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Polycyclic aromatic hydrocarbons in urban air: Levels and patterns in Yokohama, Japan and Nairobi, Kenya

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Introduction

Polycyclic aromatic hydrocarbons (PAHs) present in the environment are mainly due to incomplete combustion of organic matter. They are widely distributed ubiquitous environmental pollutants, and a number of PAHs especially high molecular weight are known carcinogens, mutagens and some are suspected to be endocrine disrupters[1]. Certain PAH concentration ratios to benzo[e]pyrene have been used to differentiate PAH sources sucessfully[2]. Due to the stability and health concerns of particle bound PAH, only samples collected using quartz filter papers were analyzed. Our aim for the present work was to report the concentration levels and patterns of these PAH including the higher molecular weight fractions which are potentially toxic and lacking in many PAH researched studies. We, therefore, analyzed daily air samples collected for thirty different PAHs in three different sites covering residential, industrial and central business district during the period of 25th August to 12th September 2003 in Nairobi, Kenya. To the best of our knowledge, no or little data is available on PAH levels in Nairobi.

Materials and Methods

Sampling sites were located in trafficked, industrial and residential areas in Nairobi, Kenya (Fig. 1). Air samples were collected on quartz filters using a mini-pump (Sibata, Tokyo, Japan) at 5 L·min^{-1} from the three different areas. Among the total of 24 samples, the volumes of air collected ranged from 0.47 to 0.93 m^3. The quartz filters sampled were folded and stored in aluminum foil under 4 ˚C until analysis.

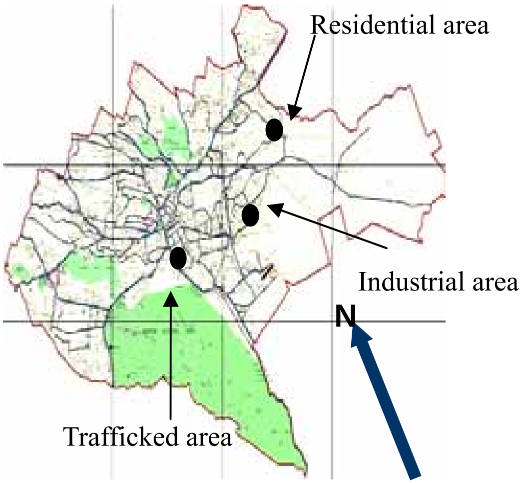

Fig. 1. Sampling sites in the city of Nairobi, Kenya

PAH analysis was adapted from previously published methods[3, 4]. Briefly, extraction was carried out using automated Soxhlet extractor (Soxtherm, Gerhardt, Germany) for 2 hours and 31 minutes using acetone and hexane (1:1) as solvent. The extract was then cleaned by Sep-Pak plus silica cartridge (Waters, USA) and concentrated. The concentrate were injected into a GC-MS (Agilent HP6890 series GG and HP5973 series MS) equipped with a DB-5 capillary column (60 m x 0.25 mm i.d.; 2.5 µm film thickness, J&W Scientific, Folsom, CA) and detected by selected ion monitoring mode. Agilent special programs such as retention time locking, chemstation program and NIST library were used to determine PAH concentration in the samples.

横浜とケニア、ナイロビの都市大気中の PAH：濃度と組成

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Results and Discussion

Concentrations of twenty six out of the thirty different PAHs are reported in this paper. Results of the study indicated that pyrene was the most abundant PAH with concentration ranging from 0.53 to 42.2 ng/m^3. Concentrations of higher molecular weight PAHs which are more carcinogenic are also presented in this paper. Graphical PAH profiles obtained from ratios of higher molecular weight PAHs and benzo[e]pyrene were different among the samples. Generally, 5- and 6-ring PAHs were more abundant in trafficked areas (55%), while 3- and 4-ring PAHs were mostly found in the residential areas (60%).

