Sains Malaysiana 41(2)(2012): 179–191

# Urban Air Environmental Health Indicators for Kuala Lumpur City

(Indikator Kesihatan Persekitaran Udara Bandar untuk Bandaraya Kuala Lumpur)

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ABSTRACT

*Air environmental health indicators were defined operationally as a combination of "air quality" and "air-related health" indicators. Clean air is a basic precondition of human health. Air pollutants had been identified with potential negative impact on health especially on respiratory and cardiovascular diseases. Thus, studies are necessary to identify and understand the state of environmental health. This study was aimed to examine and analyse the air environmental health condition in city of Kuala Lumpur by using a set of indicators. House to house questionnaire survey was carried out to collect air-related health data, and air quality sampling was carried out to identify ambient air quality level of the city. In general, city of Kuala Lumpur was found to have a "moderate level" of air quality. Air-related illnesses indicated by acute respiratory infection and asthma were found to be higher in more developed or higher density zones, as compared to other zones. Besides, air-related illnesses were significantly correlated to respondents' exposure to air pollution. The findings imply that human health can be improved by managing the urban development and its environmental quality properly.*

*Keywords: air quality; air-related health; city; indicators*

ABSTRAK

*Indikator kesihatan persekitaran udara didefinisikan secara operasi sebagai satu pergabungan indikator "kualiti udara" dan "kesihatan berkaitan dengan udara". Pencemar-pencemar udara telah dikenal pasti dengan kesan negatif ke atas kesihatan terutamanya penyakit-penyakit pernafasan dan kardiovaskular. Oleh itu, kajian perlu dilakukan untuk mengenal pasti dan memahami keadaan kesihatan persekitaran. Kajian ini telah dijalankan untuk memeriksa dan menganalisis keadaan kesihatan persekitaran udara bagi bandaraya Kuala Lumpur dengan menggunakan satu set indikator. Kajian soal-selidik dari rumah ke rumah telah dilakukan untuk mengumpul data kesihatan berkaitan udara, dan persampelan kualiti udara telah dilakukan untuk mengenal pasti kualiti udara ambien bandaraya tersebut. Secara amnya, bandaraya Kuala Lumpur dikenal pasti dengan kualiti udara pada tahap "sederhana". Penyakit berkaitan udara yang diukur dengan indikator jangkitan pernafasan akut dan asthma telah dikenal pasti lebih tinggi di zon-zon yang lebih membangun atau berketumpatan tinggi jika berbanding dengan zon-zon lain. Di samping itu, penyakit berkaitan udara adalah mempunyai korelasi yang ketara dengan perdedahan responden kepada pencemaran udara. Penemuan kajian ini menunjukkan bahawa kesihatan manusia dapat dipertingkatkan dengan pengurusan pembangunan bandar dan kualiti persekitaranya dengan baik.*

*Kata kunci: Bandaraya; kesihatan berkaitan dengan udara; kualiti udara; indikator*

## INTRODUCTION

Environmental health comprises those aspects of human health and diseases that are determined by factors in the environment (WHO-Europe 2007). It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect health. Thus, the environmental health was defined operationally as a combination of "human health" conditions and "environmental quality" in this paper. The environmental quality component is the environmental factor which potentially affects human health. For the purpose of this study, the urban air environmental health condition of the area of study was identified by using indicators.

With the focus on urban air environmental health indications, "air-related health indicators" were used instead of overall health conditions of the general public. At the same time, general environmental quality was replaced by "air quality indicators". Thus, the urban air environmental health indicators are consisting of air-related health indicators and air quality indicators.

The urban and regional planning system seeks to guide appropriate development to the right place and prevent inappropriate development taking place aiming at securing sustainable development (Dasimah & Ling 2006). However, the rapid urban growth due to high fertility and rural-urban migration caused pressure on the environment in many national urban settings (UN 2001). Cities in developing countries, especially, are facing increasing environmental pollution from vehicle emissions, and from industries and domestic heating sources at a level that exceeds the capacity to disperse and dilute emissions to non-harmful exposure levels (UN 2001). Besides, there were illegal and unregulated factories in urban areas, which had caused much environmental pollution. Unregulated factories are not always equipped with proper facilities to reduce air pollution. Many such industrial activities especially small and medium enterprises (SME) are constructed and distributed haphazardly and poorly managed (JPBD 2006).

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 Kuala Lumpur, 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 (Ling et al. 2010a). The primary emissions of sulphur oxides, nitrogen oxides, carbon monoxides (CO), respirable particulates and metals (such as lead and cadmium) were severely polluting cities and towns in Asia, Africa, Latin America and Eastern Europe (Christiani & Woodin 2002).

Clean air is a basic precondition of human health (WHO 2008). Respiratory and cardiovascular diseases are especially relevant to air pollution susceptibility throughout the world (Kinney & O'Neill 2006). Research had shown that many air pollutants may contribute to the onset or aggravation of heart diseases, especially carbon monoxide (CO), ozone ($O_3$) and fine particulate matter ($PM_{2.5}$) (US EPA 2003; Utell et al. 2006). Studies on the laboratory animals and human populations showed significant associations of acute cardiovascular system effects (such as heart rate variability, HRV) with air pollution levels (e.g. $PM_{10}$ and $O_3$) (Saldiva et al. 2006).

Epidemiologic and laboratory studies also demonstrate that ambient air pollutants (e.g. PM, $O_3$, $SO_2$ and $NO_2$) contribute to various respiratory problems including bronchitis, emphysema, and asthma (Botkin & Keller 2003; Romieu 1999; US EPA 2007; Utell et al. 2006; WHO 2005a). People suffering from respiratory diseases are the most likely to be affected by air pollution (Botkin & Keller 2003). In Malaysia, studies by Rafia et al. (2003) and Norela et al. (2008) showed a clear increase of respiratory infection (acute respiratory infection and asthma) and conjunctivitis cases during haze episode as compared to the periods before and after the haze event.

