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Source apportionment of $PM_{2.5}$ in urban area of Hong Kong

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Abstract

A monitoring program for $PM_{2.5}$ had been performed at two urban monitoring stations in Hong Kong from November 2000 to February 2001 and June 2001 to August 2001. $PM_{2.5}$ samples were collected once every 6 days at PolyU and KT stations with the sampling duration of 24-h. A sum of 25 chemical species in $PM_{2.5}$ were determined and selected for receptor models. Enrichment factors relative to earth crust abundances were evaluated and it was noted that most crustal elements including Al, Ti, Mg, Ca and K have small enrichment factors. Correlation and multivariate analysis technique, such as principal components analysis (PCA)/absolute principal components analysis (APCA) and cluster analysis (CA) are used for source apportionment to identify the possible sources of $PM_{2.5}$ and to determine their contribution. Six factors at each site were isolated by using PCA/APCA and cluster analysis. Similar sources (crustal matter, automobile emission, diesel emission, secondary aerosols, tire wear, and non-ferrous smelter) are identified by the PCA/APCA and cluster analysis.

Keywords: Source apportionment; Enrichment factors; Absolute principal components analysis (APCA); Cluster analysis

1. Introduction

Receptor models provide a theoretical and mathematical framework for quantifying source contributions. They interpret measurement of physical and chemical properties taken at different times and places to infer the possible or probable sources and to quantify the contributions from those sources [1]. The purpose of a receptor source apportionment model is to estimate the contributions of specific source types to pollutant levels in the atmosphere at a sampling (or receptor) site. The contributions of each source are distinguished through differences in their physical and chemical properties. Computer-generated source apportionment results must be interpreted by those with knowledge of the site and the associated potential sources.

Principal component analysis (PCA) is one of the oldest and most widely used multivariate statistical techniques in the atmospheric sciences [2]. Usually the data for atmospheric aerosols exhibit many large correlations among parameters and PCA results in a much more compact representation of their variations. By using PCA, Saucy (1991) was able to identify three major sources that contributed to the atmospheric aerosol (near Phoenix, Arizona), namely crustal material, copper smelters and marine air [3]. Fung and Wong (1995) sampled total suspended particulates (TSP) in the western part of the New Territories in Hong Kong between 1986 and 1987 and analyzed various trace metals (e.g. Se, As, Sr, V, etc) as markers [4]. Then PCA was applied to identify the sources and the mass contributions of each source obtained. In many recent source apportionment studies, quantitative aerosol source apportionment was performed using absolute principal component analysis [5–8]. The APCA model can determine: (1) the number of relevant source types influencing the receptor site, (2) the source profiles of these sources in absolute numbers and, finally (3) the impact that each source type has on the concentration levels of the measured air pollutants at the receptor site [5].

The cluster analysis is another effective multivariate statistical method. Although cluster analysis is a potentially useful technique for grouping samples, its application to atmospheric studies has not been attempted broadly. One of the reasons might lie in the difficult interpretation related to the dendrograms. Environmental variables may force unclear sample groups such that the dendrogram is difficult to interpret. In

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spite of this, it is considered that cluster analysis should be performed, at the very least, to confirm the sample score groups [9]. Saucy (1991) also coupled cluster analysis with principal component analysis to examine compositions and time-dependent concentrations of aerosol particles; they revealed 15 chemically distinct particle types from the samples [3]. Most source identification/apportionment applications have been based on inorganic aerosol components, primarily trace elements often combined with ionic components [10,11]. Moreover, previous work on receptor modeling study of aerosols in East Asia is rather limited [4,12–15]. The objective of this study was to isolate, identify and quantify possible sources that contributed to fine particulate matter ($PM_{2.5}$) in urban area of Hong Kong.

2. Methodology

2.1. Sampling sites

Two sampling sites including The Hong Kong Polytechnic University (PolyU campus) and Kwun Tong (KT) were selected for $PM_{2.5}$ monitoring. The field descriptions were given as follows (Fig. 1).

PolyU campus: It situated at about 6 m above ground level and about 8 m away from the main traffic road. The station is adjacent to Hong Chong Road, which leads to the Cross Harbour Tunnel. The traffic volume of the road is extremely high which is more than 170,000 vehicles per day.

