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Aerosol Size Segregated of Tehran's Atmosphere in Iran

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ABSTRACT: Tehran is located in a valley at the foot of the Alborz Mountains in northern Iran (35 degrees latitude north). Urban expansion in Tehran resulted from a high rate of population growth and rural-urban migration combined with a strong tradition of centralization in the capital. Airborne particulate of Tehran's atmosphere was fractionated in a 6-stage high-volume cascade Impactor. The first objective was to measurement of PM in twenty sites in Tehran areas. Other objectives were to obtain detailed measurements of aerosol size distribution in Tehran's atmosphere during the 2004 at five sites. In all samples the PM is high for stage 6 (< 0.49 µm). In Enghelab station mean of PM value (< 0.49 µ) is 260.97 µg/m^3. The highest PM (10-7 µm) concentration is found 115.12 µg/m^3 at the Enghelab station. And the highest PM (3-1.5 µm) was found 40.5µg/m^3 at the Baseej site.

Key words*:* Aerosol particle, size distribution, vehicle emission, R.S.P

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INTRODUCTION

Particulate matter (PM) is one of the main air pollution problems with significant economic and human health implications, especially in those urban areas with poor ventilation, unfavorable geographical and meteorological conditions, and a high number of emission sources including uncontrolled sources. Tehran has a population of about 10 million people and a sprawling area of nearly 2300 km^2 (Halek, *et al*., 2004). It is surrounded on the north, northwest, east and southeastern parts by high to medium height (3800-1000 m) mountain ranges. The northern Alborz range essentially blocks the moist and rain-bearing air from Caspian Sea from reaching the Tehran area and wash out the air pollution. The climate is generally moderate to dry. More than 20% of Iran's entire population lives in Tehran area As in many large cities with limited ventilation, Tehran city experience air pollution problems especially suspended particles. A persistent haze blankets the city, especially during winter the effect of suspended particles on health (SCI, 2000). Health effect related to the inhalation of ambient aerosols is largely dependent on the size of the particles on which the compounds are found (Keywood, *et al*., 1999; Kipopulou, *et al*., 1999). Because of their low inertia, these particles can penetrate deeply into the lungs, increasing negative health effects (Bagleg, *et al*., 1996).Aerosols that contribute to this visibility degradation are usually a combination of primary and secondary particles (Gray & Cass, 1998). Primary particles are directly emitted from different sources; while secondary particles form in the atmosphere from gases emissions. As major contributors to ambient airborne PM levels, both light-duty spark ignition (LDSI) and heavy-duty diesel (HDD) vehicles are subject to numerous control measures (Abdul-Khalek, *et al*., 1998). To this respect, fossil fuels have gained attention as an important PM source. One of the environmental policies consists of improving composition of fuels employed in transportation and residential use such as unleaded gasoline and substitution of fuel oil by natural gas (Griffin, *et al*., 2003).

Gasoline-powered vehicles were required to have unleaded fuel after 2002 in Iran. In the recent years some of diesel buses and trucks are replaced with newer vehicles powered by modern engines and cleaner fuels (Rogge, *et al*., 1993). These efforts have attenuated the emissions engendered by growth, but 24 hour PM (particulate matter) concentrations with aerodynamic diameter less than 10 µm exceeding several hundred µg/m^3 are still measured at many monitoring sites (Eiguren, *et al*., 2003).

Monitoring and characterization airborne particulate matter (PM) has been an important research area because of the impact of PM on human health, visibility reduction and material damage (Mathal, 1990; Pope, *et al.*, 2002).

Much attention has been focused on particulate phase components of exhaust fumes due to possible acute and chronic respiratory effects. Exhaust fumes are a complex mixture of particulate (Monoli, *et al*., 2002; Seinfeld & Pandis, 1998).

This study reports results of airborne level of size distribution particulate in twenty locations in Tehran.

MATERIALS & METHODS

The first goal of this study is to provide additional and more comprehensive information to explain the nature and causes of particulate concentrations in Tehran city. The second goal is future characterize the major sources contributing to significant of PM_{10}, $PM_{2.5}$ and $PM_{0.45,}$ including sources that directly emit particles. A micro orifice uniform deposit Impactor (MOUDI) was used to measure the size distributions of the aerosols (Mitranda, *et al*., 2002).