The state of air environmental health of a city needs to be examined for a better evaluation of existing urban development patterns in towards a healthy environment. Thus, a study was carried out with the objectives to determine the relevant indicators established locally and globally, and to formulate air environmental health indicators for the city of Kuala Lumpur; to examine and analyse the air environmental health condition of the city of Kuala Lumpur based on the formulated indicators, and to make recommendations on the city planning and development strategy.

## Materials and Methods

### Area of Study

To examine urban air environmental health condition for a Malaysian city, city of Kuala Lumpur was chosen as an area of study. City of Kuala Lumpur (KL) is a premier city in Malaysia, and has a total population of 1 556 200 in 2005 with a density of 6386 persons per km$^2$. Total land area for KL is 243.7 km$^2$ (AJM 2006). KL is located in the Klang Valley or Kuala Lumpur Conurbation. It is connected with the surrounding areas by highways (e.g. KESAS, Federal Highway, NPE, ELITE), roads, and railways (Light Rail Transits and KTM Komuter). The most developed areas in Klang Valley are the Port Klang–Klang–Shah Alam–Subang–Petaling Jaya-Kuala Lumpur corridor at the western side of KL, and the Multimedia Super Corridor (MSC) at the southern side of KL. Under the Kuala Lumpur Structure Plan (2004-2020) and the Kuala Lumpur City Plan, KL was divided into six strategic planning zones for the purposes of city planning (AJM 2006).

### Methods of Data Collection and Analysis

For the purpose of this study, air-related health data of KL residents was collected for the period of April 2008 to July 2009 through questionnaire survey among residents of KL. By using the stratified random sampling technique, household members of 563 units of houses were chosen as respondents from a total of 440 806 units of houses in KL, which covered all the six strategic planning zones with different housing types and pricing. It covered general households (Malaysian only) with various socio-economic, demographic and pre-existing health backgrounds. Table 1 shows the general demographic characteristics of sampled respondents. The sampled respondents include young children (12 years old and below), teenagers and adults (13 to 64 years old) as well as the elderly (65 years old and above) for both male and female. Majority of respondents were Malays and Chinese who were the biggest ethnic groups in KL as well as in Malaysia in general.

Ambient air quality of KL was identified through air sampling. In the study, six background/ambient air quality sampling stations were identified, as shown in Figure 1 and Table 2. These stations were proposed to cover all the six strategic planning zones in KL. The air sampling stations were located in the areas (mostly housing estates) selected for the questionnaire survey. Thus, the ambient air quality of the respondents' housing areas was measured in the air sampling. The aim of the air quality sampling was to determine the background air quality which was not strongly influenced by any specific source of pollution.

TABLE 1. Demographic background of respondents, by percentage, Kuala Lumpur

| | Percentage of respondents in six zones, KL (%) | | | | | |
|---|---|---|---|---|---|---|
| Age Groups | Bukit Jalil-Seputeh | Bdr. Tun Razak-Sg. Besi | Wangsa Maju-Maluri | Sentul-Menjalara | Damansara-Penchala | City Centre |
| Age below 13 | 22.82 | 26.56 | 14.66 | 12.60 | 14.73 | 25.83 |
| Age 13 to 64 | 75.05 | 72.79 | 82.33 | 87.11 | 83.72 | 74.17 |
| Age 65 and above | 2.13 | 0.66 | 3.00 | 0.28 | 1.55 | 0.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Ethnic Groups | | | | | | |
| Malays | 25.65 | 69.51 | 68.00 | 22.19 | 30.23 | 56.67 |
| Malaysian Chinese | 66.38 | 27.21 | 16.00 | 55.34 | 51.16 | 38.67 |
| Malaysian Indians | 6.90 | 3.28 | 16.00 | 22.47 | 18.60 | 2.00 |
| Other bumiputeras | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Gender | | | | | | |
| Male | 51.42 | 46.33 | 45.08 | 48.03 | 50.39 | 57.34 |
| Female | 48.58 | 53.67 | 54.92 | 51.97 | 49.61 | 42.66 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| No. of respondents | 470 | 305 | 300 | 357 | 129 | 151 |
| No. of sampled households | 121 | 97 | 125 | 121 | 47 | 52 |