Kwun Tong (KT): It is close to the residential buildings and most of vehicles are light- and heavy-duty vehicles. Kwun Tong belongs to one of the EPD air quality monitoring stations, which were chosen for data comparison; it represents as mixed residential/commercial/industrial area. The samples were collected on the rooftop of 25 m.

2.2. Sampling method

The monitoring program for $PM_{2.5}$ had been performed at two urban monitoring stations in Hong Kong during the two studies periods ((1) November 2000 to February 2001 and (2) June 2001 to August 2001). $PM_{2.5}$ samples were collected once every 6 days (24-h sampling duration) at PolyU and KT stations.

The high volume (hi-vol) samplers manufactured by Andersen Instruments/GMW were used for $PM_{2.5}$ sampling at two monitoring stations. The hi-vol samplers were operated at flow rates of 1.13–1.41 $m^3\ min^{-1}$. $PM_{2.5}$ samples were collected on 20.3 cm × 25.4 cm Whatman quartz microfiber filters. The filters were pre-heated before sampling at 900 °C for 3 h. A balance for hi-vol filters (Sartorius, analytic) with accuracy of 0.1 mg was used to weigh the filter paper which was conditioned in an electronic desiccator before and after sample collection for 24 h. After collection, loaded filters were stored in a refrigerator at about 4 °C before chemical analysis to limit the evaporation of volatile components. Field blank filters were also collected to indicate the artifacts collected onto the filter before/during/after sampling.

2.3. Chemical analysis

After sampling, the filters were conditioned and weighted again to determine the mass concentration of the loaded particles. The filters were then cut into four portions for individual analysis. The filters are then analyzed with different analytical methods: (1) atomic absorption spectrophotometer (AAS) for

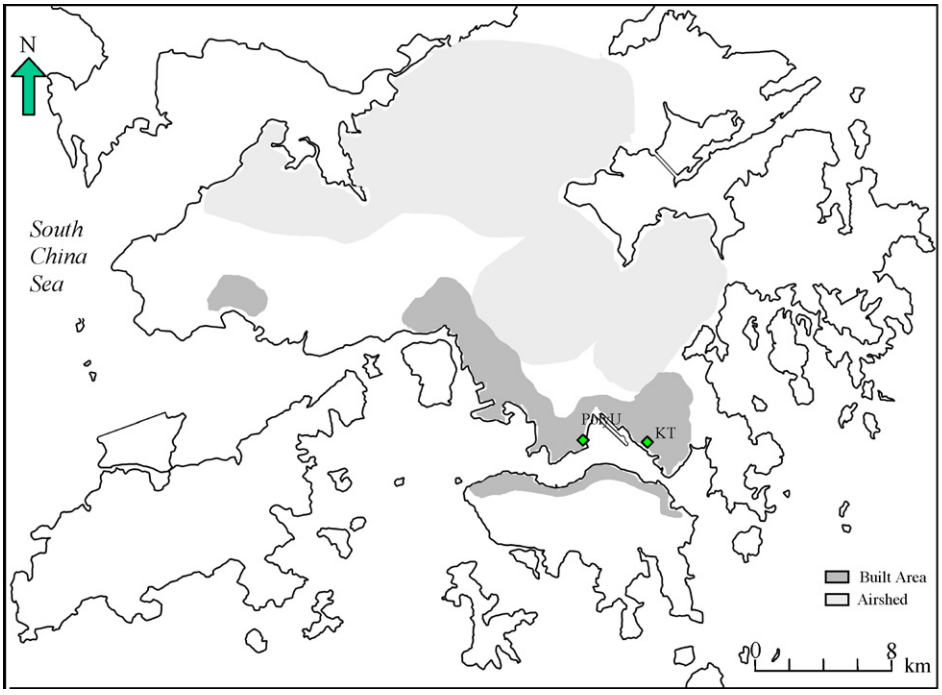

Fig. 1. Location of monitoring sites: Hong Kong Polytechnic University Campus [PolyU]; Kwun Tong (KT); Hok Tsui (HT).