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Research note

Levels of PM_{10} and its Chemical Composition in the Atmosphere of the City of Isfahan

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Abstract

Airborne particulate matter (PM_{10}) was collected from the atmosphere of the city of Isfahan. The concentration of heavy metals and anions associated with airborne particulate matter were determined using atomic absorption spectrometric and ion chromatographic techniques. A comparison was made between the variation in the concentration of PM_{10} and that for heavy metals and CO. An excellent similarity was found between the variation model of $PM_{10,}$ heavy metals and CO. Due to the atmospheric concentrations of heavy metals, the enrichment factors were calculated and showed that the well-known toxic heavy metals are mostly released into the city atmosphere from anthropogenic sources.

Keywords: *Air pollution, Airborne particulate matter, Heavy metals in atmosphere, Anions in urban air, Atmospheric chemistry*

1- Introduction

Particulate matter (PM) is one of the most important air pollutants in industrialized areas and the population exposure to ambient particulate matter has recently received considerable attention as a result of findings from epidemiological studies [1,2]. The epidemiological studies have indicated that there is a statistical relationship between the atmospheric levels of fine particles and the numbers of daily deaths and hospitalizations as a result of pulmonary and cardiac diseases [3]. The United States Environmental Protection Agency (USEPA) has promulgated a national ambient air quality standard federal register for fine particles [4]. During the last decades, it has been proven that many toxic organic and inorganic pollutants are associated with ambient aerosols [5-8]. Fine particles such as PM_{10} offer a higher surface area and are able to collect more toxic organic and inorganic compounds on their surface despite these particles easily penetrating the lower part of the respiratory system, transferring a combination of organic and inorganic compounds into the lungs and blood circulation system, causing various adverse health effects on human health [9,10].

Air pollution has recently become a major problem in Iranian mega cities, where usually huge numbers of industries are located in the surrounding areas. The city of Isfahan is located in the central part of Iran beside a huge desert and a large number of

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industries are located around the city. The concentration of total suspended particulate (TSP) in Isfahan's atmosphere has already been investigated and is very high [11], but no information is available about the PM_{10} and its chemical composition. The determination of atmospheric concentration of fine particulate matter and their sources are important not only because of their adverse effect on human health, but also for programming and designing the strategies for the reduction of air pollutants. The chemical composition of fine particulate matter can reveal the hazards of this air pollutant for human health, which is very important concerning the size of the population at risk and the continuous nature of exposure.

In this work, the levels of PM_{10}, its chemical composition, and also their sources into the atmosphere have been investigated from September 2005 to December 2006.

2- Experimental

2.1 - Sampling

The city of Isfahan is located in the central part of Iran, next to a large desert and surrounded by highlands exceeding 2500 m above the sea level containing mineral mines, especially lead and zinc. The pattern of airflow is mostly from southwest to northeast and also from west to east. Airborne particulate matter are transferred from the south and west where the industrial and mining activities are located into the city atmosphere and combine with the particulate matter produced by automobiles and transporting systems, forming high levels of airborne particulate matter in the atmosphere of the city.

In this investigation, airborne particulate matter was collected from four different geographical directions and also from the central part of the city. Airborne particulate matter was collected from a height of 1.5 m above ground level and at a distance of 5 m from the road shoulder. Samples were collected with a PM_{10} high volume air sampler (Ecotech, Australia) operated at a flow rate of 1 m^3 min^{-1}. The sampling period was 24 hours in order to collect sufficient material for performing a sensitive analysis. Samples were collected from September 2005 to December 2006.

3- Preparation of samples

3.1 - Extraction of heavy metals

The exposed filters were folded several times and placed in a PTFE beaker and moisturized with a few ml of de-ionized distilled water and then 10 ml of concentrated nitric acid was added. The lid of the beaker was replaced and the beaker was heated at 90^o for 8 hours until all organic material was oxidized. The PTFE lid was then removed and the beaker was heated at 90^oC. When the volume of the mixture reduced to half, 5 ml more nitric acid and 5 ml hydrofluoric acid were added and the mixture refluxed for 4 hours in order to dissolve the remainder of the material completely. The mixture was finally evaporated to near dryness to remove the remainder of the hydrofluoric acid. The residual was extracted in nitric acid, transferred into a 25 ml volumetric flask and made to the volume with distilled de-ionized water.

3.2 - Extraction of anions

From each exposed filter five circles with a diameter of 3 cm (one from the center and four others from the area between the center and the edges of the exposed filter) were punched and placed in a centrifuge tube. 15 ml distilled de-ionized water was added on the filter and the mixture was placed in an ultrasonic bath with a frequency of 35 KHz for 25 min. The mixture was then centrifuged at 3000 rpm. The upper liquid phase extract was transferred into a volumetric flask and made to the volume with doubly distilled de-ionized water and used for the analysis of anions.

