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Seasonal variability of concentration, chemical composition and aerodynamic distribution of particulate matter in Tehran

Balal Oroji[*a]

[a] Faculty of Biological Science, University of Kharazmi, Karaj, Iran

A B S T R A C T

In recent years, the concentration of suspended particles in the atmosphere of Tehran has been increasing. Therefore, we see more polluted days in this city. This situation has had economic, health, welfare, social and negative effects. In this study, we want to investigate the seasonal changes in particle concentration, chemical composition and aerodynamic distribution in Tehran. Atmospheric matter sampling was performed in four seasons in 2020 to 2021. Sampling was performed by Andersen Cascade Impactor 8 stages. Also, in each period of sampling process, samples were prepared to study the physical and chemical properties by SEM method. The particle surfaces with magnifications of 5000x, 10000x, 20000x and 50000x were studied. The EDS method was used to study the chemical composition of particulate matters. The results show that the north and northwest of the region are affected by the prevailing wind and a large volume of particulate matter produced by fixed and moving pollutants move to these areas. The highest and lowest concentrations of total PM collected in Azadi square and Hakimiyeh were 162.11±16.5 μg/m^3 and 139.21±12.22 μg/m^3, respectively. Also, the distribution of particulate matter in the western and southern regions of the region was more towards coarse particles, while the distribution of particles in the eastern and northern regions was more towards smaller particles. Due to the geomorphological characteristics of the region, the production of particulate matter should be controlled and monitored by moving and fixed sources, to reduce the destructive effect of particles on the health of people living in the region.

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*Corresponding author
E-mail address:
BalalOroji@yahoo.com
(B. Oroji)

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1. Introduction

Atmospheric pollutants are one of the most important environmental problems studied around the world and several studies have been conducted in this field. In recent years, atmospheric suspended particles are one of the most important environmental problems that pose a constant threat to health, well-being and quality of life. These compounds are composed of a complex mixture of physicochemical (mineral) and biological (organic) components (Mellouki et al., 2020; Silva et al., 2019; Silva et al., 2020; Zamberlan et al., 2020). Pollutant suspended particles vary in diameter and physicochemical composition depending on the source of emission, geography and local meteorology.

The degree of particles toxicity is directly related to diameter. The particulate matters included in size: ultra-fine particles or UFPs (with an aerodynamic diameter of ≤0.1 μm or 100 nm), fine particles (with an aerodynamic diameter of 0.1 – 2.5 μm) and coarse particles (with an aerodynamic diameter of ≥2.5-10 μm), according to the results, the degree of toxicity for ultra-fine particles is increased (Oroji et al., 2018a).

Due to their size, particulate matters can with respiratory system enter the vital organs and have significant consequences for human health.