A major field campaign was carried out in Tehran city through 2004. Measurements during the field program included:

- TSP measurements in 20 sites, inside and suburbs of city (Table 2 and Fig. 1)
- Seasonal of PM concentration at 8 locations throughout the city. (Fig. 2)
- PM <10, PM < 0.45 (PM size distribution) at 5 sites. (Tables 3 and 4)
- Hourly measurements of PM_{10} at 3 sites (Figs. 3, 4)

Airborne particulate matter was sampled with a cascade Impactor of sierra instruments Inc., consisting of 5 stages with rectangular jets and a back-up filter. The equivalent aerodynamic cut-off diameters at 50 % collection efficiency for a flow rate of about 15-18 scfm are given in Table 1 (the specific gravity of the particles is assumed to be 1 g/cm). As the collection media, whatman glass fiber filters type GF/A are used. The total volume of sampled air passed through a rotameter equipped with a photo relay. Sampling is interrupted when the flow rate decreases more than 5% as would occur in the case of reduced pumping speed due to back-up filter clogging or reduced motor efficiency. The Equivalent aerodynamic cut-out diameters at 50 % collection efficiency of the different Impactor stages are based on the manufacturer's data (Eiguren, *et al*., 2003; Hays, *et al*., 2002). Practically, the most useful information is obtained for well determined fractions in the size range below 10 µm, containing the particles penetrating the non ciliated pulmonary region (Brook, *et al*., 1997; Wilson & Suh, 1997). Distribution patterns have to be described in different manners to allow a valid interpretation. In this paper, primarily the concentration Vs particle size and cumulative mass distribution representations will be used. Particulate matter (PM) was measured by 47 mm fiber filter (< 0.45 µm pore size) were pre-weighed on a microbalance. Filters were removed after sampling and allowed to equilibrate at the laboratory prior to gravimetric analysis.

Table 1. Sierra Hi-volume cascade Impactor characteristics

Stage number	Equivalent aerodynamic cut-out Diameters at 50 % efficiency (µm)
1	10-7.2
2	7.2-3.0
3	3.5-1.5
4	1.5-0.95
5	0.95-0.49
6	<0.49

RESULTS & DISCUSSIONS

Particle size has important health implications, with the smaller particles having a greater ability to penetrate deeper into the airways and lungs of a person who is breathing in these particles.

From our results, which are based on a 1-year survey, it can be observed that the particulate concentrations are associated with traffic volumes and seasonal conditions.

The major anthropogenic sources of PM may be split into stationary and mobile combustion sources. Mobile sources include motor vehicles (both gasoline and diesel) have a significant portion in Tehran pollution.

Fig. 1 shows that the highest PM concentrations were observed at "Shoosh" site, whereas the lowest concentrations were recorded at the "Haram-Emam" Site.

A statistical summary of the total suspended particulate from the 20 sites across the period Jan. 2004-Jan. 2005 is presented in Table 2. The data are seen to vary from a minimum of 62 µg/m^3 at Haram-Emam site (Tehran suburbs are not inhabited and are less impacted by traffic) to a maximum of 1915 µg/m^3 at Shoosh site (crowded district of in the south of Tehran) and subsequently Shahre-Rey site with 1127 µg/m^3.

Table 2. Distribution of total suspended particulate matter (μg/m^3)

Number	Station	Mean	Maximum	Minimum
1	Tajreesh	249.44	438.57	133.78
2	Vanak	219.04	323.53	117.43
3	Arjantin	180.46	196.19	159.59
4	Tehran-pars	249.66	387.25	112.0
5	Amir-abad	535.98	420.34	217.4
6	Sadeghieh	391.25	439.02	308.77
7	Karaj-road	0	215.77	83.1
8	Azadi	269.71	502.57	69.6
9	Enghelab	397.19	674	96.62
10	Ferdoosi	126.99	175.96	96.62
11	Emam-hossein	195.72	250.0	140.0
12	Bahman	569.97	1017.2	308.2
13	Shoosh	425.51	1915.2	79.71
14	Rah-ahan	177.57	559	94.6
15	Emam-khomeini	153.99	199.28	106.89
16	Sanat	253.52	391.11	111.34
17	Baseej	233.95	395.73	150.84
18	Afsarieh	274.23	413.19	132.27
19	Shahre-Rey	1627.52	1127.5	93.5
20	Haram-Emam	141.97	213.36	62.11

