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RESEARCH ARTICLE

STUDIES ON SIZE DISTRIBUTION AND ELEMENTAL COMPOSITION OF ATMOSPHERIC AEROSOL PARTICLE OF EL-MINIA CITY, EGYPT

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Abstract

Using X-ray diffractometer in conjunction with an 8-stage cascade impactor sampler, we have measured the size distribution of elemental mass concentrations in the atmospheric aerosols derived from different sources. Semi quantitative analysis for both atmospheric and car exhaust aerosol particles were performed. Mass size distribution of the particles can be described by bimodal log-normal distribution. It was found that Sr2Sio4 and ZnCl2 are the major aerial contaminant in the fresh aerosol particles. The ratios between coarse and fine particles containing Mn, Fe, Cu, Zn and lead were also studied.

Introduction:-

Aerosols in general are a type of complex material contained in various organic and inorganic compounds and there are obvious differences in size, volume, shape, chemical constituent, etc. Some of them can absorb and scatter the solar radiation in the long wave region, and they can offer the balance of the earth atmospheric system (Da-Tang ning, et al 1996). Moreover, aerosol plays a carriers role, i.e. they transport chemical compounds from certain places to other places. Likewise, the effects and behaviors of aerosol particles such as light scattering, lung capture, residence time and removal mechanisms strongly depend on the size of the particles.

The concentration and composition of aerosols near ground level are often controlled by local particulate source (Ali, et al 1994). In some cases elemental concentrations of aerosol particles can be used as signatures characterizing air pollution over a given area (Borbely, et al, 1988). Different sizes of particulate matters may cause different environmental affects.

Whitby, et al 1987 classified the aerosols into three modes according to their size, these modes are; fine mode, accumulation mode, and coarse mode. The fine mode includes the particles in the size range smaller than 100nm; this mode is formed by the condensation of atmospheric gases into primary particles, which then coagulate into aggregates. The second mode is the accumulation mode, includes in the size range 100nm<Dp<2000nm. This mode is formed from gas-to-particle conversion through chemical reactions. The third mode is the coarse mode, includes the particles in the range Dp>2000nm, these particles are generated by mechanical processes. This mode contains windblown dust and sea salt spray (Whitby, et al 1987).

The physical separation of the fine and coarse modes originates because condensation produces fine particles while mechanical processes produces mostly coarse particles. The dynamics of fine particle growth ordinarily operate to prevent the fine particles from growing larger than about 1μm. Thus, the fine and coarse modes originate separately, are transformed separately, are removed separately and are usually chemically different (Willeke, et al 1978, Davies, et al 1974 and Kelkar, et al 1977).

The measurements of detailed size distributions of elemental concentrations in the atmospheric aerosol particles are extremely important of the studies of origins, effects, and long-range transport of pollutants (Zhu, Guanghua, et al 1993). For example Br and Pb elements are regarded generally as reliable indicators of human's activity, considering particularly car exhaust, which is the major contributor of Pb and Br in fine and coarse airborne particles of the atmosphere.

The toxicity of lead inhaled is well known for a long time and its chronic effects on humans have been extensively studied (Ali, et al 1994). Aerosol particles in the air control the variation of several atmospheric parameters, from optical properties to cloud microstructure. On the other hand, they affect human health after being deposited onto the soil and earth surface. Since the concentration of different species in the atmospheric aerosol is influenced significantly by human activities, the study of the elemental composition of the particles is of crucial importance for environmental management on local, regional, and continental scale (Molnar, et al 1993).

For this reason the elemental composition of atmospheric aerosol particles has been widely investigated (Rahn, et al 1981, Pacyna, et al 1985 and Pacyna, et al 1989).
The aim of the present investigation is to contribute with local data to the international ones, furthermore, size distribution and semi-quantitive analysis for both atmospheric and fresh exhaust aerosols particles has been carried out

Experimental method:-

Atmospheric aerosol samples were collected separately during different times foraged and fresh aerosol particles. All samples were collected with a low-pressure Berner cascade impactor. The impactor consisted of eight size-fractionating stages and a back-up filter holder. It operated at a flow rate of 1.7 m^3/h. Aluminium foils were used as collection media and glass fiber filter as a back-up filter. Efficiency curves and inter-stage losses were measured with monodisperse liquid radioactively labeled aerosol particles in the diameter range 70-6000 nm. The measured 50% cut-off diameters range from 82 nm up to 5960nm. The total inter-stage losses of the labeled aerosol particles are less than 2% of the total activity.

