Characterization and Source Identification of Polycyclic Aromatic Hydrocarbons in Suspended Particulate Matter in Yokohama

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ABSTRACT

Ten polycyclic aromatic hydrocarbons (PAHs) associated with suspended particulate matter (SPM) in the ambient air were collected at roadside (15 days for each sample), urban and suburban residential areas (30 days for each samples) of Yokohama, Japan from 1999 to 2005. Fine particulate matter (PM2.5) samples (2 days for each sample and thrice in a month) were also collected for the period of 2009-2010 at two other urban sites of Yokohama. The target PAHs were determined using gas chromatography-mass spectrometry. The concentrations were higher in roadside compared to urban and suburban residential areas. Strong monthly and seasonal variation were found showing higher concentration in colder months and lower in warmer months both in SPM associated PAHs and PM2.5-bound PAHs.

1. Introduction

Air pollution in urban areas gives rise to direct and uncontrolled exposure of large population to toxic substances. Among the toxic substances, polycyclic aromatic hydrocarbons (PAHs), resulting from the incomplete combustion are of special interest, due to their toxicity, carcinogenicity, mutagenicity antiestrogenic and antiandrogenic properties. In urban areas, PAHs and their derivatives are the main culprits for causing cancer. Therefore, the association of PAHs with the respirable fraction of particulate matter is of particular importance in terms of health effects. So, location specific assessment on particulate matter associated PAHs are considered to be afflicting concern of human health and environment. Thus, present study was carried out in multiple sites of Yokohama, Japan to provide information on characterization, source identification and health risk assessments of particulate matter associated PAHs. The impact of the emission regulations for automobiles in large cities, which were enacted during 2002 and 2003, was also studied from the SPM samples collected of Yokohama.

2. Material and Methods

SPM samples were provided by the Yokohama City Research Institute for Environmental Science. These samples were collected from March, 1999 to May, 2005 at three sampling sites of Yokohama City namely Mineoka, Hiranuma Elementary School and Nagahama representing the roadside (15 days for each sample), urban residential area and suburban residential area (30 days for each sample), respectively. Size segregated fine particulate matter (PM2.5) samples (2 days for each sample and thrice in a month) were collected for the period of 2009-2010 at two other urban sites of Yokohama City namely Negishibashi and Yokohama National University. SPM and PM2.5 samples were collected with Shintaku low volume air samplers and cascade impactor, respectively. Ultrasonic extraction was performed with dichloromethane and the concentration of ten particulate associated PAHs such as fluoranthene (Flt), pyrene (Pyr), benz[a]anthracene (BaA), chrysene (Chry), beno[b]fluoranthene (BbF), beno[k]fluoranthe (BkF), beno[e]pyrene (BeP), beno[a]pyrene (BaP, indeno[1,2,3-cd]pyrene (Ind) and beno[ghi]perylene (BghiP) were determined using gas chromatography-mass spectrometry (GC-MS). Statistical analysis was performed using statistical software (SPSS 11.5). The data was analyzed for sources by Spearman correlation and Principal Component Analysis (PCA).

3. Results and discussion

Total SPM associated PAH concentration ranged from 0.72 to 8.54 ng/m³ with a mean of 2.73 ng/m³, 0.31 to 6.16 ng/m³ with a mean of 2.07 ng/m³ and 0.33 to 2.87 ng/m³ with a mean of 1.02 ng/m³ at roadside, urban

residential and suburban residential areas, respectively as shown in Fig. 1, 2, and 3. The carcinogenic PAHs of B[b]F, Ind, B[ghi]P and B[e]P were dominated in Yokohama accounted for 75%, 77% and 72% of the total mean SPM associated PAHs in samples at the above mentioned sites, respectively. The mean concentration of most potent carcinogenic PAHs B[a]P were 0.10 ng/m³, 0.90 ng/m³ and 0.09 ng/m³ at aforementioned sites, respectively.

The predominant PAHs determined in PM$_{2.5}$ particulate matter were Flt, Chry, B[b]F and B[e]P. The average total of PM$_{2.5}$-bound PAHs was 1.18 ng/m³ and 0.72 ng/m³, respectively at Negishibashi and Yokohama National university sites of Yokohama. Strong seasonal variations of PM2.5-bound PAHs were found showing higher levels during winter and lower in summer.