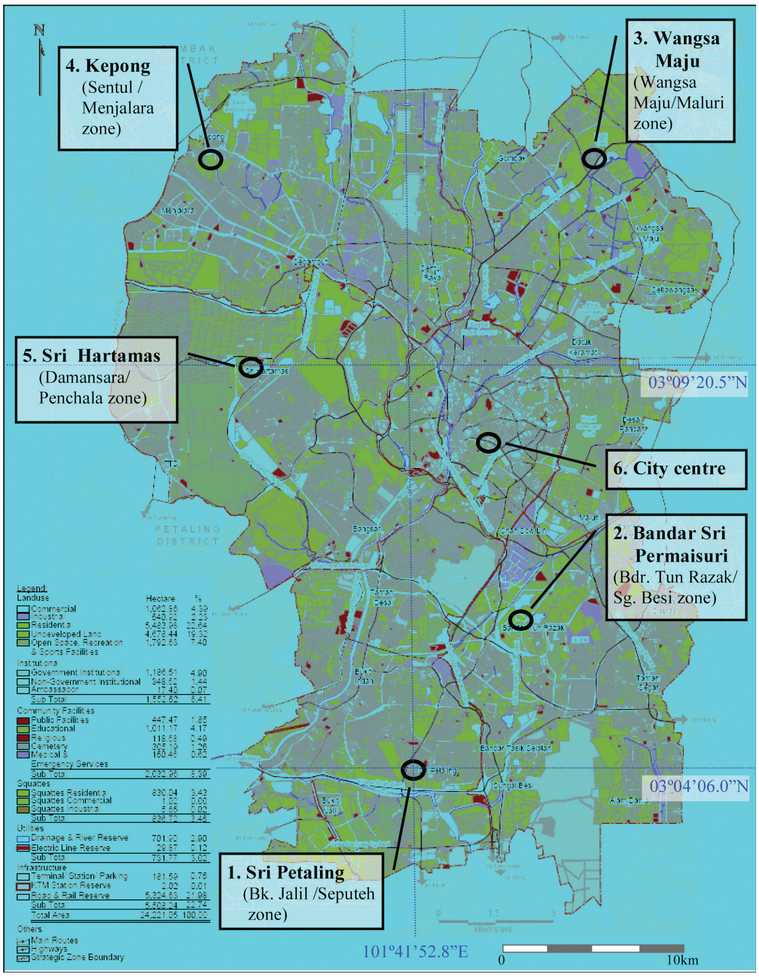


FIGURE 1. Land use and the location of the six air sampling stations in Kuala Lumpur

Source of land use plan: AJM 2006

TABLE 2. Air quality sampling stations in Kuala Lumpur

| Station | Strategic zone (main zone) | Major surrounding land uses / activities & characters |
|---|---|---|
| 1. Bdr. Baru Sri Petaling (SM Sri Petaling, around 100 m from main road, surrounded by houses) N 03º04'06.0" E101º41'52.8" | Bukit Jalil / Seputeh (KL outer zone) | • Mixed housing (medium/high cost)<br>• Adjacent to KESAS highway & Puchong-Sg. Besi Road<br>• Next to Bukit Jalil (KL major sports / recreation facility) & Bk. Jalil Country Resort<br>• KL southern entrance |
| 2. Bdr. Sri Permaisuri (SM Bdr. Sri Permaisuri, DOE' station located, surrounded by houses) N 03º06'26.1" E101º43'00.2" | Bandar Tun Razak / Sungai Besi (KL outer zone) | • Mixed housing types<br>• High density, high rise housing area (mixed, of different costs)<br>• Newly planned / developed urban area with LRT |
| 3. Wangsa Maju (open space at Tmn. Bunga Raya, surrounded by houses) N 03º12'39.3" E101º43'39.4" | Wangsa Maju / Maluri (KL outer zone) | • Mixed housing area<br>• Next to Universiti Tunku Abdul Rahman (UTAR)<br>• Near to the MRR2<br>• Neighbourhood with LRT station |
| 4. Tmn. Kepong (open space, around 100 m from the busy road, Jalan Kepong-Kuala Selangor, surrounded by commercial activities & houses) N 03º12'36.6" E101º37'51.7" | Sentul / Menjalara (KL outer zone) | • Mixed housing area<br>• Near to Tmn. Perindustrian Kepong & Kepong Metropolitan Park KL<br>• Adjacent to busy road (around 100m)<br>• KL northern entrance, accessed by Kepong-Sungai Buloh-Kuala Selangor road (high traffic volume) |
| 5. Tmn. Sri Hartamas (open space, surrounded by houses) N 03º09'20.5" E101º38'56.2" | Damansara / Penchala (KL middle zone) | • High-cost housing area, with on-going construction of new buildings<br>• Less traffic volume<br>• Surrounded by green fields (e.g. Bk. Kiara area) |
| 6. City Centre (open space close to Bursa Malaysia & offices) N 03º08'52.7" E101º42'04.1" | City Centre | • Commercial centre & offices, high-cost houses (landed & high-rise), shop houses/apartments<br>• Near to KL main bus station - Pudu<br>• High traffic volume in the zone |

The location of samples followed the criteria of being at least 100 m from any busy road, not being close to high buildings, and being located in open areas so that they were well exposed to the atmosphere (air flows were unobstructed from most directions) (Harrison 1999; Lau et al. 2009). The advantage of background stations are that they do not present extremes of concentration but represent the background concentration as contributed by many air pollution sources. The majority of people live in background-type areas hence these stations can represent the air quality outside many people's homes (Harrison 1999; Lau et al. 2009).

With the intention of covering both the wet and dry seasons in a year, air quality sampling was undertaken over twelve sampling days from December 2008 until July 2009. The period of December 2008 to March 2009 was categorised as the wet season (east-north monsoon). Meanwhile, the period of May to July 2009 was categorised as the dry season (west-south monsoon) with a slight encroachment into the transition period between the two seasons (i.e. May). The sampling days were 4 and 13 December 2008 (Thursday and Saturday), 29 and 31 January 2009 (Thursday and Saturday), 6 and 7 March 2009 (Friday and Saturday), 27 and 31 May 2009 (Wednesday and Sunday), 13 and 15 June 2009 (Saturday and Monday), 12 and 13 July 2009 (Sunday and Monday).

$PM_{10}$, CO, $NO_2$, $SO_2$ and surface $O_3$ were the five air pollutants (parameters) measured in the air quality sampling. For the purpose to calculate the air quality levels by using Malaysian Air Pollution Index system (API), the concentration of each air pollutant was recorded and calculated in average for specific period of time as follows: $PM_{10}$ and $SO_2$ on 24-hour average; CO on 8-hour averages; and $O_3$ and $NO_2$ on 1-hour average. In-situ air pollutant analysers were used in the air sampling. GRIMM Aerosol Spectrometers were used to measure the concentration of ambient $PM_{10}$. Meanwhile, VRAE Multi Gas Monitors were used for ambient CO, $NO_2$ and $SO_2$. The concentrations of the four parameters were recorded every 15 minutes for the whole day. LaMotte Gas Pumps, LaMotte Ozone Sets (sodium arsnite solution 0.5% and DPD#4) and Harts Spectrophotometer were used to measure the concentration of $O_3$ every hour on the sampling days.

