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Sources apportionment of fine and coarse aerosol in Klang Valley, Kuala Lumpur using positive matrix factorization

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ABSTRACT

Samples of fine and coarse fraction of airborne particulate matter were collected on weekly basis during the period from 2004 to 2008 at Klang Valley, Kuala Lumpur. The samples were collected using a Gent stacked filter sampler in two fractions (<2.5 µm, fine and 2.5–10 µm, coarse sizes). The samples were analyzed for their elemental composition and black carbon content by Particle Induced X–ray Emission (PIXE) and Smoke Stain Reflectometer, respectively. The data set was then analyzed by the factor analysis method, Positive Matrix Factorization technique in order to identify the possible sources of particulate matter and their contribution to the ambient particulate matter concentrations in the Klang Valley. Five factors from PMF solutions were found for elemental composition of fine and coarse particulate matter in the Klang Valley area. The sources identified as motor vehicles, industry, smoke/biomass burning, soil and road dust. The PMF results showed that motor vehicles were the main source for both fine and coarse particles of Klang Valley. In case of fine particles two stroke and motor vehicles all together contribute about 67.6% of the fine mass measured. The industry source contributes to about 16.7% and the rest 26% comprises emissions from smoke/biomass burning and soil source. In case of coarse particles, motor vehicles including two strokes contribute about 55.5% of the coarse mass while the industry source apportioned to be about 17.6%. Soil dust including road dust contributes about 26.8% to the coarse particle mass.

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1. Introduction

The Klang Valley region is an area in Malaysia with rapid development and population growth. The area comprise the capital city Kuala Lumpur (latitude 3°8'N; longitude 101°44'E) and its suburbs, along with the adjoining cities in the state of Selangor. It is geographically delineated by Titiwangsa Mountains to the north and east and the Strait of Malacca to the west. The current estimated population is more than 5 million. The weather is hot and humid with uniform temperatures throughout the year between 25 °C to 35 °C. The winds over the region are light and variable, however there are uniform periodic changes in the wind flow patterns namely, the southwest monsoon, northeast monsoon and inter–monsoon seasons. The southwest monsoon season is usually established in the latter half of May or early June and ends in September while the northeast monsoon season usually commences in early November and ends in March. The seasonal wind flow patterns coupled with the local topographic features determine the rainfall distribution patterns over the country. Generally, the primary maximum rainfall occurs in October and November and February is the month with minimum rainfall. The secondary maximum generally occurs in March to May while in June–July very little rainfall occurs but it may be overcast.

Economic growth with uncontrolled development of industrial premises, non–regulated motor vehicles and human activities related to the high population density in Klang Valley are responsible for the emissions of various pollutants in the area. During the haze episodes in 1997, 1998, 2003, 2004, and 2006 arising from forest fires in a neighboring country, the area of Klang Valley was the most affected. The pollutants emitted from forest fires as well as from vehicles and industrial activities have given rise to severe air pollution in the area.

Study of aerosol chemical composition is essential to understand the aerosol formation sources of air pollution. The Malaysian Nuclear Agency has been involved in the International Atomic Energy Agency/Regional Cooperative Agreement (IAEA/RCA) project on air particulate matter since 1998. The study area is the Klang Valley region. The study of fine particles ($PM_{2.5}$) for the samples collected during the period from 2000 to 2006 at Klang Valley identified five sources of aerosols in the Klang Valley (Rahman et al., 2009a; Rahman et al., 2009b). These sources include sea spray, motor vehicle, smoke, industry, soil and an unknown source. This paper is about the elemental concentrations observed for the samples collected for a period of 5 years (2004–2008) of the IAEA/RCA project. The study focuses on both fine ($PM_{2.5}$) and coarse particle (between 2.5 and 10 µm). The chemical composition data were determined and receptor modeling using positive matrix factorization in the form of EPA PMF3.0 (EPA, 2010) was used to obtain information on the possible local pollutant sources in the Klang Valley. In order to identify the most probable direction of local point sources, Conditional Probability Functions (CPFs) were calculated from the resolved source contributions and the measured wind directions (Kim et al., 2003).

2. Methodology

2.1. Site description

The Klang Valley monitoring site is located at Universiti Teknologi Malaysia (UTM), Kuala Lumpur campus (3°10′30″N, 101°43′24″ E) just north to the city center park and the Petronas Tower, Kuala Lumpur (Figure 1). The campus is just a few hundred meters from the roadside and lies between two highways to the north and south and surrounded by busy roads closely linked to the Kuala Lumpur city center. On average, the wind speed in the area was 7.6 m/s during southwest monsoon with minimum wind speed of 2.8 m/s and maximum wind speed of 13.4 m/s, while the average wind speed during the northeast monsoon was 6.6 m/s with minimum and maximum wind speed of 2.3 m/s and 8.3 m/s, respectively. Predominant wind directions were from the west and southeast as shown in the wind rose plot for the fine and coarse masses in Figure 2.