In addition, PM contaminants are associated with carcinogenic activity, genotoxic, mutagenic and respiratory conditions in humans (Moreno-Ríos et al., 2022). Very fine particles are formed by dynamic processes such as coagulation, compaction and nucleation. They are mainly composed of organic and mineral compounds, nitrates, sulfates, potentially toxic elements and trace metals that can enter vital organs through the respiratory system and interfere with cellular metabolism, and finally, they cause respiratory, genetic, cancer, neurological and cardiovascular disease (Zhang et al., 2020; Munoz-Salazar et al., 2020). These particles are available in large, fine and ultra-fine sizes, with particles as small as 300 nanometers and smaller as large as 10 micrometers and larger (Rizza et al., 2018; Liu et al., 2020). Research has shown that fine particles stay in the atmosphere longer than coarse particles, so these can enter the respiratory system very quickly (Abdel-Shafy and Mansour, 2016; Buzea et al., 2019). Due to their aerodynamic properties, these particles can be easily removed during the wet and dry deposition process (Munoz-Salazar et al., 2020; Kumar et al., 2011). The fine particles are also able to be easily transported through the respiratory system by penetrating the pulmonary alveoli and thus lead to pulmonary deposition and systemic displacement (Bhargava et al., 2019). The results of studies in this field have shown that long-time exposure to atmospheric particles leads to complications and various respiratory and lung diseases (Moller et al., 2020; Geo and Sang, 2020; Nho, 2020; Zhao et al., 2022). Also, in recent studies show that fine particles (diameter of 2.5 µm) and ultrafine particles (diameter of 0.1 µm) are the most toxic airborne particles (Soppa et al., 2019). Depending on the source of the contamination, the particulate matter varies in size and composition. Natural resources, such as volcanic eruptions, forest and range fires, airborne particles, runoff and local minerals, as well as human resources such as gas, coal or hydrocarbon combustion, biomass burning (as agricultural products incineration, forest and range fires and Garbage disposal), vehicle traffic, industrial emissions, wear and tear of tires due to car brakes, air traffic, seaport, maritime transport, construction, demolition, repair and processing of concrete, wood-burning stoves, outdoor burning Kitchen and smoke (Moller et al., 2022; Stacey, 2019; Agudelo-Castaneda et al., 2019; Li et al., 2021). Due to the differences in air quality in different regions, many studies inside and outside the country have examined factors that are closely related to changes in air quality, such as meteorological conditions, changes in surface coverage, urbanization and economic development, transportation methods and Urbanization (Oroji et al., 2018a; Oroji et al., 2019; Zhao et al., 2020; Isaev et al., 2022). The city of Tehran, the capital of Iran, is one of the most polluted cities in the region and the world, and increasing the concentration of particulate matter is one of the biggest challenges for its inhabitants. A significant volume of atmospheric particle concentrations in Tehran is related to human resources, which are produced by motor vehicles and industrial factories and home heating systems. Another part of the production of atmospheric particles in Tehran is local storms (Oroji et al., 2019; Oroji et al., 2018b). Atmospheric stability increased personal vehicle traffic in the city, and the construction of high-rise buildings in recent years has raised the concentration of atmospheric particles in the area to dangerous levels and drastically reduced the air quality. Study and research in the field of physical and chemical properties of suspended particles, identifying their behavior in different climatic conditions and recognizing the sources that produce them can improve decisions about their control and management. In this study, we intend to study the aerodynamic distribution of atmospheric particles in Tehran to study their chemical composition during the year (from 2020 to 2021).

2. Material and Methods

2.1. Geographical Location

The metropolis of Tehran is located on the southern slops of the Alborz Mountains with an area of about 73 km^3, with a population of about 15 million people as the capital of Iran and one of the most populous metropolises in the world (Arhami et al., 2018). The geographical location of the study area is shown in Figure 1. Population growth, land cover, land-use change and, most importantly, a significant increase in the number of moving pollutants (motor vehicles) have led to an increase in air pollution, which has posed significant risks to the ecosystem and human health and safety

(Alizadeh-Choobari et al., 2016). In the last decade, atmospheric pollution and the production of particulate matter are known as the most important environmental problem in Tehran (Halek et al., 2010). Local storms, sources of constant pollutants (such as manufacturing industries, electricity generation with fossil fuels and sand mines), mobile pollutants (such as motor vehicles) and soil re-suspension are the most important sources of pollution in Tehran. Due to the geographical location of the region and the direction of the prevailing wind flow in the area, it limits natural ventilation, increases inversions in wet seasons such as winter, and increases the effects of local dust storms (Halek et al., 2010; Halek et al., 2010b).