PAH isomer ratio analysis showed that PAH from Nairobi is mainly from gasoline, diesel, biomass and probably industrial oil combustion. The correlation coefficient between coronene and benzo[ghi]perylene was high (R=0.94, n=10) in the trafficked area suggesting diesel and gasoline as probable PAH sources[5]. High correlation between benzo[c]phenanthrene and 3,6-dimethyl phenanthrene (R=0.98, n=8) for industrial area samples indicated that industrial oil combustion was the major source[6]. For residential area samples, correlation between benzo[b]fluoranthene and benzo[j+k]fluoranthene (R=0.99, n=6) suggested PAHs could be due to domestic fuel burning[6].

The result of factor analysis employed to improve on the isomer ratio analysis results is shown in Fig. 2 by a plot of factor one (explaining 32% of the total variance) vs. factor 2 (11%). Four distinct PAH sources namely; traffic gasoline, traffic diesel, domestic fuel and industrial oil burnings were obtained. PAH source profiles (Fig. 2) agreed well with published research[5, 6].

Statistical analysis using Kruskal-Wallis test showed that 5-ring PAHs among the sampled areas were not significantly different, suggesting that a single source may be responsible for its emission while it showed 3- to 7-ring excluding 5-ring PAHs were significantly different ($p<0.0005$), indicating that various sources are responsible.

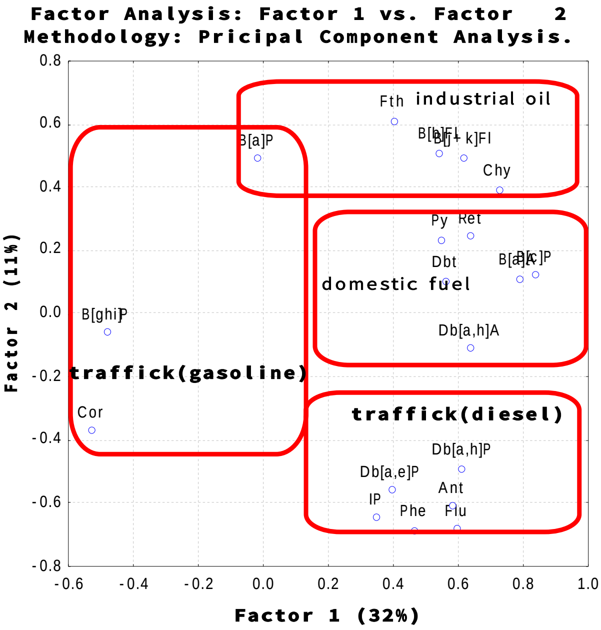

Fig. 2. Normalized factor analysis for PAH data

In summary, PAH concentration levels, patterns and sources in urban air in Nairobi, Kenya is well described in this paper. Further source distinction, however, needs better models like positive matrix factorization (PMF)[7] which have been used successfully to apportion sources of pollutants. This will be used for Yokohama samples.

References: 1) Brostrom C-E., Gerde P., Henberg A., Jernstrom B., Johansson C., Kyrklund T., Rannug A., Tornqvist M., Victorin K. and Westerholm R. (2002). *Environmental Health Perspectives*. 110: 451-488. 2) Ohura T., Amagai T., Fusaya M. and Matsushita H. (2004). *Environ. Sci. Technol*. 38: 49-55. 3) US EPA, (1996). Method 3541 and 3630C. *http://www.epa.gov /SW-846*. 4) Jaouen-Mandoulet A., Abarnou A., Le Guellec A.-M., Loizeau V. and Leboulenger F. (2000). *Journal of Chromatography* A. 886: 153-173. 5) Miguel, H., Kirchstetter, W., Harley A. and Hering S. (1998). *Environ. Sci. Technol*. 32: 450-455. 6) Li A., Jang J. and Scheff P. (2003). *Environ. Sci. Technol*. 37: 2958-2965. 7) Paatero, P., (2000). *User's Guide for Positive matrix Factorization Programs PMF 2, part 2*.