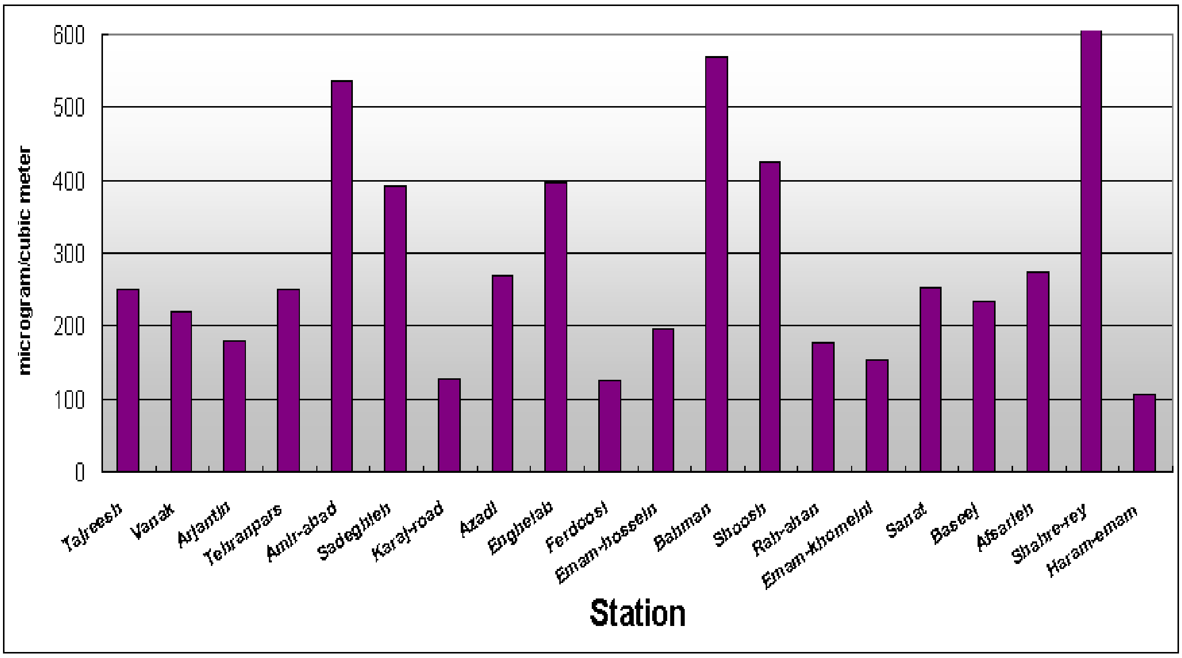

Fig. 1. Average of PM concentrations in 20 sampling sites

This variable data range across all 20 sites highlighted the important of motor vehicles as a major source of air PM (more than 2 million vehicles traveling on streets daily). The sites of Shoosh, Shahre-Rey and Bahman square have year-round high traffic densities.

The distribution of suspended particulate matter*:* Fig. 2 shows the size distribution of total suspended particulate matter (μg/m^3) at 5 locations in Tehran area. As shown in Fig. 2, concentration of PM<0.49 μm (fine particle mass) makes up 50-60% of PM-10, from point of view of entering of the particles in respiratory system and their staying in the lungs are more hazardous. The size fractioned PM for the five sites are shown in Fig. 3. The data appear to be bimodal, with a peak below 0.49 μm and another at 7.2-10 μm. This shape is consistent with a pattern based on two primary mechanisms for the generation of particles in the air, namely combustion and physical processes. The average of summed size fractioned PM varied from 126.44 to 404.42 μg/m^3 across the studied period (Fig. 3).