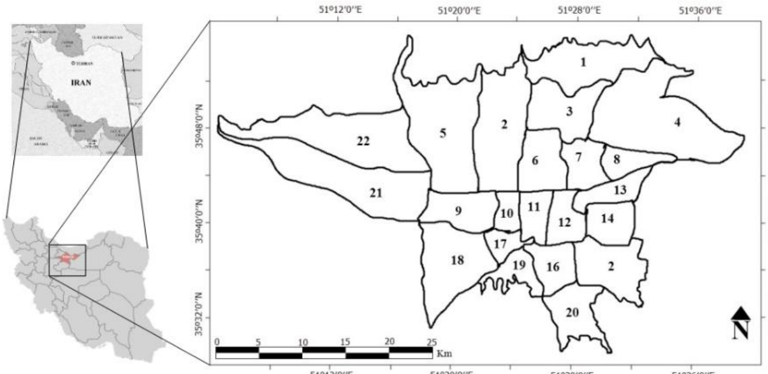

Fig. 1. Geographical Location of the study area

2.2. Sampling and Measurement

Atmospheric matter sampling was performed in four seasons from 2020 to 2021. Figure 2 shows the geographical location of sampling stations in the study area. Due to the prevailing wind direction, the volume of motor vehicle traffic and human activity four points were selected as sampling stations. The geographical coordinates of the sampling stations are shown in Table 1. Sampling was performed by Andersen Cascade Impactor 8 stages. The cascade shock absorber is a multi-jet, multi-stage device that works with a constant flow rate and provides the ability to analyze atmospheric suspended particles in terms of particle size distribution. Sampling was performed with a constant air flow of 28.3 L/min (1 ft^3/min). The duration of sampling varied from 1 hour to 72 hours. The distribution of particles with diameters ≥11, 11-7, 7-4.7, 4-3.3, 3.3-2.1, 2.1-1.1, 1.1-0.4 and ≤0.4 µm will be possible by this sampler. In the last stage of particle collection in this sampler, particles smaller than 0.4 µm are collected by glass fiber filters. In the Anderson falls shock absorber, the particles are carried by a stream in a curved path and, depending on their Stokes number, are collected in different stages according to their aerodynamic size (Papastefanou, 2008). After each sampling period, atmospheric particles collected on the impactor steel plates were counted by weight. Also, in each period of the sampling process, samples were prepared to study the physical and chemical properties by the SEM method. This method studied particle surfaces with magnifications of 5000x, 10000x, 20000x and 50000x were studied. The EDS method was used to study the chemical composition of particulate matter.

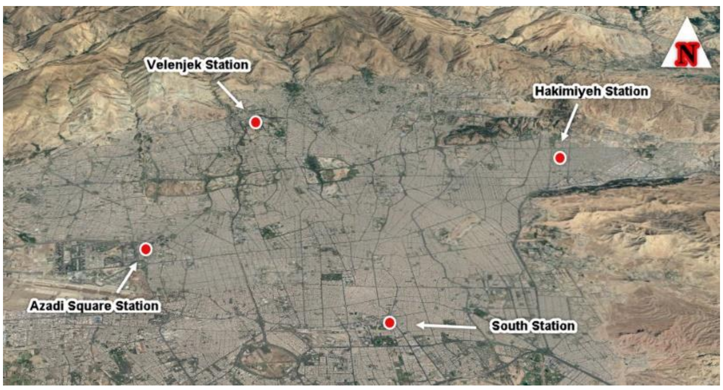

Fig. 2. Location of sampling stations

Table 1. Geographical Coordinates of stations

Stations	Geographical Coordinates
Hakimiyeh	N 35°45′ E 51°35′
South	N 35°39′ E 51°26′
Azadi square	N 35°41′ E 51°20′
Velenjak	N 35°47′ E 51°23′