Analyses of the air-related health conditions and air quality of KL were carried out based on the requirement of indicators established in this study. The API system and Recommended Malaysian Air Quality Guidelines (RMAQG) were used in the air quality indication.

## Results and Discussion

### URBAN AIR ENVIRONMENTAL HEALTH INDICATORS

Environmental health indicators have been used globally as a measurement tool in identifying the state of environmental health and its causes. Besides, indicators are also used to evaluate policies or effectiveness of any human plan or action. In this study, local and international related indicators were reviewed before a set of air environmental health indicator was proposed for KL.

In general, for the purpose of indicating urban air quality for environmental health or sustainability, the five pollutants ($PM_{10}$, $O_3$, CO, $SO_2$, $NO_2$) and API were usually selected. Table 3 shows the summary of air quality indicators used or proposed by various organisations or studies.

With reference to the various air quality indicators used by various local and international organisations, the air quality indicators formulated in this study were based on the city's air quality target. The target for KL is to achieve API values within the good range for 20% of the year and within moderate range for the remaining 80% of the year (AJM 2006). Four air quality indicators were formulated in this study, as: (1) Total number (or percentage) of good, moderate, unhealthy, very unhealthy, hazardous or emergency API days in the dry and wet seasons, as well as during the whole period of study. The KL's target for air quality was used as the benchmark to indicate the "excellent" air quality level. The classifications of air quality levels for this indicator are shown in Table 4. (2) Total number (or percentage) of good, moderate, unhealthy, very unhealthy, hazardous or emergency API days for every single pollutant (*i.e.* $SO_2$, $NO_2$, $O_3$, $PM_{10}$, CO) in the dry and wet seasons, as well as during the whole period of study. The same methodology and classifications as in Indicator 1 were used. The reason for this indicator in addition to the Indicator 1 was to assist in the identification of the potential sources and factors of air pollution which are related to the urban development and activities. (3) Percentage of city's population living in areas where the ambient air quality was experiencing unhealthy, very unhealthy, hazardous or emergency API level. (4) Percentage of people frequently exposed to air pollution as self-reported.

Beside the air quality indicators, air-related health indicators were also identified in this study for KL. Existing international or local air-related health indicators were formulated by using readily available data especially from the hospital records. In Malaysia, there was no specific set of environmental health indicator that had been established or implemented. However, there are some Healthy Cities initiatives or projects which are on-going in Malaysian cities or towns, which are Healthy City Johor Bahru since 1994 (Rozlan 1998; Daud 2002), Malacca (Pereira & Mohd Nordin 2004), Healthy Cities Kuching since 1994, and subsequently in other major towns in Sarawak (Rozlan 1998). In general, these healthy cities projects or initiatives were aiming for a better city environment with good features such as higher quality of life, safety,

TABLE 3. Summary of air quality indicators

| Organisations / studies | Air quality indicators |
|---|---|
| WHO Environmental Health Indicators (Briggs 1999) | mean annual or percentile concentration of 6 major ambient air pollutants, *i.e.* $O_3$, CO, PM, $SO_2$, $NO_2$ and Pb. |
| Briggs (1999) and Gosselin et al. (2001) | number of days/hours in excess of air pollution standard |
| New Zealand (Hambling & Slaney 2007) | number of days exceeding WHO guidelines for the major 5 pollutants, i.e. $PM_{10}$, $O_3$, $SO_2$, $NO_2$, and CO |
| Seattle, Washington, US (Peralta 2003) | number of "good" air quality days in the calendar year |
| Atlanta (CDC 2006) | annual high levels of criteria pollutants: $PM_{10}$, $O_3$, $SO_2$, $NO_2$, CO and Pb |
| WHO's Healthy Cities Movement (Barton & Tsourou 2000) | atmospheric pollution based on the pollution level of $SO_2$, $NO_2$, CO, $O_3$, Pb and dust |
| US EPA (2003) | number and percentage of days that metropolitan statistical areas have AQI values greater than 100; number of people living in areas with $O_3$ (8 hour) and $PM_{2.5}$ levels above the NAAQS |
| Gosselin et al. (2001) for U.S.-Mexico region | percentage of children living in counties in which air quality standards are exceeded air quality standard |
| Kuching Healthy City, Malaysia (Andrew 1998) | number of pollution free days in a month; number of areas with air pollution in a month |
| Selangor Sustainable Development Indicators, Malaysia (Selangor State Government 2001) | total number of day with API exceeding unhealthy level; SO & NO pollution level in Petaling Jaya & Shah Alam; small particulate matter & $PM_{10}$ concentration |
| Malaysian Sustainable City Award (Tan et al. 2006) | number of days exceeding standard for selected year of CO and $NO_x$ concentration level in ambient air |

TABLE 4. Classifications of air quality level for Indicator 1 and 2

| Classification | Criteria |
|---|---|
| Excellent | Good API level for 20% or more of a year (or a period) and the remaining days are moderate. No unhealthy / hazardous / emergency days. |
| Good | Good API level for 10 to <20% of a year (or a period) and the remaining days are moderate. No unhealthy / hazardous / emergency days. |
| Moderate | Good API level for <10% of a year (or a period) and the remaining days are moderate; or |
| | Unhealthy API level for <10% of a year (or a period) and the remaining days are moderate or good. |
| Unhealthy | Unhealthy API level for 10 to <20% of a year (or a period) and the remaining days are moderate or good. |
| Hazardous | Unhealthy API level for 20% or more of a year (or a period) and the remaining days are moderate or good; or<br>There is any very unhealthy, hazardous or emergency API level in a period. |

cleanliness, harmony, provided with amenities, and well-planned. Besides, there are few initiatives of sustainable indicators and environmental targets in Malaysia which cover some aspects of environmental health.