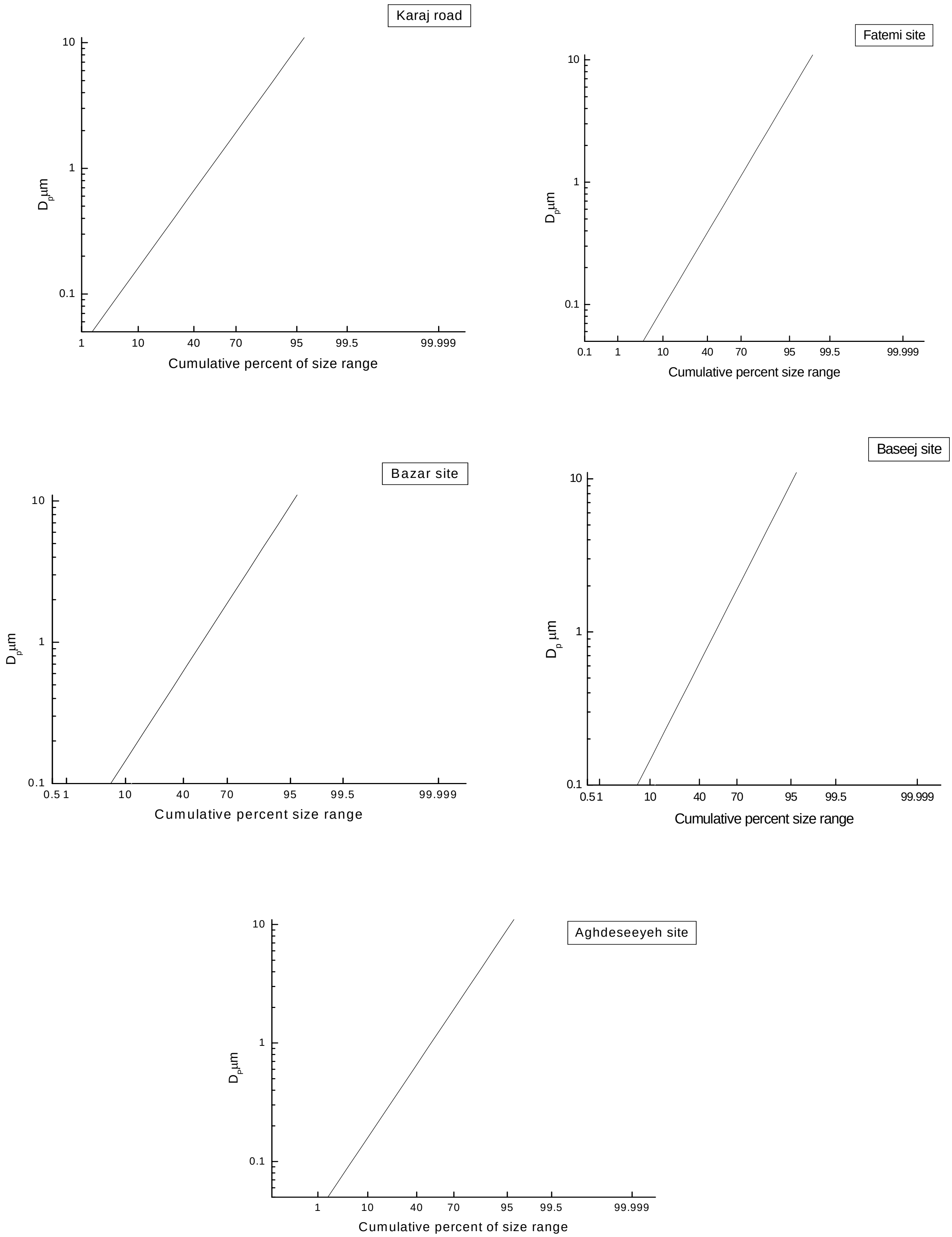

Fig. 2. Cumulative % less than stated size (City Center: Fatemi site; North: Aghdeseeye site; East: Baseej site; West: Karaj-Road site; South: Bazar site)

The relative importance of selected size fractions has been evaluated on an individual basis, and a comparison has been made across days of high, moderate, and low particulate loading.

