PAHs in atmospheric particulate matters (PM$_{10}$): distribution and health risk assessment

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Abstract

A study was carried out to determine the distribution and levels as well as identify sources of polycyclic aromatic hydrocarbons (PAHs) in ambient air particulate matter (PM$_{10}$) in the Klang Valley and Bangi, Malaysia. PM$_{10}$ samples were collected on glass fiber filter paper using a High Volume Sampler for 24 h during a period from September 2010 to April 2011. The exposed filter papers were extracted using dichloromethane-methanol (3:1) and the 16 USEPA priority PAHs were determined using gas chromatography with mass spectra (GC-MS). Total PAHs concentrations in the Klang Valley and Bangi ranged between 1.35 ng/m$^3$ to 4.92 ng/m$^3$ and 1.66 ng/m$^3$ to 5.23 ng/m$^3$ respectively with 5-6 ring PAHs dominating (> 80%) the total PAHs distribution. PCA and diagnostic ratio analyses suggested substantial contributions from traffic emission with minimal influence from coal combustion. Health risk estimation through toxic equivalency factors (TEFs) analysis showed the PJ station in the Klang Valley recorded the highest potential of carcinogenicity activities.

Keyword: particulate matter, PAHs, traffic emission, principle component analysis, diagnostic ratio, toxic equivalent factors.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous atmospheric contaminants generated by incomplete combustion of organic materials mainly through anthropogenic activities such as
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biomass burning and combustion of fossil fuels. PAHs are reported to be carcinogenic and mutagenic and USEPA has listed 16 main PAHs as priority pollutants. It is generally reported that PAHs are associated with fine particles and thus human exposure to PAHs in air is of concern worldwide. In Malaysia, studies to determine levels PAHs and assessment of their potential health risk are still limited, thus this study was initiated to determine the concentration of PAHs in particulate matter (PM$_{10}$) and identify their sources as well as assess the potential health risk of PAHs to the public.

Materials and Method

Ambient air samples were collected at two sites within the Klang Valley (Kuala Lumpur, KL and Petaling Jaya, PJ) and one site in a semi-urban area of Bangi. Samplings were carried out during the months of September 2010 to April 2011 spanning the four seasons viz. southwest monsoon (June-September), northeast monsoon (December – March) and two inter monsoon seasons (April – May and October-November). PM$_{10}$ samples were collected over a 24hr period for at least 4 times during each monsoon season. Airborne air particle were collected using a High Volume Sampler (HVS) with selective PM10 inlet fitted with annealed glass fiber filter (20.3 cm X 25.4 cm, Whatman EPM2000) and operated at flow rate 1.13 m$^3$ min$^{-1}$ (Omar et al., 2002). The mass of particulate matter on filters were determined by gravimetric method using a microbalance to an accuracy ±0.001g. The exposed filter was extracted with DCM:MeOH solvent mixture (3:1 v) using ultrasonic agitation using (Omar et al., 2002 and Tahir, et al., 2008). The final extract was derivatised using BSTFA-TMCS prior to determination using a gas chromatography-mass spectrometry (GC-MS). Verification of peaks was based on key fragment ions and retention times compared to those external standards and/or GC-MS library mass spectra. The results were blank-subtracted, and the concentrations were corrected for the recoveries of internal standards. The recoveries of the procedure for internal standards ranged from 60.9 to 115.9%.

Source identification was carried out diagnostic ratios (Yunker et. al, 2002; Pandey et. al, 1999; Zhang et. al, 2005) coupled with statistical analysis using principle component analsis, PCA. In this study, exposure pathway via inhalation of air particles contaminated with PAHs was used to estimate the population health risk (USEPA, 1989).

Results and Discussion

The average PM$_{10}$ concentration for the Klang Valley and Bangi ranged from 26.07± 3.7 to 51.52 ± 19.9 µg/m$^3$ and 20.23± 6.5 to 47.95± 8.0 µg/m$^3$, respectively with KL station in the Klang Valley exhibiting highest concentration during September sampling (30/9/2014; 83.5 µg/m$^3$). The lowest PM$_{10}$ concentration was recorded on April 21, 2011 at Bangi station (11.8 µg/m$^3$). All PM10 values recorded in this study are still below the recommended Malaysian guideline for PM$_{10}$ of 150 µg/m$^3$ (Malaysian DOE, 2011). Total PAHs concentrations in the Klang Valley and Bangi ranged between 1.35 ng/m$^3$ to 4.92 ng/m$^3$ and 1.66 ng/m$^3$ to 5.23 ng/m$^3$ respectively. In general, PJ station in the Klang Valley exhibited higher concentration of PAHs relative to the remaining two stations, particularly
during the drier southwest monsoon and two inter monsoons. Seasonal variations of total PAHs could also be observed at the other sampling stations. In addition to the differences in the socio-economic activities in the vicinity of each sampling station, results also showed that meteorological factors such as wind and rainfall play an important role in influencing the concentration and distribution of total PAHs in the study area. Most abundant PAHs found at all sampling locations were the high molecular weight PAHs such as benzo fluoranthenes (BbF, BkF), benzo [a] pyrene (BaP), indeno [1,2,3-cd] pyrene (IcP) and benzo[g,h,i] pyrene (BgP) with 5-6 ring PAHs accounting over 80% of the total PAHs distributions. This indicates the similarity in origin of PAHs at all the locations. Most researchers have attributed the presence of these compounds to vehicular emissions (Omar et. al, 2002; Zhang et. al, 2005; Ravindra et. al, 2008). Additionally, a strong correlation between BgP and total PAHs (R>0.9) and the presence of coronene (COR) in ambient atmosphere at all sampling locations provide further evidence for vehicle emissions as the main source of PAHs in the study area. Evaluation of PAHs diagnostic ratios (Yunker et. al, 2002; Pandey et. al, 1999) and principal component analysis also revealed that the main source of PAHs in the study area originates mainly from vehicular emissions, either through gasoline or diesel engine emissions. Minor contributions from biomass combustion and petrogenic sources could also be detected.

Health risk estimation through toxic equivalency factor (TEFs) analysis using BaP as surrogate compound has been used because BaP was found to represent over 50% of the total carcinogenicity of PAHs. In this study, inhalation of PAH contaminated air particulate matter is considered as the exposure route. Result showed that the PJ station in the Klang Valley recorded the highest potential of carcinogenicity activities. However, evaluation of the incremental lifetime cancer risk (ILCR) from exposure to airborne BaPeq was found to be negligible at all sampling sites for all age-specific groups.

Conclusion
Although the concentrations of PAHs found in this study were generally lower than previously reported in the Klang Valley, their sources of origin were similar with vehicular emission dominating other combustion sources. This is evidenced by the dominant presence of high molecular weight PAHs (5-6 rings) and strong correlation between BgP with total PAHs. Health risk assessment showed that the incremental lifetime cancer risk (ILCR) from exposure to airborne BaPeq is negligible at all sampling sites for all age-specific groups.

References