3. Results and discussion

The averages of particles distribution concentrations in each region for the whole period are shown in Table 2. Based on the sampling results at the Velenjak station (north of Tehran), the highest concentration of total particulate matter collected in the summer was 145.23±22.12 μg/m^3. The lowest concentration of total particulate matter collected in the spring was 90.26±32 μg/m^3. The average of total particulate matters in this area was 118.6±34.2 μg/m^3 for the dry season and 107.15±30.2 μg/m^3 for the wet season. This area is affected by the airflow from the plains to the mountains during the day and a large volume of particulate matter produced in the city by moving sources, moves to this area and therefore is one of the polluted areas in Tehran (Oroji et al., 2018b). This area is affected by the prevailing wind and therefore the collected particulate matters have a source of moving and fixed sources located in the area (Oroji et al., 2018b). Also, the averages of particles distribution concentrations for dry and wet seasons are presented in Table 3. The sampling results at the Azadi square station (west of Tehran), show that the highest concentration of total particulate matter collected in the summer was 162.11±16.5 μg/m^3. The lowest concentration of total particulate matter collected in the spring was 105.38±13.6 μg/m^3. According to the results in Table 3, the average of total particulate matters in this area was 156.5±34.2 μg/m^3 for the dry season and 142.65±24.2 μg/m^3 for the wet season. This area is mostly affected by particulate matters produced by fixed sources and sand factories in the southwest of Tehran. Also, a significant number of particulate matters in this area is created by heavy trucks and passenger cars. Based on the sampling results at the South station, the highest concentration of total particulate matter collected in the summer was 153.7±18.4 μg/m^3. The lowest concentration of total particulate matter collected in the spring was 111.18±13.3 μg/m^3. According to the results in Table 3, the average of total particulate matters in this area was 149.55±18.1 μg/m^3 for the dry season and 137.55±15.8 μg/m^3 for the wet season. This area is mostly affected by particulate matters produced by fixed sources and sand factories in the southwest of Tehran. Also, a significant number of particulate matters in this area is created by heavy trucks. Also, at the Hakimiyeh station (East of Tehran), the highest concentration of total PM collected in the summer was 139.21±12.22 μg/m^3. Also, the results showed that the lowest concentration of total PM collected in the spring was 88.16±12.4 μg/m^3. The average of total particulate matters in this area was 126.85±18.22 μg/m^3 for the dry season and 107±16.1 μg/m^3 for the wet season. This area is affected by the prevailing wind and therefore the collected particulate matters have a source of moving and fixed sources located in the area.

Table 2. Average annual distribution of particulate matter collected in the area (μg/m^3)

Particle size (μm)	Hakimiyeh St.	South St.	Azadi square St.	Velenjak St.
≥ 11	15.5	20.2	20.67	15.15
7-11	14.55	18.27	19.45	13.5
4.7-7	14.37	17.45	18.35	13.42
3.3-4.7	13.6	17.2	17.72	13.07
2.1-3.3	12.9	15.97	17.22	12
1.1-2.1	12.62	15.1	16.75	12.25
0.7-1.1	12.2	14.27	14.92	12.1
0.4-0.7	11.3	13.3	12.87	11.77
≤ 0.4	9.87	11.85	11.6	9.67
Total	116.92	143.55	149.57	112.87

Table 3. Average distribution of PM collected in dry and wet seasons for stations (μg/m³)

Particle size	Velenjak St.		Azadi square St.		South St.		Hakimiyeh St.	
(μm)	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
≥ 11	14.4	15.9	19.65	21.7	18.45	21.95	14.85	16.15
7-11	12.7	14.3	18.25	20.65	16.95	19.6	13.6	15.5
4.7-7	12.75	14.1	17.45	19.25	16.05	18.85	13.4	15.35
3.3-4.7	12.2	13.95	16.8	18.65	17.2	17.2	12.5	14.7
2.1-3.3	11.3	12.7	16.15	18.3	15.15	16.8	11.75	14.05
1.1-2.1	11.25	13.25	15.85	17.65	14.7	15.35	11.1	14.15
0.7-1.1	11.505	12.55	15.1	14.75	13.85	14.7	10.8	13.6
0.4-0.7	11.35	12.19	12.05	13.7	13.35	13.25	10.05	12.55
≤ 0.4	9.7	9.65	11.35	11.85	11.85	11.85	8.95	10.8
Total	107.15	118.6	142.65	156.5	137.55	149.55	107	126.85