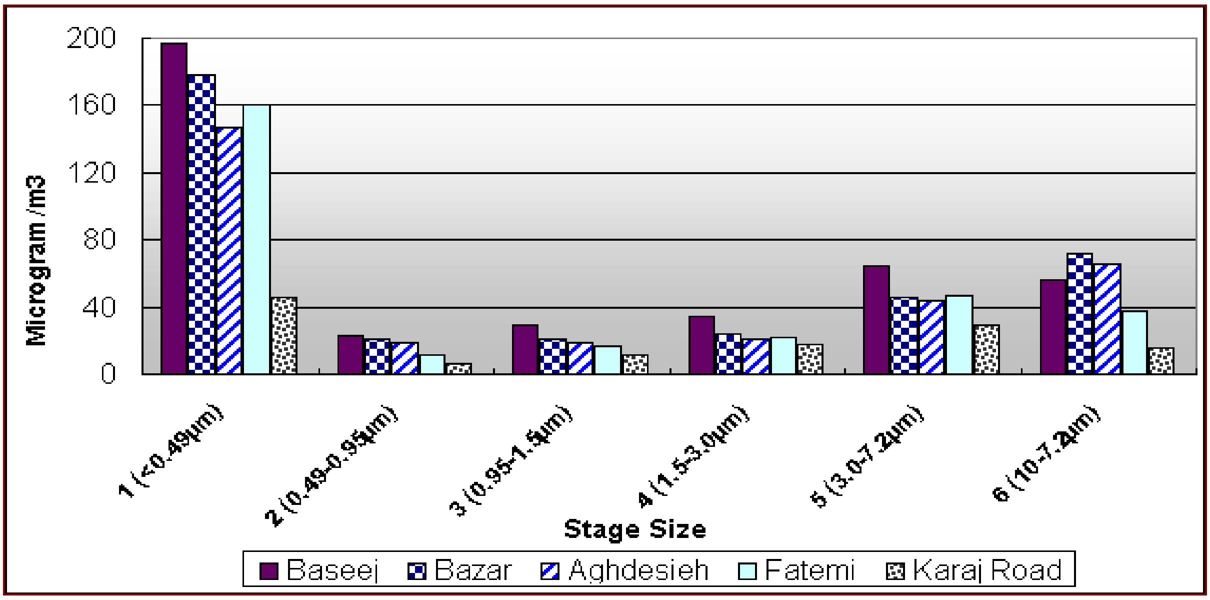

Fig. 3. Particles size fractioned at the 5 sampling sites

These data reflected that most of the time mean of PM concentrations at the Tehran areas exceeded the standard (NAAQS[(1)]); 15-20 times per year.

High particulate levels were 438.57 µg/m^3 on September 20 and 413.19 µg/m^3 on August 6 in Bazar and Baseej sites respectively. Low particulate level was 104.02 µg/m^3 on September 12 in Karaj-Road site.

Average 24 h PM_{10} concentrations over the period of study at the 3 sites in the Tehran city were 147.40 µg/m^3 (Bazar site), 72.86 µg/m^3 (Fatemi site) and 70.16 µg/m^3 (Aghdesieh site). During the study period , the 24-hr standard of 150 µg/m^3 were exceeded for 37% of samples in Bazar site , 3% of samples in Fatemi site and only 0.6% of samples at Aghdesieh site Hourly PM_{10} concentrations exhibited diurnal patterns (Figs. 4 and 5), with dual