The first and second columns of Table 5 show some of the air-related health indicators established or used by local and international organisations. The third column shows the proposal of air-related health indicators for this study. Number of ARI ill-symptom cases (ARI incidence) is measured based on self-reported frequency of getting ARI symptoms by respondents, which suffered for a period within 14 days per case. Any illness experienced for a period within 14 days was considered as an episode/case of acute illness. This is similar to the definition used by the Institute of Public Health, Malaysia. The majority of ARI episodes lasted within duration of 14 days and was an acute, self limiting condition (IPH 2008).

## AIR QUALITY INDICATION

The results of the four air quality indicators are discussed briefly as follow. Air quality (measured in API) in KL was more polluted in the period of May-July 2009 (dry season) as compared to the period of December 2008-March 2009 (wet season) in most of the zones, except for the City Centre (Table 6). It showed that wet season with more rainfall could reduce the concentration of air pollutants in the air. The most polluted area in KL was Bandar Tun Razak/Sungai Besi zone ("hazardous" during May-July 2009), and followed by Bukit Jalil/Seputeh ("unhealthy" level during May-July 2009). The best air quality area was Wangsa Maju/Maluri ("good" level). An unhealthy (or higher levels) day was indicated by the concentration of most polluted pollutant which was higher than the standard in RMAQG.

Among the five pollutants, KL was more polluted by $O_3$ and $PM_{10}$ (Tables 7). Nitrogen Dioxide ($NO_2$) concentrations were showing either good or moderate API levels for all the six strategic planning zones. Meanwhile, CO and $SO_2$ concentrations were showing good API levels for every sampling day in all the six zones. $PM_{10}$ is a parameter consists of various types of pollutants including gases and dusts. In Malaysia, stationary sources (including industries & power plants) contributed almost 90% of the emissions of $PM_{10}$ (EPU 2006). Ozone is the secondary pollutant formed by volatile organic compounds (VOC) and nitrogen dioxide ($NO_2$) with the existence of sunlight. Thus, with an increase in $O_3$ concentrations, the other pollutants (especially the $NO_2$) decreased at the same time. VOC is produced from combustion of fossil fuels (in industries and vehicles) and incineration, evaporation of liquid fuel and leakage from pressurized system (*e.g.* natural gas and methane). Meanwhile, $NO_2$ was mainly produced by mobile sources (EPU 2006). The findings showed that air pollution in KL was mainly contributed by mobile sources (especially motor vehicles) and stationary sources (especially industries).

The most polluted area, Bandar Tun Razak/Sungai Besi zone consisted of 16.47% of KL population. The biggest population group (23.47%) was living in the most healthy air quality zone, i.e. Wangsa Maju/Maluri (Table 6). Table 8 shows that there were 5% to 15% of respondents in KL (among the six zones) who were frequently exposed to air pollution due to their presence in air polluted areas such as factories, workshops, busy roadsides and construction sites. Damansara/Penchala zone had the highest percentage of respondents (14.73%) who were frequently present in air polluted areas. It was due to the surrounding areas of Damansara which were undergoing active property construction activities. The construction activities were adjacent to some houses, offices, schools, parks and main roads.

## AIR-RELATED HEALTH INDICATION

This paper is not intended to discuss results of all the air-related indicators in detail. Out of the 13 air-related health indicators, only the selected findings of the Indicators 1 and

TABLE 5. Indicators for air-related diseases or ill-symptoms

| Existing established indicators | Organisations / sources | Proposed indicators for this study |
|---|---|---|
| Number of cases & number of deaths for acute respiratory infections (ARI) in a year. | WHO (2005b) for Singapore | 1. Acute respiratory infections (ARI) rates (hospitalisation, outpatient visits & ill-symptoms) per 10 000 people. |
| Incidence of morbidity due to the ARI in children under 5 years of age; & elderly. | WHO Environmental Health Indicators (Briggs 1999) | 2. Rates of hospitalisation / outpatient visits/ ill-symptoms due to ARI among children below the age of 5 & 13 (per 10 000 children);<br>3. Rates of hospitalisation / outpatient visits/ ill-symptoms due to ARI among elderly (aged 65 & above) per 10 000 people; |
| Incidence of mortality due to the ARI in children under 5 years of age. | | *ARI mortality incidence was not identified in this study.* |
| Ratio of Asthma case to 10 000 population. | MURNInet (JPBD 2005) | 4. Rates of asthma cases (hospitalisation / outpatient visits / emergency unit visits) per 10 000 people; |
| Rate of hospitalisation of children for asthma. | Seattle's Environmental health indicators (Peralta 2003; Gosselin et al. 2001) | 5. Rates of asthma cases (hospitalisation / outpatient visits / emergency unit visits) among children below the age of 5 & 13 (per 10 000 children); |
| Number of asthma-related deaths. Incidence of asthma. | Atlanta's Environmental Public Health Indicators (Centers for Disease Control and Prevention 2006) | *Incidence of respiratory dead was very rare in this study* |
| Rates of hospitalisation & emergency department visits for acute asthma events. Proportion of population filling prescription for asthma medication. | | 6. Increase of severity of chronic respiratory or cardiac illnesses due to air pollution (or haze), as measured by increase in intake of medicine (in percentage); |
| Number of work days missed because of asthma. | | 7. Number of work days missed per patient due to asthma;<br>8. Rates of work days missed due to asthma (per 10 000 people); |
| Number of school days missed because of asthma. | | 9. Number of school days missed per patient due to asthma;<br>10. Rates of school days missed due to asthma per 10 000 school children; |
| Number of admissions for coronary heart disease. | Kuching Healthy City (Andrew 1998) | *Combined with other indicators* |
| Rates of hospitalisation & emergency department visits for acute cardiovascular & respiratory events. | Atlanta's Environmental Public Health Indicators (CDC 2006) | *Combined with other indicators* |
| Cancer incidence and mortality rates (optional indicator). | | *Cancer case was not identified in this study.* |
| Number of peoples visit to hospital due to asthma, upper respiratory infections (URI) & conjunctivitis. | Malaysian Government (Norlela et al. 2005) | 11. Rates of ill-symptoms / hospitalisation / outpatient visits due to conjunctivitis (per 10 000 people). |
| Emergency consultations for asthma, bronchitis, cardio-pulmonary disease | Gosselin et al. (2001) | 12. Rates of hospitalisation / outpatient visits / emergency unit visits due to chronic respiratory diseases (non-asthmatic) per 10 000 people.<br>13. Rates of hospitalisation / outpatient visits / emergency unit visits due to cardiac diseases (per 10 000 people). |
| Annual number of hospital admissions for respiratory diseases | Environmental Health Indicators for New Zealand (Hambling & Slaney 2007) | *Incidence of respiratory / cardiovascular dead was very rare in this study.* |
| Annual number of hospital admissions for diseases of the circulatory system; & asthma (per 100 000 population) | | |
| Annual mortality rate due to respiratory diseases / cardiovascular diseases | | |
| Annual prescription rate for asthma medication (per 100 000 population) | | *Combined with other indicators* |