The atmospheric aerosol samples were collected in the open air on the roof of the Physics Department (20m above the ground, Faculty of Science, El-Minia University (south of Egypt). This site is far from direct pollution sources. Fresh aerosol samples were taken directly from car exhaust tube with a simple technique, which consisted of a metal cylinder, a holder and Berner cascade impactor with flow rate 1.7 m^3/h (Ali, et al 1992). The sampling was carried out under variable meteorological conditions. The aerosol particle concentration during the sampling period was monitored by a condensation nuclei counter (TSI, Model 3020) and varied between $4x10^{10}$ and $3x10^4$ particle/cm^3.

For the determination of the deposited aerosol mass, the foils of the impactor stages are weighted under controlled conditions (electronic micro-balance with a sensitive of 1 μg) before and after air sampling. The difference between the two weights of each foil was considered the deposited aerosol mass.

Semi-quantitative analysis has been carried out by x-ray diffractometer (JEOL – Model JSDX - 60 PA), by using Ni-filtered, Cu-K_α – radiation (=1.54184 ^{0}A) at 35 KV and 15 mA. The 2Ω rang was chosen to cover all the possible diffraction patterns of the elements and other compounds.

Results and discussion:-

The relative mass concentration for car exhaust aerosol particles (fresh particles) and atmospheric aerosol particles (aged particles) and its aerodynamic particle diameter (cut-off diameter) are shown in Figures 1 and 2. It can be seen from the figures that most of the deposited fresh and aged aerosol mass particles were found in the size range between 125 and 5900nm, which correspond to the accumulation and coarse mode. Therefore, the mass size distribution for fresh and aged aerosols represented by two log-normal distributions.

For fresh aerosol particles, the mass median aerodynamic diameter of the accumulation and coarse mode were found to be 610 and 3500nm, respectively, with relative geometric standard deviations 2.2 and 2.5, respectively. The mass median aerodynamic diameter of 1000 and 4500nm aged aerosol have relative geometric standard deviations 1.9 and 1.6, respectively. Moreover, 71% of the deposited mass was found in the accumulation mode while the rest (29%) was found in the coarse mode.

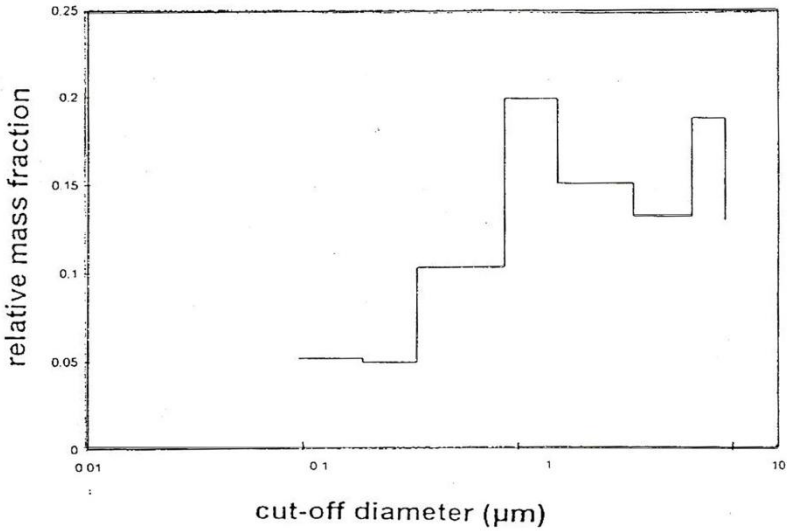

Figure. 1. Average mass size distribution of atmospheric aerosol particles.

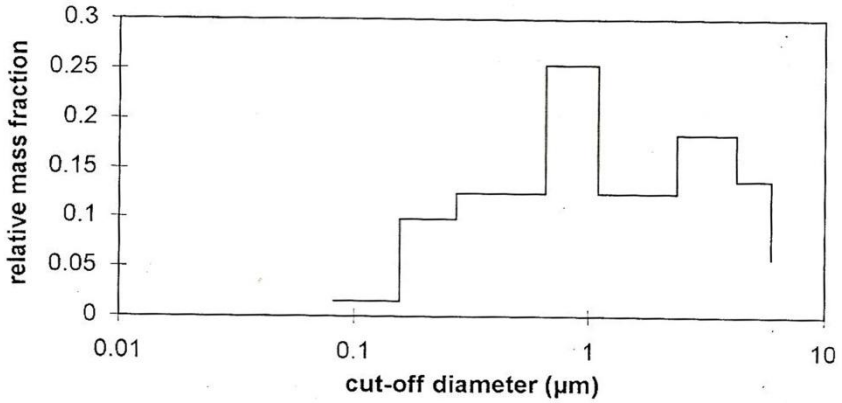

Figure. 2. Average mass size distribution of car exhaust aerosol particles.

