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Urban Growth and Air Quality in Kuala Lumpur City, Malaysia

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Abstract

Urban developments, land use patterns and activities not only influence the volume of emissions into the ambient air environment but also affect the ability of the urban ecosystem to purify the air. Therefore, urbanisation affects the quality of air in urban areas. However, urban air quality is also affected by global, regional or trans-boundary pollutants. The objectives of this paper are to understand the trend of air quality level and urban growth in Kuala Lumpur city (KL), and examine the relationship between these variables. Results of analysis show a significant and strong relationship between the number of unhealthy/hazardous days and urban land uses. The finding is contrary to the argument that the high concentration of air pollutants (unhealthy level) in the Malaysian city is contributed by the forest fire in a neighbouring country (haze).

Keywords: Ambient air quality; Urban landuse; City; Urbanisation; Correlation.

1. Introduction

The environmental changes associated with urbanisation were significant during the last century and are expected to continue through the next several decades (Alberti and Marzluff, 2004). Urban development fragments, isolates and degrades natural habitats, simplifies and homogenises species composition, disrupts hydrological systems, modifies energy flow and nutrient cycling (Alberti and Marzluff, 2004); increases regional temperature, degrades air and water quality (Tratalos et al., 2007). Urbanization is seen as the process by which humans replace ecosystem services (such as air purification) with human services. Ecosystem services are the processes and conditions that sustain humans and other species (Alberti and Marzluff, 2004). Human services in urban areas such as housing, water supply, transportation, waste disposal and recreation still depend on ecosystems for natural resources and their productivity over the long term. Besides, human services also depend on the ecosystem's ability to act as a sink to absorb emissions and wastes. Therefore, the decline of ecosystem services due to urbanisation is also reducing the overall urban system services and the ability to purify environment.

Beside the local origin air pollution issue, air pollution has also been discussed as global or trans-boundary issues. People are arguing that the air quality of their cities are polluted by other countries or neighbouring areas beside the localised pollution sources. The Kuala Lumpur City Plan Study mentioned that, the reducing number of good air quality days in KL (2000-2003) is probably contributed by localised air pollution, and the unhealthy days are most likely contributed by the yearly haze form by trans-boundary pollution (AJM, 2006). Studies in Malaysia (Rafia et al., 2003; Norela et al., 2008) also focus on examination of health effects from the haze episode caused by neighbouring country's forest fire. This paper aims to discuss the trend of air quality and urban growth in Kuala Lumpur city, and examine the relationship between the city's air quality level and the growth of urban landuses, population and traffic of the city itself.

2. Study area and Methods

The study was conducted in Kuala Lumpur city, Malaysia. The total land area of the city is 243.7 km^2 (24,221.05 hectare), which is 100% urban area. It had a population of 1,556,200 people in year 2005 with an average population density of 64 persons per hectare.

Data of ambient air quality, population, landuses and traffic volume had been collected from various public authorities and documents. Ambient air quality data was recorded at air quality monitoring station by Department of Environment Malaysia. The monitoring station of KL was located at Victoria Secondary School (in City Centre) in year 2003 and before. However, the monitoring station has been moved to Sri Permaisuri which is located outside from city centre from year

2004 onwards. For the traffic volume data, the average of April & October counts for both directions have been used. The traffic data was recorded every hour manually by the Ministry of Works Malaysia for 16 hours (06.00-22.00 hour) during sampling days for five stations namely WR101: Jalan Kepong (KL-Kuala Selangor), WR102 & WR103: KL-Ipoh, WR105: KL-Seremban Expressway, and WR106: KL-Petaling Jaya (Old Damansara road).

Spearman correlation method was used for the purpose to determine whether there is a significant relationship between urban parameters (urban growth) and air quality in KL. Spearman correlation was used instead of Pearson, due to the frequency distribution of values for the variables were significantly different from normal distribution. Air quality in KL was measured by the number of good air quality days, moderate air quality days and unhealthy/hazardous days based on the Malaysian Air Pollution Index (API).

3. Results and Discussion

3.1 Air quality trend in Kuala Lumpur

Table 1 and figure 1 show the trend of air quality level in Kuala Lumpur from year 1999 to 2007 as measured by number of good, moderate and unhealthy/hazardous days (based on API classification). There was a drop of number of good days from year 2000 to 2003 where the number of good days reduced from 137 to 2. However, there was an increase of number of good days after year 2003. Such results provide indication that the air quality in Kuala Lumpur deteriorated from year 2000 to 2003, but recovered back since 2004. From year 2004 onwards, the Kuala Lumpur air quality monitoring station has been moved to Bandar Sri Permaisuri which is located outside from city centre. The new location of the monitoring station might have recorded a different trend of air quality level.