Note: Rates of illness in the proposed indicators were calculated as ratios of illness cases among respondents to total number of respondents (or any segment of respondents) which may consist of repeated cases of the same respondent.

TABLE 6. Air Quality Indicator 1 (percentage of days for each level of API, for the periods of December 2008-March 2009 and May-July 2009), and Air Quality Indicator 3 (size of population)

| API levels / Sampling stations/zones | Dec. 08 - Mar. 09 | | | | | May - July 09 | | | | | Size of population, 2005* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Good | Moderate | Unhealthy | Very Unhealthy | Level of indicator | Good | Moderate | Unhealthy | Very Unhealthy | **Level of indicator** | No. | % |
| Bk. Jalil/Seputeh | 16.7 | 83.3 | 0.0 | 0.0 | Good | 0.0 | 83.3 | 16.7 | 0.0 | Unhealthy | 318,300 | 19.65 |
| Bdr. Tun Razak/Sg. Besi | 16.7 | 83.3 | 0.0 | 0.0 | Good | 0.0 | 66.7 | 33.3 | 0.0 | Hazar-dous | **266,900** | **16.47** |
| Wangsa Maju/Maluri | 16.7 | 83.3 | 0.0 | 0.0 | Good | 16.7 | 83.3 | 0.0 | 0.0 | Good | **380,300** | **23.47** |
| Sentul/ Menjalara | 16.7 | 83.3 | 0.0 | 0.0 | Good | 0.0 | 100.0 | 0.0 | 0.0 | Moderate | 344,500 | 21.26 |
| Damansara/ Penchala | 16.7 | 83.3 | 0.0 | 0.0 | Good | 0.0 | 100.0 | 0.0 | 0.0 | Moderate | 167,100 | 10.31 |
| City Centre | 0.0 | 83.3 | 16.7 | 0.0 | Unhealthy | 0.0 | 100.0 | 0.0 | 0.0 | Moderate | 143,000 | 8.83 |
| Kuala Lumpur | | | | | | | | | | | 1,620,100 | 100.00 |

Notes:
1. The calculation of API was based on the average density of every pollutant ($SO_2$, $NO_2$, $O_3$, $PM_{10}$, CO) which acted as API sub-index. The dominant pollutant with the highest value determined the API value. The key reference point in the API systems was the index value of 100 (the "safe" limit), which was based on the air quality guidelines for the specific air pollutants concerned as referred to RMAQG.
2. Good level (API 0 – 50); moderate level (API 51 – 100); unhealthy level (API 101 – 200); very unhealthy level (API 201 – 300); hazardous level (API 301 – 500); emergency level (API >500).
Source: Ling et al. 2010b; *CHKL 2009

TABLE 7. Air Quality Indicator 2 - number of days for each category of API for $PM_{10}$, $O_3$, $NO_2$, CO and $SO_2$, December 08-July 2009

| PM-10 | Good Q. (API 0 - 50) | | Moderate Q. (API 51-100) | | Unhealthy Q. (API 101-200) | | Levels of indicator |
|---|---|---|---|---|---|---|---|
| | No | % | No | % | No | % | |
| Bk. Jalil/Seputeh | 8 | 66.67 | 4 | 33.33 | 0 | 0.00 | Excellent |
| Bdr. Tun Razak/Sg. Besi | 9 | 75.00 | 2 | 16.67 | 1 | 8.33 | Moderate |
| Wangsa Maju/Maluri | 11 | 91.67 | 1 | 8.33 | 0 | 0.00 | Excellent |
| Sentul/Menjalara | 9 | 75.00 | 3 | 25.00 | 0 | 0.00 | Excellent |
| Damansara/Penchala | 11 | 91.67 | 1 | 8.33 | 0 | 0.00 | Excellent |
| City Centre | 10 | 83.33 | 2 | 16.67 | 0 | 0.00 | Excellent |
| Average | 9.7 | 80.56 | 2.2 | 18.06 | 0.2 | 1.39 | Moderate |
| $O_3$ | | | | | | | |
| Bk. Jalil/Seputeh | 3 | 25.00 | 8 | 66.67 | 1 | 8.33 | Moderate |
| Bdr. Tun Razak/Sg. Besi | 2 | 16.67 | 9 | 75.00 | 1 | 8.33 | Moderate |
| Wangsa Maju/Maluri | 4 | 33.33 | 8 | 66.67 | 0 | 0.00 | Excellent |
| Sentul/Menjalara | 3 | 25.00 | 9 | 75.00 | 0 | 0.00 | Excellent |
| Damansara/Penchala | 4 | 33.33 | 8 | 66.67 | 0 | 0.00 | Excellent |
| City Centre | 1 | 8.33 | 10 | 83.33 | 1 | 8.33 | Moderate |
| Average | 2.8 | 23.61 | 8.7 | 72.22 | 0.5 | 4.17 | Moderate |
| $NO_2$ | | | | | | | |
| Bk. Jalil/Seputeh | 7 | 63.64 | 4 | 36.36 | 0 | 0.00 | Excellent |
| Bdr. Tun Razak/Sg. Besi | 8 | 72.73 | 3 | 27.27 | 0 | 0.00 | Excellent |
| Wangsa Maju/Maluri | 9 | 81.82 | 2 | 18.18 | 0 | 0.00 | Excellent |
| Sentul/Menjalara | 6 | 54.55 | 5 | 45.45 | 0 | 0.00 | Excellent |
| Damansara/Penchala | 8 | 72.73 | 3 | 27.27 | 0 | 0.00 | Excellent |
| City Centre | 6 | 54.55 | 5 | 45.45 | 0 | 0.00 | Excellent |
| Average | 7.3 | 66.67 | 3.7 | 33.33 | 0 | 0.00 | Excellent |