Results show that in Velenjak station, 38% of the volume of collected particles had a diameter of fewer than 3.3 µm. During the dry months, especially in late summer and early fall, due to strong winds and local storms, more than 58% of the particles collected in the particle distribution test had a diameter of more than 7 µm. According to these results, during the sampling period of wet and cool months, the number of particulate matters with a diameter of fewer than 3.3 µm was recorded at about 36% and for particulate matters with a diameter of more than 11 µm up to 25%. The sampling results for the particle distribution test in the dry and hot months of the sampling period the highest number of particles with a diameter of fewer than 0.4 µm was recorded at about 11.2±4.3 µg/m^3 and the lowest at about 10.1+4.1 µg/m^3. Also, during the cold and wet months, especially in winter, with the occurrence of temperature inversion, the maximum value was about 16.3±4.6 µg/m^3 and the lowest value was about 8.4±3.7 µg/m^3. These results are shown in Figure 3. Based on these results, differences in the distribution of atmospheric particles for large particles (larger than 2.5 µm) are seen in both the dry and wet seasons. The particle size difference gradually decreases toward fine particles (smaller than 1 µm). Studies show that atmospheric particles collected at this station are mostly produced by moving sources in the central and southern areas of the study area. Also, based on the results of the aerodynamic distribution test of particulate matter at the Azadi square station, 48% of the volume of collected particles had a diameter of fewer than 3.3 microns. While during the dry months, especially in late summer and early fall, due to strong winds and local storms, more than 60% of the particles collected in the particle distribution test had a diameter of more than 7 µm. According to these results, during the sampling period of wet and cool months, the number of particulate matters with a diameter of fewer than 3.3 µm was recorded at about 45% and for particulate matters with a diameter of more than 11 µm up to 35%. The findings of this study show that in the dry and hot months of the sampling period, the highest number of particles with a diameter of fewer than 0.4 microns was recorded at about 26.6±8.3 µg/m^3 and the lowest at about 13.2±6.3 µg/m^3. Also, during the cold and wet months, especially in winter, with the occurrence of temperature inversion, the maximum value was about 18.1±15.2 µg/m^3 and the lowest value was about 9.1±21.3 µg/m^3. These results are shown in Figure 3. Significant differences in atmospheric particle size distributions for coarse particles (larger than 2.5 µm) are seen in both the dry and wet seasons. This difference gradually decreases toward fine particles (smaller than 1 µm). Atmospheric particles collected in this area are mostly affected by the entry of pollutants from moving sources in the western and southwestern areas of the study area. The concentration of coarse particles in this area is mostly influenced by the prevailing wind flow in the area. Therefore, in the dry season, most of the large particles sampled in this area are of mineral origin and incineration of agricultural waste. Studies also show that in the wet season, most of the station's pollutants are generated by vehicles from fossil fuels. The results of surveys at the South station show that 46% of the volume of collected particles had a diameter of fewer than 3.3 µm. During the dry months, especially in late summer and early fall, due to strong winds and local storms, more than 55% of the particles collected in the particle distribution test had a diameter of more than 7 µm. According to these results, during the sampling period of wet and cool months, the number of particulate matters with a diameter of fewer than 3.3 µm was recorded at about 46% and for particulate matters with a diameter of more than 11 µm up to 38 %. Sampling results for particle distribution test in the dry and hot months of the sampling period, the highest number of particles with a diameter of fewer than 0.4 µm was recorded at about 19.2±18.5 µg/m^3 and the lowest at about 14.6±8 µg/m^3. Also, during the cold and wet months, especially in winter, with the occurrence of temperature inversion, the maximum value was about 17.8±5.2 µg/m^3 and the lowest value was about 10.2±4.1 µg/m^3. Differences in the distribution of atmospheric particles for large particles (larger than 2.5 µm) are seen in both the dry and wet seasons. This difference gradually decreases toward fine particles (smaller than 1 µm). Atmospheric particles collected in this area are mostly affected by the entry of pollutants from moving sources in the western and southwestern areas of the study area. Coarse particle concentrations in this region are mostly influenced by fixed pollutant sources located in the southern and southwestern regions of the region. The results show that most of the coarse particles collected in the dry season for this region are produced from fixed and mobile sources. The activity of mining factories, heavy vehicles, production and conversion factories, as well as burning of agricultural waste are the sources of suspended particles in this region. Also in the wet season, in addition to fixed sources, a significant volume of particles collected at this station is produced by moving sources, especially light and heavy motor vehicles. In the Hakimiyeh, during the dry months, especially in late summer and early fall, due to strong winds and local storms, more than 53% of the particles collected in the particle distribution test had a diameter of more than 7 µm. While the results showed that 47% of the volume of collected particles had a diameter of fewer than 3.3 µm. According to these results, during the sampling period of wet and cool months, the number of particulate matters with a diameter of fewer than 3.3 µm was recorded at about 33% and for particulate matters with a diameter of more than 11 µm up to 30 %. Also, in the dry and hot months, the highest number of particles with a diameter of fewer than 0.4 µm was recorded at about 13.4±4.2 µg/m^3 and the lowest at about 11.6±2.1 µg/m^3. Also, during the cold and wet months, especially in winter, with the occurrence of temperature inversion, the maximum value was about 17.8±4.6 µg/m^3 and the lowest value was about 10.1±3 µg/m^3. The difference in the distribution of atmospheric particles in this region was different from other regions. The results show that there is a large difference between the particle distribution in the dry and wet seasons at this station. Due to the prevailing wind direction in the area, this station was located in the path of all particles entering the center of the area and therefore a significant volume of particles collected in this station had a size of less than 1 µm. Atmospheric particles collected in this area are mostly affected by the entry of pollutants from moving sources (Oroji et al., 2018b).