The trend for the number of moderate days from year 1999 to 2007 shows a zigzag pattern, with moderate days between 217 and 334 days per year. It shows that the number of moderate air quality days is quite constant within a range of number. The number of unhealthy/hazardous days was showing a clear increasing trend until year 2005 with a drop in year 2006. However, the number of unhealthy/hazardous days increased again in year 2007. These records do not show a clear improvement of air quality in KL even though the number of good days has increased. Increasing trend of unhealthy/hazardous days should be the main concern in indicating air quality level in KL due to the scientifically proven negative impact of air pollution on human health such as respiratory infection and cardiovascular illness (Forastiere et al., 2006; Lippmann and Ito, 2006).

3.2 The urban growth

Kuala Lumpur, since its independence days in 1957, has undergone dramatic changes arising from scientific and technological revolutions throughout the world (Dolbani, 2000). The population census of June 1970 recorded a population of approximately 485,000 residents for the Municipal Area (Dolbani, 2000) and it had increased 221% to 1.56 million population by 2005. However, one of the main contributions to the high population growth rate in Kuala Lumpur is the enlargement of Kuala Lumpur territory area. In 1974, Kuala Lumpur had enlarged from 36 square miles (93 km^2) to 94 square miles (243 km^2) in area (Dolbani, 2000; DBKL, 1984).

With the past Comprehensive Development Plans and Structure Plans, urbanization in Kuala Lumpur has been guided by these urban planning efforts. For the 1984-2005 period, the overall landuse composition of

Table 1. Number of good, moderate and unhealhty/hazardous days in Kuala Lumpur.

Year	Number of days (API)		
	Good	Moderate	Unhealthy/hazardous
1999	56	293	16
2000*	137	217	12
2001*	27	327	11
2002*	3	217	30
2003*	2	334	28
2004**	23	280	63
2005**	64	234	67
2006**	67	293	5
2007**	104	242	19

Source: DOE (1999); *AJM (2006); ** DOE (2005, 2006, 2007, 2008).

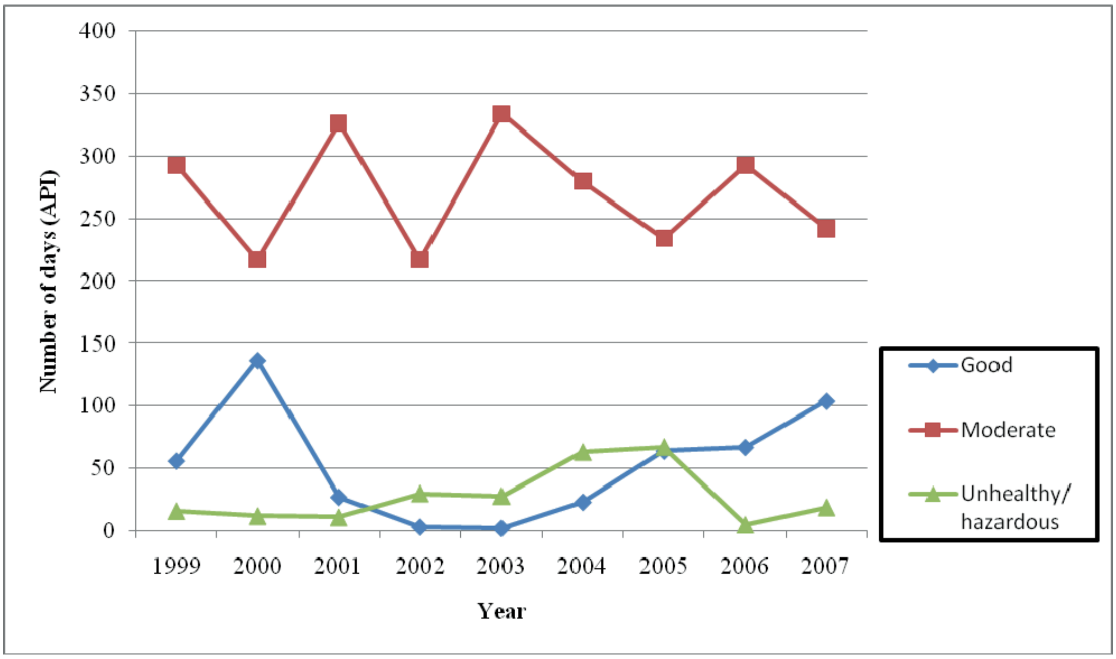

Figure 1. Number of good, moderate and unhealhty/hazardous API days.
Source: adapted from DOE (1999, 2005, 2006, 2007, 2008); AJM (2006).

