Journal of Advanced Research (2015) 6, 827–832

Cairo University

Journal of Advanced Research

ORIGINAL ARTICLE

Mass size distributions of elemental aerosols in industrial area

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ARTICLE INFO

Article history:
Received 9 April 2014
Received in revised form 14 June 2014
Accepted 22 June 2014
Available online 28 June 2014

Keywords:
Mass concentration
Aerosol particles
Size distribution
Cascade impactor

ABSTRACT

Outdoor aerosol particles were characterized in industrial area of Samalut city (El-minia/Egypt) using low pressure Berner cascade impactor as an aerosol sampler. The impactor operates at 1.7 m^3/h flow rate. Seven elements were investigated including Ca, Ba, Fe, K, Cu, Mn and Pb using atomic absorption technique. The mean mass concentrations of the elements ranged from 0.42 ng/m^3 (for Ba) to 89.62 ng/m^3 (for Fe). The mass size distributions of the investigated elements were bi-modal log normal distribution corresponding to the accumulation and coarse modes. The enrichment factors of elements indicate that Ca, Ba, Fe, K, Cu and Mn are mainly emitted into the atmosphere from soil sources while Pb is mostly due to anthropogenic sources.

Introduction

In the recent years, aerosols have received increasing attention due to the roles they play in many climate and environmental processes. Size and chemical composition of atmospheric particles are important parameters in several processes occurring in the atmosphere [1], for instance, visibility reduction, cloud and fog formation, particle growth and gas–particle interactions [2]. Particles also have adverse health effects depending strongly on their size, specific surface area, number and chemical composition that regulate the toxicity of any specific element. In addition to the environmental and health effects of aerosol particles they also can cause corrosion and damage to materials and works of architecture and arts.

Metals are commonly found in atmospheric particles. While they can be present in almost all sizes of atmospheric particulate, in general, fine particulate carries higher concentrations of metals than coarse particulate [3,4]. Metals associated with respirable particles have been shown to increase numerous diseases [5,6]. Metals in the urban atmosphere are frequently associated with specific pollutant sources, and these are often used as tracers in order to identify the source of atmospheric particulate [7–11].

Knowledge of the size distribution of atmospheric particles within which trace elements and metals reside is not only vital in understanding particulate matter effects on human health, but also controls the extent to which metals may be dispersed via atmospheric transport and hence is a prerequisite for the determination of rates of deposition of metals to the Earth's surface [12].

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Peer review under responsibility of Cairo University.

ELSEVIER Production and hosting by Elsevier

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http://dx.doi.org/10.1016/j.jare.2014.06.006

The dispersion and accumulation of particulate matter in any location is mainly affected by the existing sources, meteorological conditions and local topography [11]. Atmospheric aerosol dispersion in industrial zones has received little attention. Therefore, the objectives of this study were to investigate the mass concentration and mass size distribution of elements in the aerosols at industrial area of Samalut in El-minia governorate (upper Egypt).

Methodology

In the present work a low pressure Berner cascade impactor was used as an aerosol sampler. The impactor contains eight size fractionating stages and operates at a flow rate of 1.7 $m^3\,h^{-1}$. The cut-off diameters of the impactor stages are 82, 157, 270, 650, 1110, 2350, 4250 and 5960 nm. Cut-off diameter is defined as the particle size that gives 50% of the collection efficiency. An accurate method of the impactor was calibrated in the isotope laboratory Gottingen University, Germany [13]. Measurements were taken from August 2012 to January 2013. Three or four runs were conducted in each month. The sampling time of each run is 6 h. Samples were collected at iron and steel Quarry closed to the cement factory in Samalut/El-minia (latitude: N 28° 18 \ 30 \ \, longitude E 30° 42 \ 28 \ \). This site represents an industrial area surrounded from the east by mountains. These mountains are formed with limestone rocks and have elevation of about 20 m (Fig. 1).