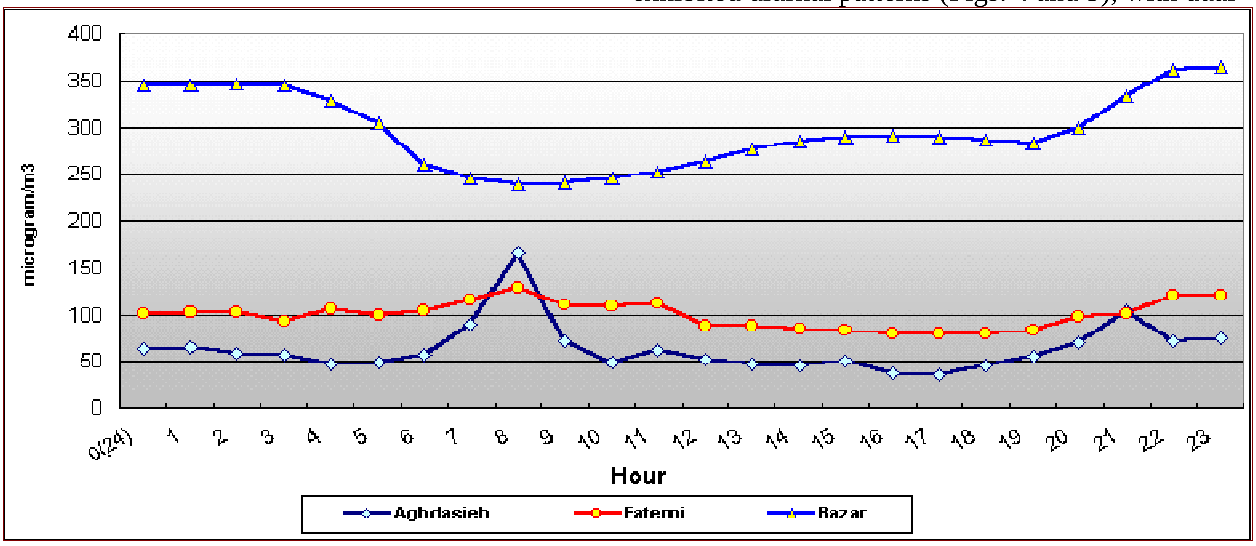

Fig. 4. Hourly concentration of PM-10 in the three stations in Tehran (June 2004) - warm season

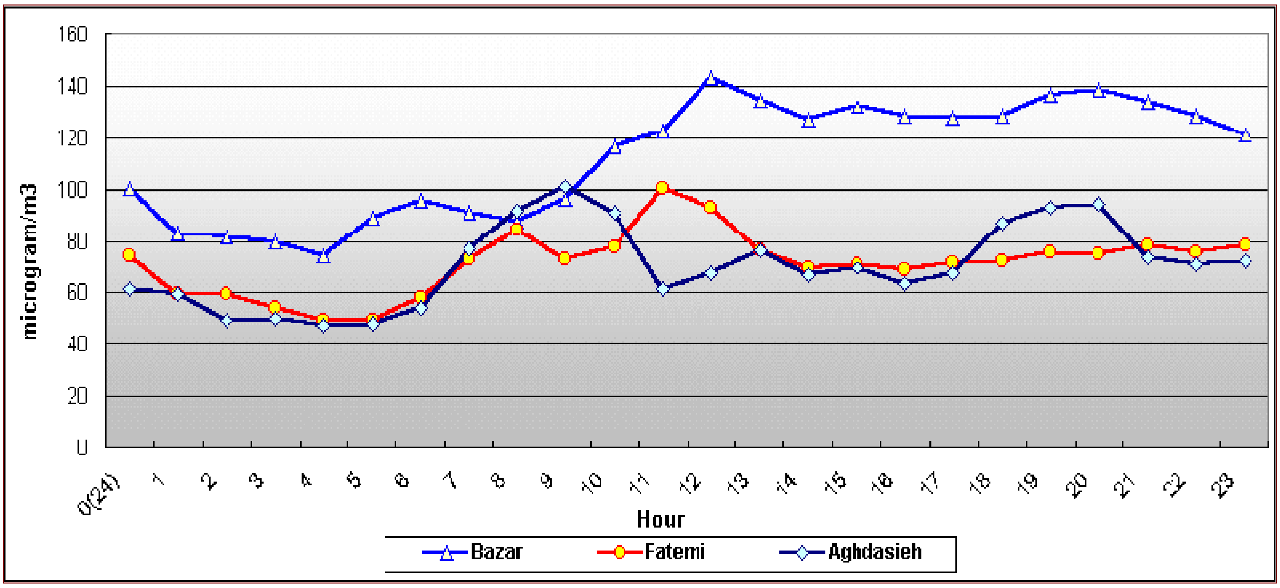

Fig. 5. Hourly concentration of PM-10 in the three stations in Tehran (Jan. 2004) - cold season