Kuala Lumpur city was changed due to the closing of mining land, decreasing undeveloped land, increase in public institutions, infrastructure/utility and squatters. The present largest landuse is the "infrastructure and utilities category" (25.9% in year 2005), followed by residential (23.6%). 23% of the infrastructure and utilities category is comprised of road reserves which take up 5,576.69 hectare of land in year 2007. With urbanisation, the changed in the functions of the Kuala Lumpur city has also resulted in landuse changes. Today, Kuala Lumpur's commercial area is not only servicing Kuala Lumpur city but also the Kuala Lumpur conurbation (Klang Valley) area, which include other cities and towns such as Petaling Jaya city, Subang Jaya town, Nilai town and Seremban town.

There was a clear increasing trend in population, commercial (office floor space, shopping floor space) and industrial units over time in Kuala Lumpur. Inline with the urbanisation of KL, the increasing rate of shopping floor spaces (average 11% annually) (table 3) is much higher than offices (5%), industries (< 2%) (table 4) and population growth (recently < 2%) (table 2). Kuala Lumpur has been planned with a vision to be a world class city and to function as a centre for the Kuala Lumpur conurbation (Klang Valley). To achieve these functions, retail and offices spaces have been developed at a higher rate than the population growth rate. Therefore, air pollutants are not only generated by local residents but also visitors and users of these commercial spaces. This might be the reason for a strong

Table 2. Total population and the annual growth rate in Kuala Lumpur, 1970 - 2020.

Year	Total population	Annual growth rate (%)
1970	485,000	
1980	919,610	8.96
1991**	1,226,700	3.04
2000**	1,379,310	1.38
2001*	1,446,000	4.84
2002*	1,474,300	1.96
2003*	1,501,800	1.87
2004*	1,529,000	1.81
2005*	1,556,200	1.78
2007***	1,559,100	0.09

Source: adapted from Dolbani (2000); AJM (2006); *** DOS (2008); ** DOS (2003); * DOS (2005).

Table 3. Kuala Lumpur shopping floor space and office floor space, 1989-2005.

Year	Shopping space (ft^2)	Office space (m^2)	Occupied office (m^2)
1989	4,386,530	2,609,654	2,274,326
1990	4,128,170	2,609,654	2,446,952
1991	4,949,558	2,625,855	2,534,881
1992	5,483,060	2,658,938	2,579,170
1993	5,733,622	2,966,048	2,699,988
1994	8,034,505	3,136,905	2,949,527
1995	8,763,997	3,388,793	3,205,509
1996	9,398,110	3,605,511	3,431,198
1997	10,431,186	3,941,345	3,865,305
1998	12,749,023	4,668,381	3,832,318
1999	13,173,691	5,027,037	3,867,172
2000	15,271,179	5,241,284	3,953,327
2001	15,511,063	5,568,194	4,043,954
2002	16,088,364	5,710,139	4,222,978
2003	18,138,179	5,750,272	4,467,458
2004	19,587,561	5,839,749	4,636,188
2005 (3rd Q.)	22,016,419	5,854,986	4,760,968
Average annual growth rate (%)	11.04%	5.29%	4.78%

Source: AJM (2006)

and significant relationship between the number of unhealthy/hazardous days with retail and office space.

The traffic volume in KL is also showing an increasing trend for 1997 to 2006 period (table 5) despite the fluctuations in the annual growth rates.

3.3 Relationship between air quality and urban growth

Result of the Spearman correlation test (table 6) indicates a significant and strong positive relationship between the number of unhealthy/hazardous days and urban parameters (shopping, office or occupied office floor spaces in KL, year 1999 to 2005) with correlation coefficients (r) of 0.821 which were significant at the 0.05 level. Besides, there was also a significant and strong positive relationship between number of unhealthy/hazardous days and industrial units in KL (year 2000 to 2005) with correlation coefficients (r) of 0.912 which was significant at the 0.05 level. It shows that increase of "shopping floor space", "office floor space" or "industrial units" is positively related with the number of unhealthy/hazardous days in KL. This result is contrary with the claim by the KL City Plan study team (AJM, 2006) that unhealthy days in KL are most likely contributed by the yearly haze form by trans-boundary pollution.

The significant relationship between landuses and air pollution was found in time series study but not for study between the six strategic zones in Kuala Lumpur. Relationship study at the zone/district level is not discussed in detail in this paper. At the zone/

Table 4. Supply of industrial units in Kuala Lumpur.

Year	Industrial units	Annual growth rate (%)
2000	4,793	
2001	4,871	1.63
2002	4,922	1.05
2003	4,922	0.00
2004	4,954	0.65
2005 (3rd Q.)	4,954	0.00

Source: AJM (2006)

Table 5. 16 Hours traffic volume in Kuala Lumpur, 1997-2006.