The present study tried to assess the impact of emission regulations which were enacted 2002 and 2003 across larger cities in Japan with respect to SPM and SPM associated PAHs at roadside, urban residential and suburban residential areas of Yokohama. Quantitated concentrations were classified into pre-regulation (April, 1999 to March, 2002) and post-regulation (January, 2001 to May, 2005). Post-regulation data indicated a moderate reduction of SPM concentration were 21%, 27.6% and 13.8% and relatively higher reduction of total SPM associated PAHs concentration were 46.6%, 47.8% and 18.6% at afore mentioned sites, respectively compared to pre-regulation data. Lifetime cancer risk was calculated by multiplying sum of the BaP$_{eq}$ with the unit risk of $(8.7 \times 10^{-5}$ (ng/m³)$^{-1}$ proposed by WHO, (1987). For the whole sampling period, the estimated lifetime cancer risk were 1.98×10^{-5}, 1.75×10^{-5} and 1.19×10^{-5} at roadside, urban residential and suburban residential area, respectively. Considering the regulation period, lifetime cancer risk were 2.40×10^{-5}, 2.18×10^{-5}, 2.18×10^{-5} and 1.38×10^{-5}, 1.15×10^{-5}, 0.82×10^{-5} in before and after the emission regulation at afore mentioned sites, respectively.
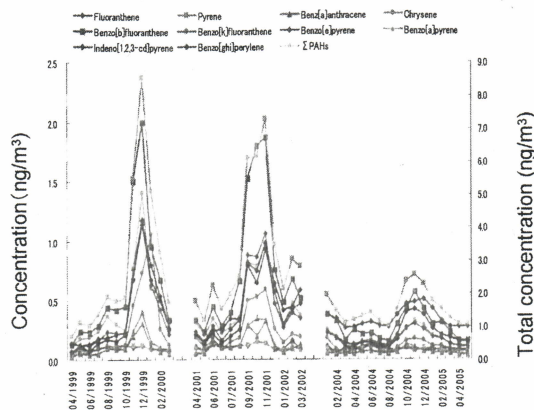

Fig 1: Monthly concentration profile of SPM associated PAHs at roadside.
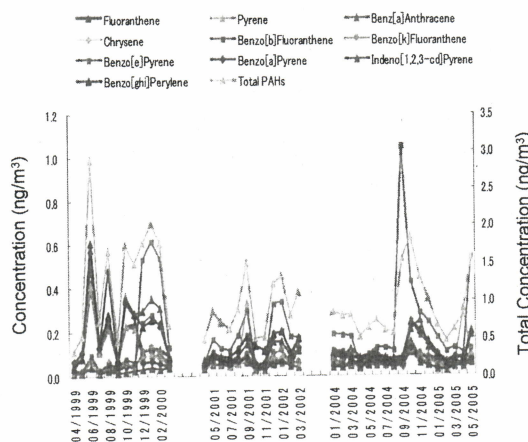

Fig 2: Monthly concentration profile of SPM associated PAHs at urban residential area.
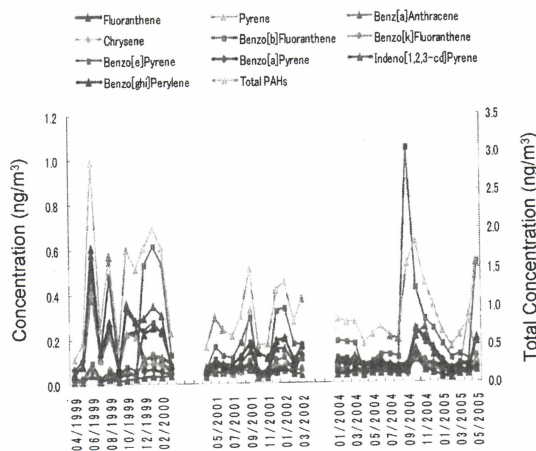

Fig. 3 : Monthly concentration profile of SPM associated PAHs at suburban residential area.