3.3 - Instrumentation

The determinations of heavy metals were carried out on a Varian atomic absorption spectrometer, Model AA-220. The instrument was equipped with an air-acetylene burner, D2 lamp, and Varian hollow cathode lamps. The wavelengths used for the absorption measurements were 217.0 nm for Pb, 228.8 nm for Cd, 357.9 nm for Cr, 232.0 nm for Ni, 213.9 nm for Zn, 253.7 nm for Hg and 309.3 nm for aluminum.

Determination of mercury was carried out by cold vapor atomic absorption spectrometry.

The determination of anions was carried out on a Metrohm ion chromatograph, Model 761. The system was equipped with a suppressor column and an electrical conductometric detector. A Metrosep anion dual column was used for the separation of anions.

4- Results and discussion

The average concentrations of PM_{10}, determined at different geographical directions in the city areas are summarized in Table 1 and indicate that the lowest level of PM_{10} was found in the east area and the highest concentration of PM_{10} was found at the south area. Many activities such as iron and steel factories and also mining activities, are located at the south and west of the city. Because the rising wind of the area is mostly from west to east and also from south-west to the north-east, obtaining a higher concentration of particulate matter at the east and north parts of the city was expected, but according to the results obtained from the investigation the higher concentrations of PM_{10} are determined at the south and west parts of the city with higher traffic densities.

Table 2 shows the concentrations of heavy metals associated with PM_{10}.and indicates that relatively high concentrations of the well-known toxic metals such as cadmium, lead, and nickel are adsorbed on the surface on PM_{10} and can penetrate into the lower part of the human respiratory system.

Table 1. Mean concentration of PM_{10} in different geographical directions ($\mu g\ m^{-3}$)

Sampling area	No. of samples	Concentration of PM $_{10}$
North	25	152
South	25	183
Central part	30	168
West	30	174
East	25	149

Table 2. Concentrations of heavy metals associated with atmospheric PM_{10} particles ($ng\ m^{-3}$)

Element	Mean concentration	Concentration range
Lead	117	79 -197
Cadmium	4.4	2.9 -6.5
Chromium	12.3	8.5 -25
Nickel	13.0	9 -22
Zinc	348	220 -418
Mercury	2.8	1.8 -3.6
Aluminium	324	209 -411

A continuous sampling in the city center was performed and the concentrations of PM_{10} and heavy metals were determined in order to investigate the relationship between the concentrations of PM_{10} and heavy metals. The results obtained from this investigation are shown in Figure 1 and indicate that an excellent similarity exists between the variation in concentrations of heavy metals and PM_{10}.

The variation in concentrations of carbon monoxide (8-hour mean) during the continuous sampling was also investigated (Fig. 2) and showed excellent similarity with those of PM_{10} and heavy metals. As a result it can be concluded that the pollutants are mostly released into the atmosphere of the city mostly from mobile sources.