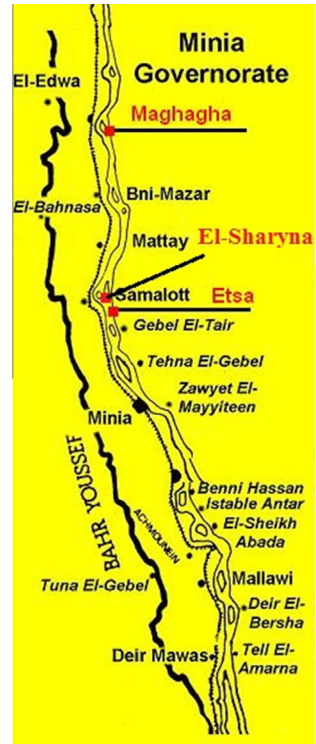

Fig. 1 Sampling site on EL-Minia governorate map.

The samples collected by low pressure Berner cascade impactor were analyzed by atomic absorption spectroscopy for seven elements including Lead (Pb), Manganese (Mn), Iron (Fe), Copper (Cu), Potassium (K), Calcium (Ca) and Barium (Ba). The sample was prepared for elemental analysis by cutting substrate into small pieces and then 5 mL diluted HCl (1 + 1) was added to the sample and gently heated on hotplate till complete dissolution. Few drops of HNO_3 are added to the solution. The solution is transferred to auto sampler cup and completed to 10 mL deionized water. This elemental analysis was performed at National Institute for Standards, NIS-Egypt.

Meteorological parameters (temperature and relative humidity) were recorded by Hi 8564 thermo hygrometer during the sampling. The temperature varied between 30 to 39 °C with mean value 36 °C while relative humidity varied between 18 to 42% with mean value 32%. Samples collected under abnormal weather conditions were canceled. Gravimetric analysis of the samples was conducted by Mettler analytical AE240 Dual Range Balance to get the collected mass of the aerosol particles on the substrates.

Knowing the mass of the collected particles, the flow rate of the impactor and the sampling time, mass concentrations of aerosol particles were calculated as follows:

$$v = \frac{m}{Q \cdot t} \ldots \mu g/m^3$$

where v is the specific mass concentration, m is the total deposited aerosol mass on the impactor stages (μg), Q is the impactor flow rate (m^3/h) and t is the sampling time (h).

The parameters of the mass size distribution, mass median aerodynamic diameter (MMAD) and geometric standard deviation (GSD) were given by the following equations [14].

$$\ln \mathrm{MMAD} = \frac{\sum n_i \ln d_i}{\sum n_i}$$

$$\ln(\mathrm{GSD}) = \left[\frac{\sum n_i (\ln d_i - \ln MMAD)^2}{\sum n_i}\right]^{\frac{1}{2}}$$

where MMAD is the Mass Median Diameter, n_i is the fraction in stage i, d_i is the cutoff diameter of the stage i and GSD is the geometric standard deviation. MMAD is defined as the diameter at 50% cumulative fractions. GSD of the size distribution is defined as the diameter at 84% cumulative mass divided by the diameter obtained at 50%.

Results and discussion

Elemental mass size distribution of aerosols

Mass size distributions of individual elements are presented in Figs. 2–5a. The distributions of the investigated elements [Pb, Mn, Fe, Cu, K, Ca and Ba] are bi-modal log normal distribution corresponding to the accumulation and coarse modes. Accumulation mode, consisting of long-lived particles of sizes of a few tenths of a micrometer (100 nm < particle diameter, Dp < 2000 nm). Particles in this mode are forming by gas to particle conversion, chemical reactions, condensation and coagulation, while the particles in the coarse mode (Dp > 2000 nm) are generated by mechanical processes such as sea spray, erosion, and resuspension and are removed by sedimentation and washout. This mode contains windblown dust, sea salt spray, and plant materials. The coarse particles are characterized by a high deposition velocity and they have short residence times. The residence time of aerosols depends on their size, chemistry and height in the atmosphere. The modal size and composition of aerosols are varied, depending on the nature of the surface cover and atmospheric condition.