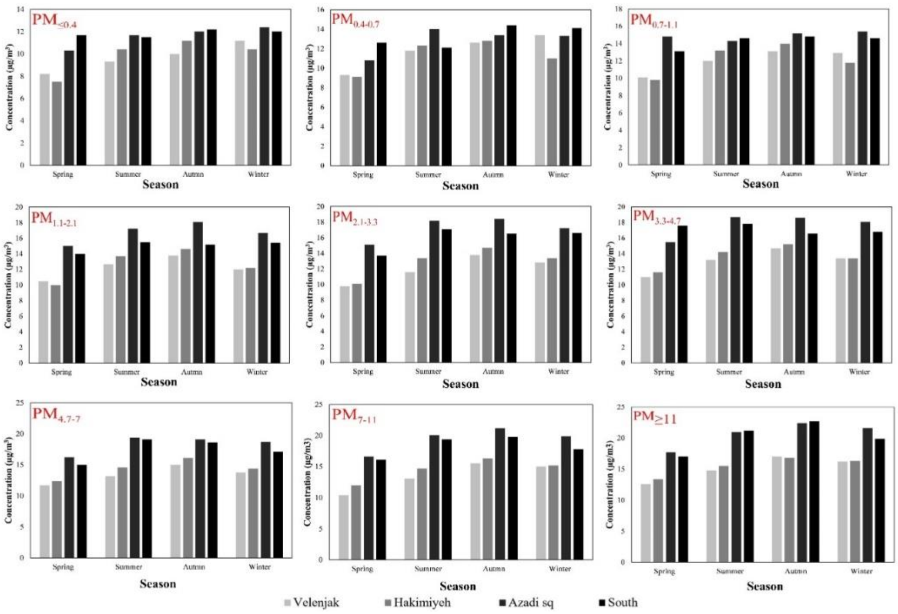

Fig. 3. Seasonal variations in particle distribution in the study area

The results of SEM analysis of the samples taken from the Velenjak station show that most of the particles are irregular, fibrous and spherical in shape as well as crystalline shapes.