Note: All the 6 sampling stations/zones showed a good level for CO and $SO_2$ concentrations with API below 50 for the period of December 2008 to July 2009. Thus, this indicator showed "excellent" levels for CO and $SO_2$ concentrations in KL.

TABLE 8. Air Quality Indicator 4 - percentage of people frequently exposed to air pollution as self-reported

| | Percentage of respondents in 6 zones, KL (%) | | | | | |
|---|---|---|---|---|---|---|
| | Bukit Jalil/ Seputeh | Bdr. Tun Razak/Sg. Besi | Wangsa Maju/ Maluri | Sentul/ Menjalara | Damansara/ Penchala | City Centre |
| Exposed | 10.26 | 5.33 | 5.61 | 7.47 | 14.73 | 8.05 |
| None | 89.74 | 94.67 | 94.39 | 92.53 | 85.27 | 91.95 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

4 are discussed in this paper. Acute Respiratory Infection (ARI) was used as indicator in Indicator 1, and asthma was used in Indicator 4. Table 9 shows the rates of ARI ill-symptoms, ARI outpatient visits and asthmatic outpatient visits cases in KL. The results indicated that the higher rates of ARI ill-symptoms were reported for the period of October 2008 to March 2009 (wet season) as compared to the period of April to July 2009 (dry season), except for Bukit Jalil-Seputeh and Bandar Tun Razak-Sungai Besi zones. The wet season (October 2008 to March 2009), however, had recorded with a better ambient air quality level as compared to the period of April to July 2009 (Tables 6). It contradicted the common assumption that respiratory cases should be higher in the dry season where ambient air quality is generally more polluted than in the wet season. This was because air-related illness (respiratory health) was not only influenced by ambient air quality but also by the rate of the individual respondent's exposure to air pollutants, the weather factor, or climate change. Besides, there are other factors that potentially affect respiratory health, for example, the impact of allergens and moulds, age, and socio-economic factor (Gouveia & Maisonet 2006; Janssen & Mehta 2006; Utell et al. 2006). Change of temperature and excessive rainfall impact other health-relevant factors such as allergens and moulds (Ayres et al. 2009).

Based on the rates of ARI outpatient visits, three areas i.e. Wangsa Maju/Maluri, Sentul/Menjalara and Damansara/Penchala zones were showing higher rates in the period of October 2008 to March 2009 as compared

TABLE 9. Rates of ARI ill-symptoms, ARI outpatients and asthmatic outpatients, population density, and shopping floor space, Kuala Lumpur

| Respiratory cases | Number of cases per 100 people | | | Population density, 2005 (person per km$^2$)* | Shopping fl. space, 2010 ('000 m$^2$ per km$^2$)* |
|---|---|---|---|---|---|
| | Oct. 08 to Mar. 09 | Apr. to July 09 | Total | | |
| City Centre | | | | 8 038 | 111.21 |
| ARI ill-symptom | 82 | 68 | 150 | | |
| ARI outpatient | 29 | 30 | 59 | | |
| Asthmatic outpatient | 4.0 | 1.3 | 5.3 | | |
| Bukit Jalil/Seputeh | | | | 7 363 | 25.85 |
| ARI ill-symptom | 49 | 53 | 102 | | |
| ARI outpatient | 29 | 30 | 59 | | |
| Asthmatic outpatient | 0.9 | 0.6 | 1.5 | | |
| Wangsa Maju/Maluri | | | | 8 163 | 18.42 |
| ARI ill-symptom | 39 | 38 | 77 | | |
| ARI outpatient | 30 | 25 | 55 | | |
| Asthmatic outpatient | 2.3 | 2.0 | 4.3 | | |
| Sentul/Menjalara | | | | 7 473 | 21.11 |
| ARI ill-symptom | 33 | 22 | 55 | | |
| ARI outpatient | 24 | 14 | 38 | | |
| Asthmatic outpatient | 0.6 | 0.6 | 1.2 | | |
| Bdr. Tun Razak / Sg. Besi | | | | 6 483 | 10.50 |
| ARI ill-symptom | 24 | 32 | 56 | | |
| ARI outpatient | 13 | 19 | 32 | | |
| Asthmatic outpatient | 0.3 | 1.0 | 1.3 | | |
| Damansara/Penchala | | | | 3 521 | 5.85 |
| ARI ill-symptom | 16 | 14 | 30 | | |
| ARI outpatient | 13 | 7 | 20 | | |
| Asthmatic outpatient | 0.0 | 1.6 | 1.6 | | |

Source: * adapted from AJM 2006

to the dry season. However, the City Centre, Bandar Tun Razak/Sungai Besi and Bukit Jalil/Seputeh zones were showing slightly higher rates of ARI outpatient visits during the period of April to July 2009 as compared to the period of October 2008 to March 2009. The rates of asthmatic outpatient visits were higher in the period of October 2008 to March 2009 as compared to the dry season for Wangsa Maju/Maluri, the City Centre and Bukit Jalil/Seputeh zones. However, Sentul/Menjalara, Damansara/Penchala and Bandar Tun Razak/Sungai Besi zones were showing higher rates in the period of April to July 2009 (Table 9). It implies that respiratory illness (ARI or asthmatic) rates were not always higher during the dry season (more polluted) as compared to the wet season.

