential air emission from the activities (*e.g.* green industry and green transportation)

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