Most of the elements in the samples taken in this area include chlorine, calcium, iron and potassium, which are found in combination with Zn. Cluster-like and shapeless structures rich in O and Zn, Mg, Fe, were observed in particulate matter with dimensions of 2.1 to 1.1 µm. In the samples of these areas, crystalline, spherical and amorphous shapes are seen in particles with a diameter larger than 4 µm with compounds rich in O, Fe, Si and Ti along with Mg and Al. The Si ratio of these compounds with Na and Al indicates feldspar and clay mineral compounds (Shao et al., 2007). Al and Si these compounds are in the form of aluminosilicates and can include kaolinite, illite and feldspar (Ostro et al., 2001). These results were similar to the findings of the research of Bhardwaj et al. (2017) in urban and rural areas of Delhi, India; Kushwaha et al. (2013) in the Allahabad region of India; Ramirez et al. 2014 in northern Mexico. Irregular, spherical, rodshaped and crystalline particulate matter are the characteristics of particles smaller than 3 micrometers collected from the characteristics of samples taken in the wet season. These samples contain compounds rich in Ca, and Zn along with Al, Ti and O. This situation indicates the origin of construction and urban transportation (Tiwari et al., 2014; Tiwari et al., 2015). Particulate matters with a diameter of 11 µm are also seen in clusters and sheets in the samples. Apart from K and Fe, particulate matter rich in Al, Mg and Na is also seen in the composition of particulate matter collected in the area for the entire sampling period. This trend indicates the origin of smoke for this group of particles (Pipal et al., 2001; Tasic et al., 2006). According to the results, it was found that the particulate matters collected in this area are more than moving sources in the city (Oroji et al., 2018b). The results of SEM analysis of the samples taken from the Hakimiyeh station show that most of the particles are spherical and fibrous. Most of the elements in the samples taken in this area include calcium, iron and potassium, which are found in combination with Ti. Amorphous structures rich in Si and Fe, Mg, Na, were observed in particulate matter smaller than 0.4 µm. In the samples of these areas, spherical and amorphous particles are seen in particles with a diameter greater than 4 µm with compounds rich in K, Mg, Zn and Ti along with Si and Al. The ratio of Al and Na of these compounds with Si indicates feldspar and clay mineral compounds (Shao et al., 2007). Al and in this Si these compounds were in the form of aluminosilicates. Particulate matter with irregular, rod-shaped and crystalline shapes were characteristic of particles smaller than 0.4 µm collected from the characteristics of samples taken in the dry season. These samples contain compounds rich in Ca, and Zn along with Al, Ti and O. This situation indicates the origin of construction and urban transportation (Tiwari et al., 2014; Tiwari et al., 2015). Particulate matters with a diameter of 11 µm are also seen in clusters and sheets in the samples. Apart from Cl and Ca. Al and Na-rich particulate matter are also seen in the composition of particulate matter collected in the area for the entire sampling period. This trend indicates the origin of the smoke for these particles. According to the results, it was found that the particulate matter collected in this area are more than moving sources in the city and particles produced by fixed sources southwest, west of Tehran. A case of the weight percentage of elements in PM collected at monitoring stations is shown in Figure 4.