Station No.	Year									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
WR106	194,003	148,443	153,752	186,443	107,187	247,427	239,620	290,341	274,154	245,799
WR105	190,023	209,971	170,076	180,382	199,350	213,363	213158	208,656	226,019	244,417
WR103	140,428	160,804	181,669	180,714	151,827	160,445	172,281	192,095	185,828	206,484
WR102	142,233	135,432	141,407	152,906	144,027	156,842	164,701	152,455	155,016	150,874
WR101	107,132	105,040	101,587	101,048	107,680	102,424	115,143	133,390	131,161	129,092
Total	773,819	759,690	748,491	801,493	710,071	880,501	904,903	976,937	972,178	976,666
Average	154,764	151,938	149,698	160,299	142,014	176,100	180,981	195,387	194,436	195,333
Annual average growth rate (%)		-1.83	-1.47	7.08	-11.41	24.00	2.77	7.96	-0.49	0.46

Source: Ministry of Works Malaysia (2006)

district level, only density of green area (parks, greens and forest) shows positive, strong and significant (at 0.01 level) relationship with the number of moderate air quality days, and negative, strong and significant (at 0.05 level) relationship with number of unhealthy air quality days. This result is supported by a study in high density residential environment in Hong Kong. The study in different districts in Hong Kong shows that in spite of the differences in land usages, planning, layout and orientation, there are no variations in air pollution characteristics and patterns at district level (Edussuriya et al., 2009). It can be explained by the characteristic of the major air pollutants that able to separate in urban level or even in regional level in short period of time, which make no significant relationship of higher air pollution in more developed zone/ district in a city or even no variation in air pollution characteristic. Pollutants from urban sources, such as nitrogen oxides, carbon monoxide, smoke (particulate matter) and sulphur dioxide, tend to be present at high concentrations throughout the city and at significantly reduced concentrations in adjacent rural areas (Harrison,

Table 6. Relationship between air quality and urban development parameter in KL, time series.

Urban development parameters		**Air quality level (API)**		
		No. of good air quality days	No. of moderate air quality days	No. of unhealthy/ hazardous air quality days
Shopping space (sq.ft) in KL	Correlation coefficient	-0.286	0.000	0.821*
	Significance level	0.535	1.000	0.023
	N	7	7	7
Office space (sq.m) in KL	Correlation coefficient	-0.286	0.000	0.821*
	Significance level	0.535	1.000	0.023
	N	7	7	7
Occupied office (sq.m) in KL	Correlation coefficient	-0.286	0.000	0.821*
	Significance level	0.535	1.000	0.023
	N	7	7	7
Industrial units in KL	Correlation coefficient	-0.294	0.164	0.912*
	Significance level	0.571	0.756	0.011
	N	6	6	6
Average traffic volume in KL	Correlation coefficient	-0.048	-0.120	0.405
	Significance level	0.911	0.776	0.320
	N	8	8	8
Total population of KL	Correlation coefficient	0.000	0.180	0.571
	Significance level	1.000	0.699	0.180
	N	7	7	7

Note: * significant at the 0.05 level.

2006). Besides, fine particles (<2.5 μm diameter, but not ultra-fine particles) and some gas-phase pollutants such as ozone have atmospheric lifetimes of days or even weeks, which permit them to be transported on a regional scale areas.

However, the relationship between air quality and other urban parameters such as total population and average traffic volume were not significant even at the 0.10 level in both time series and zone/district level study in Kuala Lumpur. It can be explained with the argument that, air pollution in KL is not only generated by residents (the population) only but also visitors and users who are working, studying or consuming in KL. The traffic sampling stations (by Ministry of Works Malaysia) were not distributed equally in KL city. Therefore, it might neither represent general traffic condition in KL nor traffic condition at the air quality sampling station (at SMK Victoria in city centre, later at Sri Permaisuri).

4. Conclusions

In line with the city growth, air quality has been polluted by the urbanisation process. With the increase of commercial (offices, shopping) and industrial floor spaces, city ambient air has been polluted with more unhealthy/hazardous days. Commercial development in the city generates and attracts human trip. Due to the unsustainable landuse setting in a city such as less mixed use, landuse segregation, less pedestrian friendly environment, inadequate supply of affordable housing, less efficient public transport system and highways development, the increase in human trips are carried out using private vehicles. Since mobile sources (transportation) are the biggest contributors of air pollutants (DOS, 2001), the increase of private vehicles and trips are emitting more harmful air pollutants such as particulate matter (PM), nitrogen oxide (NO_x), carbon monoxide (CO), hydrocarbons (HCs) and indirectly secondary gas ozone (O_3) into the air (Pola Singh, 2009). In order to reverse the situation, city planner and city council should take effective measures in managing and planning the city development. Smart growth or sustainable development shall be the first priority for tomorrow. Study in Midwestern United States (Stone et al., 2007) shows that compact development patterns, when instituted over a significant period of time, can reduce vehicle travel and pollutant emissions at the scale of the metropolitan region.

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