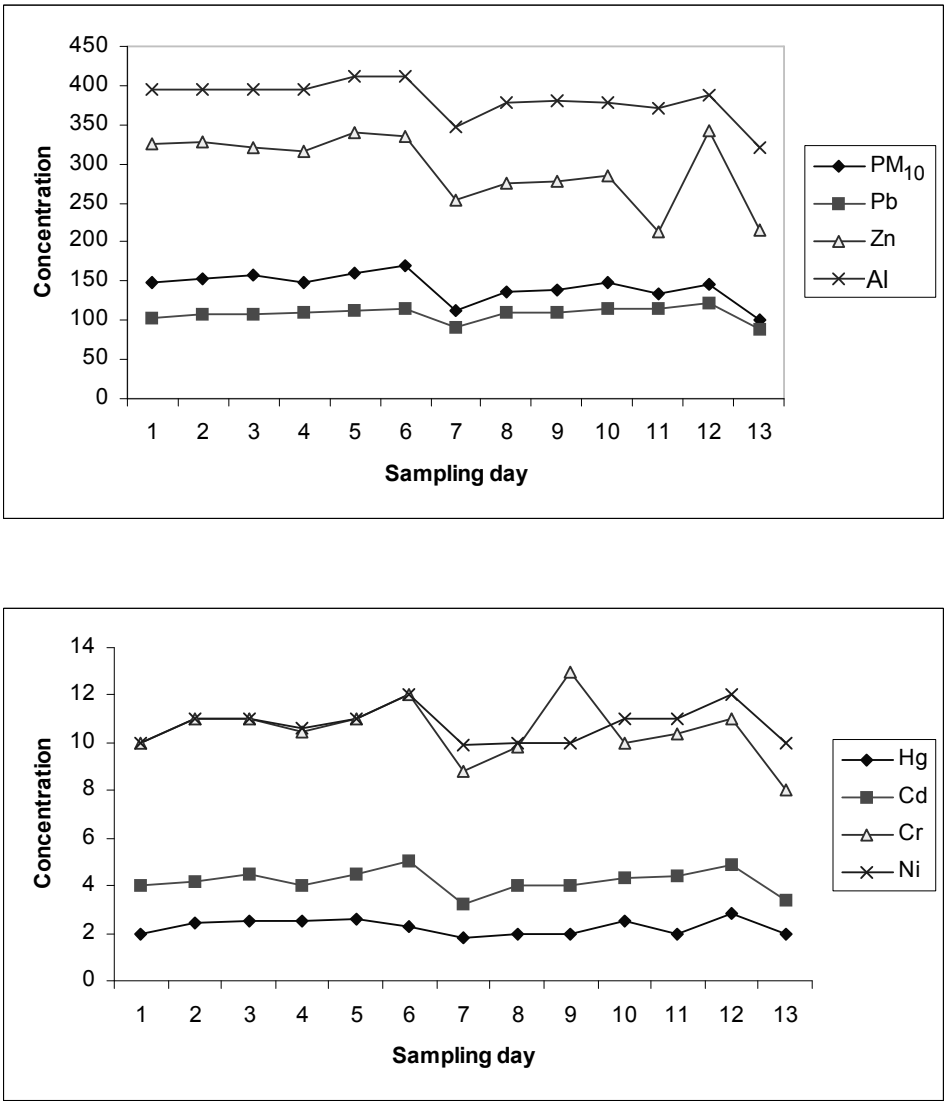

Figure 1. Variation in concentrations of PM_{10} and heavy metals (Concentration of PM_{10} is reported as μg m^{-3} while the Concentration of heavy metals are reported as ng m^{-3})

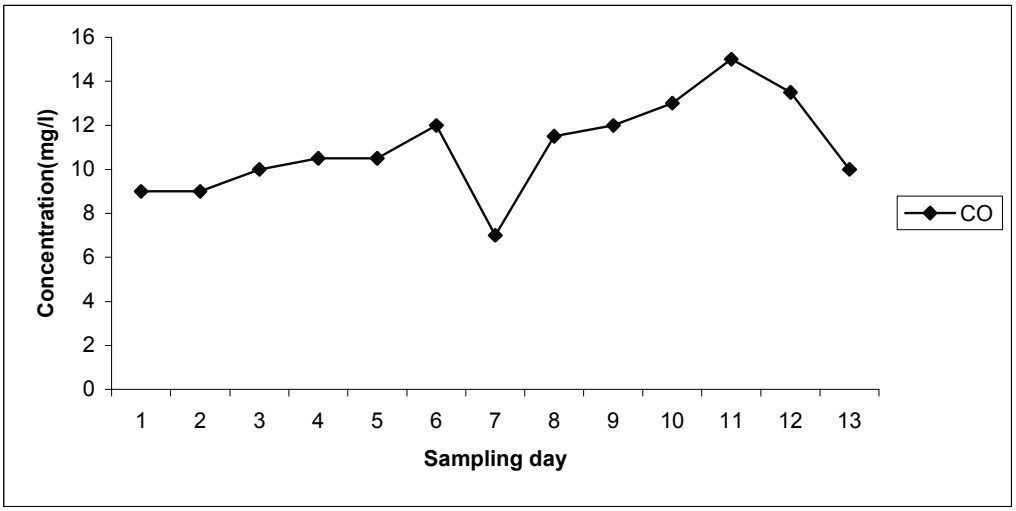

Figure 2. Variation in concentration of CO during the continuous sampling

The enrichment factor (E.F.) was calculated for heavy metals using the following formula.

$$\frac{\text{Concentration of element in sample/ Concentration of Al in sample}}{\text{Concentration of element in crust/ Concentration of Al in crust}}$$

Enrichment factor offers information about the source of heavy metals. The concentrations of heavy metals and aluminum in the crust were extracted from Taylor' s Table [12].
The enrichment factors of heavy metals associated with PM_{10} are listed in Table 3.

Table 3. Enrichment factors of the heavy metals in Isfahan atmosphere

Element	Enrichment factor
Al	1
Cr	32
Ni	44
Pb	350
Cd	5658
Zn	1263

Concerning enrichment values that are much higher than unity, it can be concluded that all heavy metals are released into the atmosphere from anthropogenic sources.

Table 4 shows the mean concentrations and the ranges of anions extracted from PM_{10} collected from the atmosphere of the city of Isfahan.

Table 4. Concentrations of anions associated with PM_{10} particles ($\mu g\ m^{-3}$)

Ion	Mean concentration	Concentration range
Fluoride	0.33	0.06 -0.42
Chloride	2.56	1.69 -3.26
Sulfate	11.65	7.14 -13.52
Nitrate	7.62	4.56 -12.81

5- Conclusion

The concentrations of PM_{10} and heavy metals in the atmosphere of the city of Isfahan is considered to be higher than those reported for the many industrialized cities all around the world. The concentrations of heavy metals in the Isfahan atmosphere were higher at the south and west areas with higher traffic

densities, while concerning wind direction, we expected to have more concentrations directed to the east and north areas. It can be concluded that mobile sources have a great role in releasing heavy metals into the city atmosphere.

The enrichment factors of heavy metals indicate that these elements are mostly coming from anthropogenic sources. The similarities between the variation in concentrations of PM_{10} and CO indicates that these elements are mostly released into the atmosphere from mobile sources and every program for the reduction of air pollution in the Isfahan atmosphere has to consider the reduction of exhaust emissions, reduction of daily trips, and developing a public trans-portation system.

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