2.2. Sampling

All aerosol samples were collected using a Gent stack sampler (Hopke et al., 1997). The sampler was placed on a rooftop of a two storey building at the Universiti Teknologi Malaysia, Kuala Lumpur at approximately 10 meters height. The sampler was programmed to run automatically at an air flow–rate of 15 L/min to collect two fractions (<2.5 µm and 2.5–10 µm aerodynamic diameter particles) of 24 hour (from 12 noon to 12 noon) samples on 47 mm polycarbonate filters at a frequency of a week or fortnight.

2.3. Mass and black carbon measurement

The total mass of each sample was determined by weighing the filter using a microbalance (METTLER, Model MT5). The balance was equipped with a Po–212 (alpha emitter) electrostatic charge eliminator (STATICMASTER) to eliminate the static charge accumulated on the filters before each weighing. Black carbon measurements of both fine and the coarse fraction were performed using an EEL Smoke Stain Reflectometer and the black carbon concentration was determined according to the method for 47 mm polycarbonate filter (Cohen et al., 2000).

2.4. Elemental analysis

Concentration of the elements for each sample was analyzed by Particle Induced X–ray Emission (PIXE) (Koltay, 1994; Cohen, 1998) at New Zealand Institute of Geological and Nuclear Science Limited (IGNS). X–ray spectra obtained from the PIXE measurements were analyzed with GUPIX software developed by Guelph University (Maxwell et al., 1989; Maxwell et al., 1995). Calibration of the PIXE system was performed by irradiating suitable Micromatter thin target standards.

2.5. Data analysis by Positive Matrix Factorization (PMF)

A factor analysis method, Positive Matrix Factorization (PMF), utilizes error estimates of the data to provide optimum data scaling (Paatero and Tapper, 1993). The method is based on solving the factor analysis problem by the least squares approach using a data point weighting method which decomposes a matrix of data of dimension *n* rows and *m* columns into two matrix, *G(nxp)* and *F(pxm)*, where *n* is the number of samples while *m* is the number of species. The model can be written as:

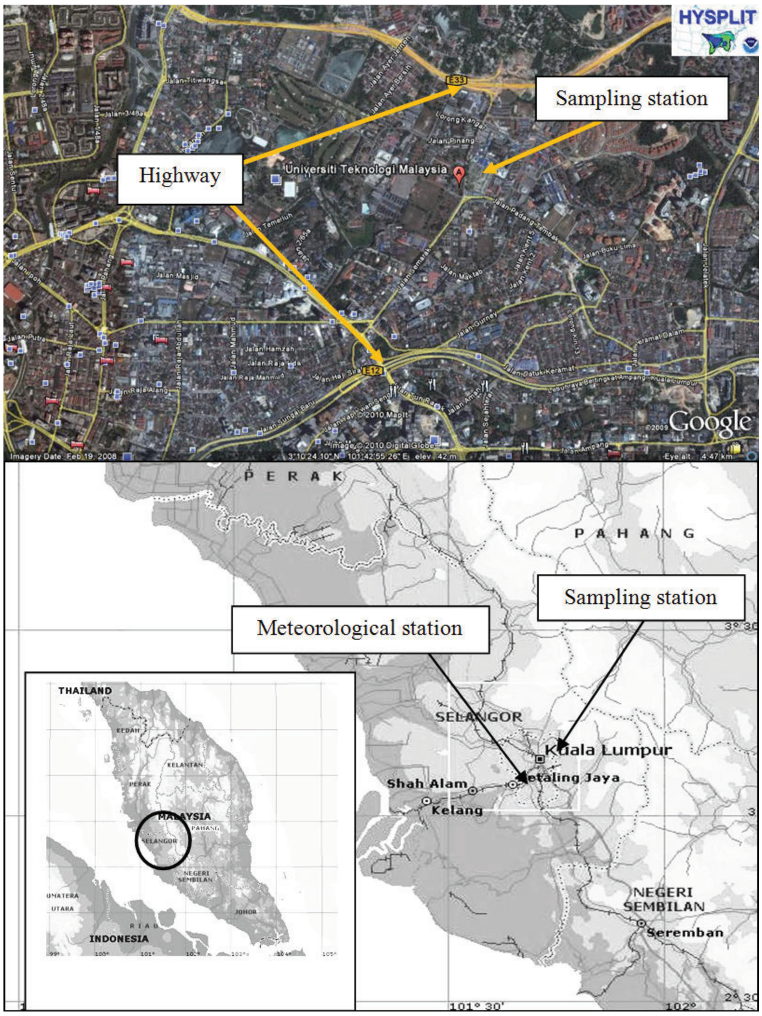

***Figure 1**. Location of sampling site in the Klang valley.*