As shown in Table 6, Bandar Tun Razak/Sungai Besi, Bukit Jalil/Seputeh and the City Centre zones had a higher number of unhealthy days as compared to the other zones. However, the higher percentages of ARI and asthma cases were identified in the City Centre, Bukit Jalil/Seputeh and Wangsa Maju/Maluri zones. Bandar Tun Razak/Sungai Besi zone with the highest number of unhealthy days was identified with lower rates of ARI and asthma cases (Table 9). Thus, positive relationship between selected air-related health indicators and ambient air quality among the six strategic planning zones were not developed.

However, by looking at the relationship between ARI or asthma cases, and density of the areas/zones, it showed a trend of higher ARI and asthma cases at the higher density zones (Table 9). The City Centre, Bukit Jalil/Seputeh and Wangsa Maju/Maluri zones were identified with higher density of population and shopping floor space as compared to other zones in KL. Meanwhile, these zones also showed higher rates of ARI and asthma cases.

Table 10 shows the results of relationship tests between air-related health indicator (rates of ARI ill-symptoms) and respondent's exposure to air pollutant (duration of time spent by respondents in air polluted areas). The relationships were tested by using the Spearman rank correlation method. The relationships were significant at most of the zones, except for Damansara/Penchala and Bandar Tun Razak/Sungai Besi zones which were not significant even at the 0.10 level. Even though the statistical relationships showed a significant but weak correlation, it implies that people's health is potentially influenced

TABLE 10. Relationships between duration of time spent in air polluted areas and rates of ARI ill-symptoms of respondents

| Sentul/Menjalara | | ARI ill-symptom (Apr. to Sept. 08) Middle of year | ARI ill-symptom (Oct. 08 to Mar. 09) Year end/begin | ARI ill-symptom (Apr. to July 09) Middle of year |
|---|---|---|---|---|
| Time spent in air polluted area (hour/ week) | Correlation coefficient (r) | 0.122* | 0.137* | 0.228** |
| | Significance level | 0.022 | 0.010 | 0.000 |
| Wangsa Maju/Maluri | | | | |
| Time spent in air polluted area (hour/ week) | Correlation coefficient (r) | 0.150* | 0.057 | 0.117* |
| | Significance level | 0.011 | 0.340 | 0.049 |
| Bukit Jalil/Seputeh | | | | |
| Time spent in air polluted area (hour/ week) | Correlation coefficient (r) | 0.103* | 0.066 | 0.056 |
| | Significance level | 0.025 | 0.153 | 0.231 |
| City centre | | | | |
| Time spent in air polluted area (hour/ week) | Correlation coefficient (r) | 0.039 | 0.130 | 0.151* |
| | Significance level | 0.637 | 0.114 | 0.066 |

Note: ˙significant at the 0.10 level
* significant at the 0.05 level.
** significant at the 0.01 level.
Source: Ling et al. 2010c

by the exposure level to air pollution. The results were also showing that people were not only receiving health impact from the ambient air quality in their housing areas (as indicated in the air quality indicators) but also from the other areas such as at workplaces.

In most of the strategic planning zones, the significant relationships between air-related health and exposure were identified in the middle of the year (dry season) only (Table 10), but not for the wet season. It might be due to the reason that air quality in the air polluted areas had been improved due to the precipitation effects during the wet season. Concentrations of air pollutants were reduced by washout and rainout effects. Thus, during the wet season, respondents potentially inhaled less air pollutants at air polluted areas.

## CONCLUSION

In conclusion, by using the urban air environmental health indicators, KL was identified as having a moderate level of air quality. The cleanest zone was Wangsa Maju/Maluri (good air quality level) and the most polluted zone was Bandar Tun Razak/Sungai Besi (hazardous level during the dry season). There were unhealthy days in Bukit Jalil/Seputeh, Bandar Tun Razak/Sungai Besi and the City Centre zones. Thus, a total population of 728 200 or 45% of the total population of KL was potentially exposed to the unhealthy air quality in their living areas (Table 6).

Analysis on the air-related illnesses showed that air-related illness was higher in the more developed or higher density zones/areas, and higher among the respondents with higher rate of exposure to air pollution (longer duration of time spent in air polluted areas). However, the ambient air quality levels were not significantly correlated to the rates of air-related illnesses among respondents.

As a recommendation from this study, all the urban developments and activities should be well managed in order to improve air quality and air health of an area. Special attention should be given to the higher density zones, and air polluted areas such as industries, which are potentially generating more negative impacts on human health. Simple land use zoning to segregate the polluting activities from the housing areas for the purpose to improve ambient air quality in the housing area is not going to improve human health effectively. It is because people are also exposed to air pollution in their workplace and along the roads.

## ACKNOWLEDGEMENT

The authors would like to thank Research Management Institute (RMI), Universiti Teknologi MARA (UiTM) for funding the study, and Department of Environment Malaysia, City Hall of Kuala Lumpur and Assoc. Prof. Dr. Mohd Talib Latif from Universiti Kebangsaan Malaysia for providing information and data.

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Received: 27 April 2011
Accepted: 22 July 2011