peaks found at morning (7-9 AM) and early evening (18-21 PM) dependence of season. The maximum hourly concentration PM_{10} were 562.5 μg/m^3 at Bazar site (2004.6.7), 532.5 μg/m^3 at Fatemi site (2004.5.17) and 482.5 μg/m^3 at Aghdesieh site (2004.8.16).

Information from the Air Quality Control Company (AQCC), linked to municipality, an annual report indicated the traffic densities at Tehran area were 2-3 million vehicles/12 h period (7:00 a.m. – 7:00 p.m.).

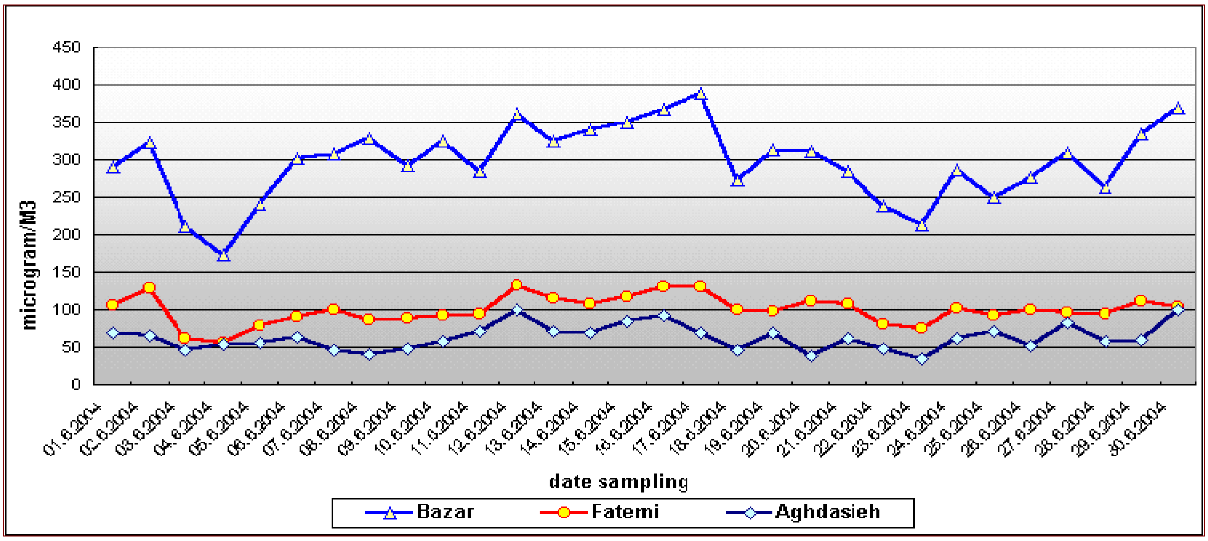

Fig. 6. Concentration of PM-10 at the three sampling site (June 2004) warm season

During the June month, the mean of PM-10 concentrations was 298.00 μg/m^3 at the Bazar site. Bazar is a major economic center (city center) that wholesales has performed for throughout of Iran, especially in summer season. Motor vehicles are recognized as a major source and primary direct emission of fine and ultra fine particles to the atmosphere in Tehran areas.