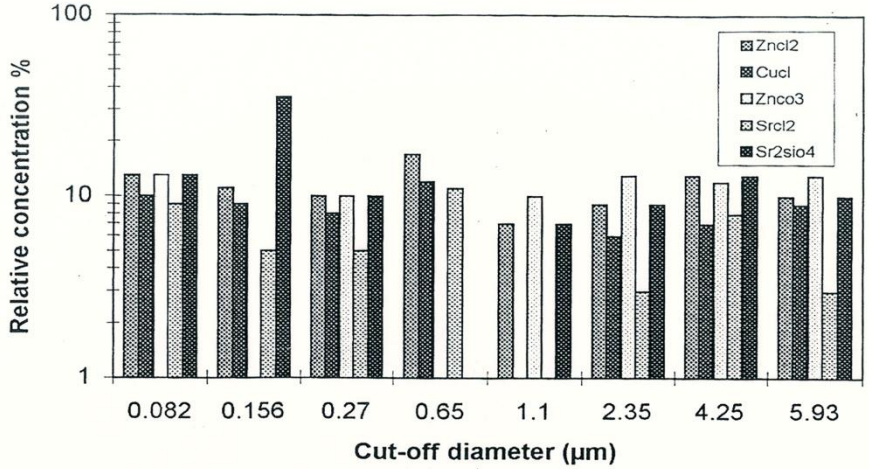

Figure. 3. Relative concentration of $ZnCl_2$, CuCl, $ZnCo_3$, $SrCl_2$ and Sr_2Sio_4 in atmospheric aerosol (aged particles).

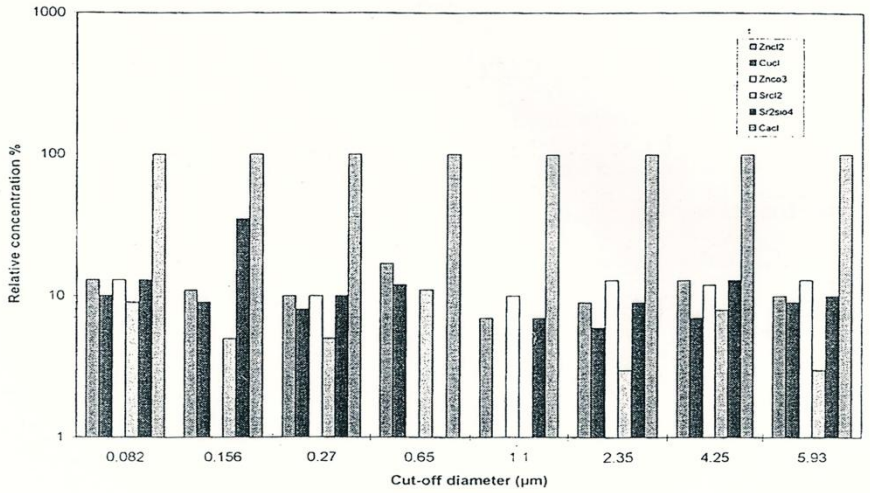

Figure4 . Relative concentration of CaCl, Pb, Mn, Fe_3Al, Fe and Cu in car exhaust aerosol 4 (fresh particles).

The relative concentration of different compounds as a function of substrate stage for aged aerosol particles is illustrated in Figure 3. It can be seen that the CuCl compound has higher concentration values than the other compounds in the all size ranges (0.082 to 5.93 µm) for both fine and coarse particle modes, therefore it was taken as standard value (%) for all the other compound. The relative concentrations of Sr_2Sio_4 and $SrCl_2$ have higher percent in the range of fine particle mode (0.082µm to 0.65µm), than in the range of coarse particles mode (1.1 to 5.93µm).

Figure 4. shows the relative concentrations of the trace elements in fresh aerosol particle. It can be seen that Zn element has high concentration percent in all the size range (fine and coarse particles modes), therefore it as taken as standard value (%) for the other elements. Lead element has high concentration percent on the size range from 0.082 to 5.93 µm, for fine and coarse modes. The large values in the fine and coarse particles indicate that car exhaust is the dominant source of the measured lead, since there are no known industrial activities, which could give rise to lead emissions of a comparable size and variability.

The motor traffic can be regarded as the main source of lead in the atmospheric airborne particles in El-Minia city, further this element is generally considered as a reliable indicator of the human activity, particularly car exhaust, which is the major contributor of fine and coarse lead particles in the atmosphere. Mn Cu elements have higher concentration values in the size range of coarse particle mode 1.1 to 5.93µm than in the size range of fine particle mode 0.082 to 0.65µm. On the other hand Fe element has minor values in all the range of fine and coarse particle modes.