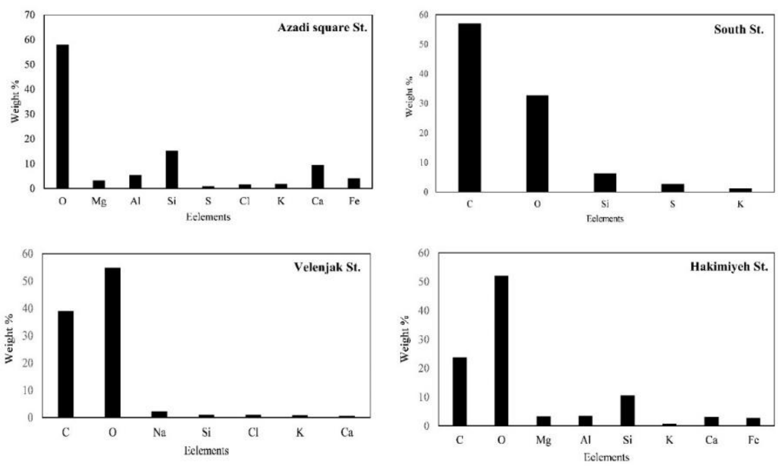

Fig. 4. Weight percentage of elements in PM collected at monitoring stations

In the southern and western parts of the study area (Azadi square and South stations), particles with dimensions larger than 7 µm are seen as spherical, clustered and irregular. The major constituents of these elements are Al, Fe, K Si, Ca, Mg, Ti and O. Calcium in these compounds was in the form of calcium carbonate corresponding to the $CaCO_3$ phase (Ostro et al., 2001; Ramos et al., 2009; Oroji et al., 2018a) Also, Na in these compounds is of crustal origin which has been published from construction activities in the area (Rodríguez et al., 2009). The presence of Pb in some samples can be the source of fossil fuels. The results overlapped with research by Singh et al. (2014) in India. Rodriguez et al. (2009) consider irregular shapes as the result of accumulation and adhesion of fine particles during the coagulation process, which in the results of the present study and studies of Pipal et al. (2011); Tiwari et al. (2015) have also been seen. During the cold seasons in the region and the increase in the volume of pollutants due to fossil fuel consumption and increased intra-city vehicle traffic, the composition of particles changes and becomes rich in human elements and compounds such as soot and metals such as Pb. The presence of clusters and amorphous structures rich in O, Zn, Mg Fe, K, Si, Na and Na in particles smaller than 3 µm and compounds rich in Ti, Mg and Pb were characteristic of particles larger than 3 µm. These findings were consistent with the results of the research of Soleimanian et al. (2019) and Jajarmi et al. (2019). Also, calcium-containing compounds in the $CaCO_3$ phase and sodium-rich particles with crustal origin are other characteristics of the samples taken at these two stations (Ostro et al., 2001; Ramos et al., 2009; Rodriguez et al., 2009). Overall, the results of the SEM study indicate that particles in the city atmosphere have both internal and external sources. Manufacturing industries workshops and transportation systems large and small, which have a large share in fossil fuel consumption, are studied as major domestic sources of particulate emissions in the atmosphere of the region. On the other hand, natural storms, local dust phenomena, biomass burning, as well as sand factories are considered major sources of emissions of foreign atmospheric particles in the region. These particles are displaced, removed and resuspended under the influence of environmental variables in the region. The size of the collected particles also varied and ranged from nanometers to several tens of micrometers. Smaller particles accumulate in the atmosphere due to collisions with other particles, forming larger particles (Papastefanou, 2008). As the particle dimensions grow, their deposition and deposition conditions are provided. Particles with irregular and amorphous shapes are of internal origin and these particles mainly include particles produced from mobile sources (Transportation), industry and fossil fuel consumption. After suspension in the atmosphere, these particles collide with surfaces form larger dimensions and precipitate cumulatively (Geng et al., 2011; Zhai et al., 2012). While particles with regular and mostly spherical shapes are of organic origin and are caused by biomass burning in the environment (Geng et al., 2011; Campos-Ramos, 2009). According to the results of other studies in this study, more fine particles are emitted during fuel combustion processes by industry and urban transportation, and larger particles during human activities such as dust produced on roads by vehicles, construction and Industries are produced and disseminated (Oroji et al., 2021; Viana et al., 2005). Figure 5, showed images of Scanning Electron Microscope (SEM) of particulate matters in sampling stations (Velenjak St. (1 and 2); Hakimiyeh St. (3 and 4); Azadi square St. (5 and 6); South St. (7 and 8)).

4. Conclusion

The results of air pollution in the Tehran metropolis show that the source of pollution in the region is mostly by moving sources such as motor vehicles and in the next stage by fixed sources such as manufacturing industries and sand mines. Among these pollutants, local storms increase the particle concentration in some months of the year. This increase in concentration in September and October was more than other times. Also, the stable condition of the atmosphere in late fall and especially the wet and cold months of the year was another reason for the increase in particle concentration in the region. The results show that the management of motor vehicles is the largest factor in the production of particulate matter in the region. Management of this section can significantly reduce the concentration of atmospheric particles. The use of new doors and windows and the use of proper mechanical ventilation can prevent a significant number of particles from penetrating into the building. Another way to reduce the volume of internal particles is not to use natural ventilation on polluted days. Opening the window on polluted days has greatly increased the concentration of particles inside. The use of indoor air purifiers can reduce the concentration of particulate matter inside the building.

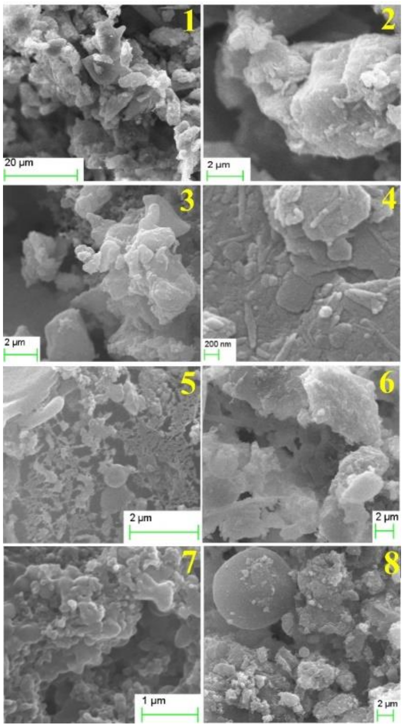

Fig. 5. Sample images of the particulate matters in sampling stations

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