CONCLUSION

Tehran, is one of the world's largest metropolitan areas, containing nearly 10 million inhabitants

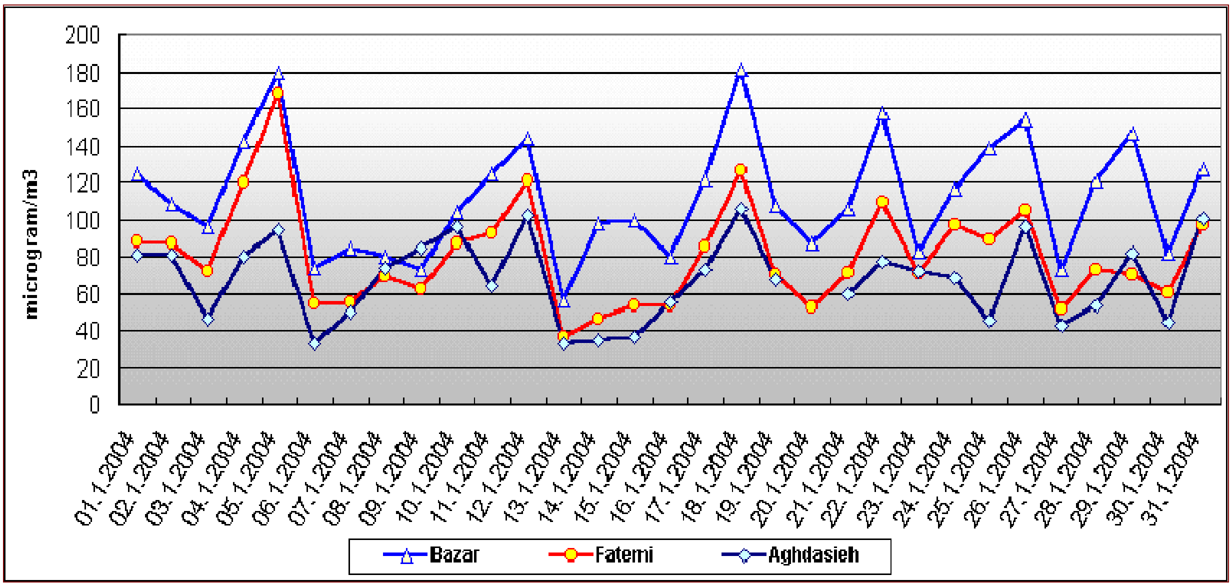

Fig. 7. Concentration of PM-10 at the three sampling site (Jan. 2004) cold season

within the foot of the Alborz Mountain. The Tehran occupies ~ 800 km^2 at a normal elevation of 900-1800 m above mean sea level. It is bordered on the north and east by mountains. Tehran city's location at degrees north latitude provides it with a temperate climate throughout the year. As many large cities and especially in ones located in valleys with limited ventilation and weak winds, Tehran experiences air pollution problems, especially PM. Several factors influence the production of PM in mobile sources, including fossil fuels, low-technology of the engine and condition of the engine.

We measured aerosol size distributions at the Tehran atmosphere at intervals of 1 month during 2004. Measurements of particulate matter (PM) extended from 10 µm (D_p) to PM<0.49 µm.

The annual average in each site exceeds the National Ambient Air Quality Standard (NAAQS) of 50 µg/m^3. The lowest average PM_{10} value (104.22 µg/m^3) was in 2004, which it has been found to be higher than Standard. In a recent study, roadside fine particles ($PM_{2.5}$) and coarse particles ($PM_{2.5-10}$) indicated a high ratio of fine: coarse PM in the sampling sites and $PM_{2.5}$ levels in highly polluted roadside areas exceeded the U.S. Environmental Protection Agency (EPA) daily average of 65 µg/m^3. There are increasing concerns about air pollution and adverse health effect in Tehran. The level of PM has been found to be associated with the daily mortality rate. Exposure to air pollutants produced by automobiles has been associated with alteration of pulmonary function among traffic police in Tehran.

The seasonal PM_{10} variations for the three sites are shown in Figs. 4-7. The ratio of PM_{10} concentrations in wet and dry season is varied. It was seen that the highest concentrations occur during the summer period. At first this may be related to the daytime (12-15 h) and subsequently traffic density, the secondly, deficit of strong wind, rainfall and dryness in the summer.

In later year's consumption of unleaded fuel for cleaner emissions in Tehran are prevalent. In recent years many old diesel buses and trucks have been replaced with newer vehicles powered by cleaner engines, but this trend is long.

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