Figures 5_a and 5_b show the size distributions of automobile exhaust elements; Mn, Fe, Cu and Pb. These elements were collected at a heavy traffic area in El-Minia city. The fine particles are centered in stage1 (0.25 – 0.5 µm), which should be from automobile exhaust, and the coarse are centered around stages 4 and 5. According to Winchester, et al 1984, upon reaching the ground the fine particles contaminate the soil and may be re-entrained as coarse particles to an extent dependent on traffic intensity.

The impact of motor vehicles on the aerosol loading of environment appears as a mixture of fugitive road dust and exhaust particles from automobiles. The former component mainly contains weekly-enriched soil derived elements. The exhaust contribution of automobiles burning leaded gasoline contains highly enriched elements, among them lead and bromine. Lead in particulate from is mainly emitted as PbBrCl, while bromine to an extent appears in gaseous from together with bromine to lead in the fuel amounts to 0.386. To measure the actual ratio of these elemental concentrations in exhaust gas and aged aerosols, it is subjected to a number of technological and meteorological parameters and to those governing physical and chemical transformation of primary components during transport processes.

Conclusion:-

Mass size distribution of atmospheric and fresh car exhaust particles was measured. Samples were collected with an 8-stage cascade impactor sampler, the atmospheric aerosol particles can be described by two-log normal distribution. For fresh aerosols (car exhaust particles), the mass median diameter of the accumulation and coarse mode were found to be 610 and 3500nm with relative geometric standard deviations 2.2 and 2.5, respectively. For the atmospheric aerosol (aged particles), the mass median diameter of 1000 and 4500nm were determined for the accumulation and coarse mode with relative geometric standard deviations of 1.9 and 1.6, respectively. The atmospheric aerosol particles emitted from soil dust mainly concentrate in coarse mode centered around 11 – 5.93 µm, with considerable fractions of large particles, while those emitted from automobile exhaust are in fine and coarse modes centered around 0.082 – 5.93 µm. According to these characteristics we can mention that, the aerosol particles in El-Minia city are partly of both anthropogenic and soil origin.

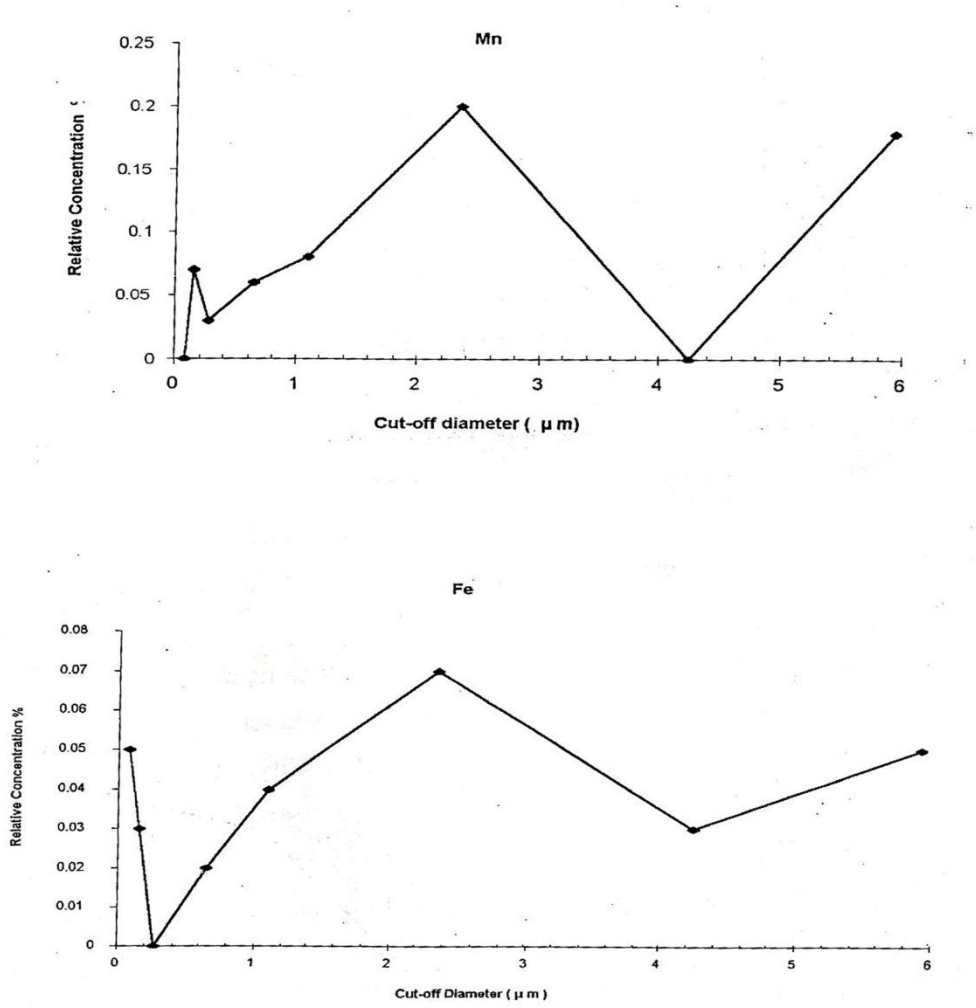

Figure 5 a. Elemental mass size distribution of Mn and Fe.

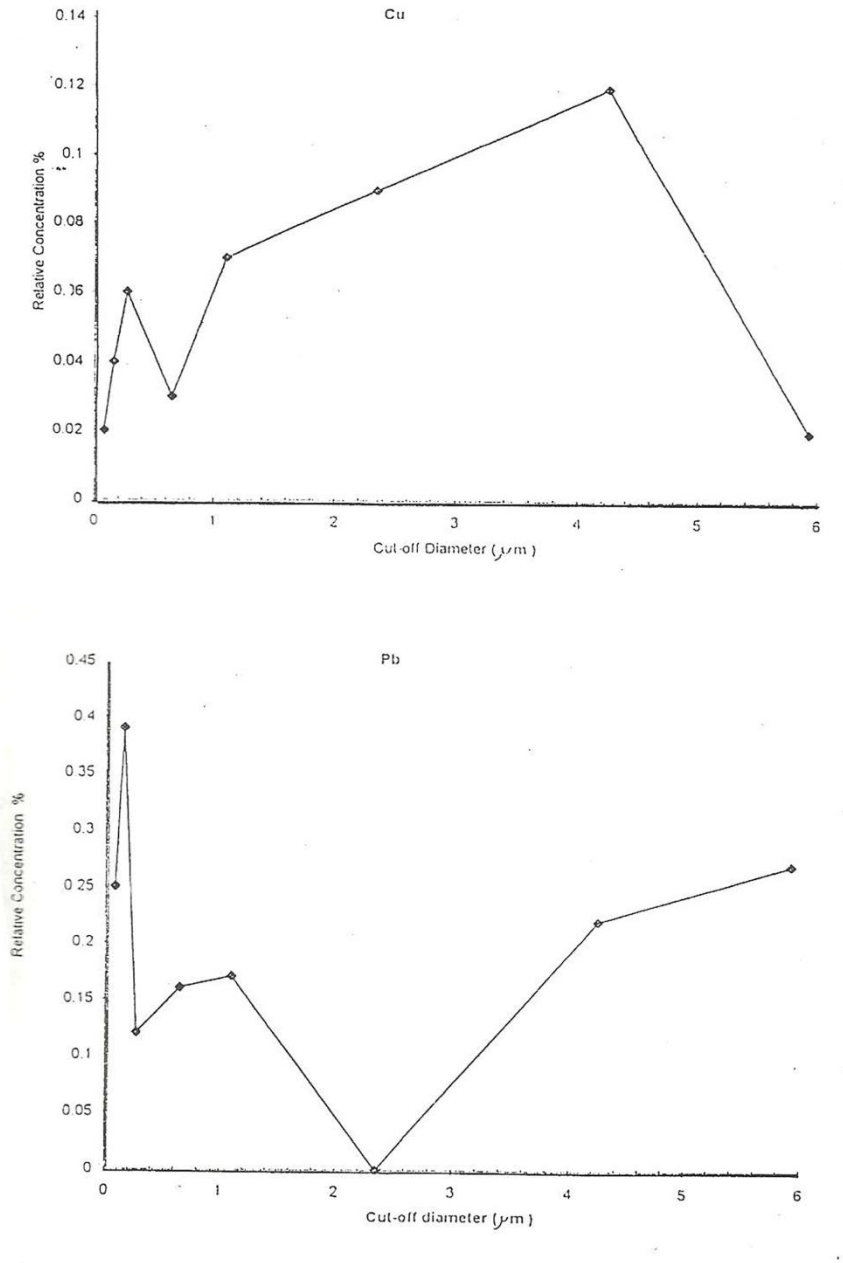

Figure 5 b. Elemental mass size distribution of Cu and Pb.

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