Concentration of Particulate Matter below 10 and 2.5 Micron in air of Shiraz, Iran

ARMIN, MASHAYEKHAN; *MEHDI, SHAYEGH

Department of Environment, Yazd Branch, Islamic Azad University, Yazd, Iran. Email:
* Corresponding author Email: mashaykhan@gmail.com

ABSTRACT: According to the United Nations Environment Programme, particulate matter is the most important air pollutant in large cities around the world, released from many sources into the air. Since one of the main causes of air pollution in Shiraz is also particulate matter, monitoring the particles is necessary to develop control programs; therefore the aim of this study was to measure the concentration of particulate matter less than 10 and 2.5micron in air of Shiraz and compare same with EPA and National Standards. In this study, 45 stations were selected and sampling was performed in mornings and afternoons using Dust trak device. So during three sampling months (June, July and August), 90 samples for $PM_{2.5}$ (45 in morningd and 45 in afternoons) and 90 samples for PM_{10} (45 in mornings and 45 in afternoons) and a total of 180 samples were taken. During the sampling for PM_{10}, July with an average of $17.1 \mu g/m^3$ was the spottiest month and August with an average of $13 \mu g/m^3$ was the cleanest month. Also for $PM_{2.5}$, July with an average of $11 \mu g/m^3$ was the spottiest month and August with an average of $8.67 \mu g/m^3$ was the cleanest month. Results showed that the concentration of $PM_{2.5}$ and PM_{10} was less than standards in most cases.

Uncontrolled expansions of cities, together with the rapid economic development and consequently increased energy consumption have caused many environmental problems for inhabitants. Air pollution in cities is one of the most important of these problems, which is always a permanent and serious threat to the health of the communities as well as the environment. The effects of air pollution on human health have been of interest to researchers and public for decades. While Air pollution control programs have been used since the early decades of the twentieth century in many developed industrial countries in order to maintain human health and to prevent environmental degradation, air pollution situation in the developing countries is deteriorating (Jamshidi *et al*., 2005). Today, the issue of air pollution from the social, economic, political and technical point of view is the subject that has a special place in the world and one of the issues raised in this area is to prevent the increase of this pollution and find the causes and factors behind it. In addition, pollutants and particulate matter such as $PM_{2.5}$ and PM_{10} are the main causes of air pollution (Azizifar *et al*., 2011). In different times, different aspects of pollution have been investigated.

On a small scale, local pollution that causes the effects of simple disturbances to dangerous and latent illnesses is under consideration and issues such as depletion of ozone layer, acid rain and Global warming are being discussed in the global context. The sources of air pollution at the beginning of the industrial revolution were mainly industries and coal consumption and in 21st century, transportation is the reason of air pollution in cities. Fossil fuels consumption for transportation and the use of raw materials and manufactured products for industrial processes are the major causes of anthropogenic pollution (Hatami *et al*., 2012). According to the United Nations Environment Programme, particulate matter is the most important air pollutant in large cities around the world, released from many sources into the air. The dust that spreads from the ground into the air by wind together with dust from forest fires and volcanoes, viruses, bacteria and pollen are considered as natural sources of particulate matter, while un-natural sources include combustion of fuel, particles from various processes in industries, particles from crushing and rubbing materials, traffic and vehicles. According to World Health Organization, the mortality rate increases by 1 to 3% per an increase of 10 $\mu g/m^3$ of particulate matter (Jamshidi *et al*., 2005). These materials as a branch of pollutants are very diverse and complex and like their concentration in air, their particle size and chemical composition are also important (Afyuni and Erfanmanesh, 2008). Scientific studies conducted over the past two decades have shown that particulate matter is important from the view point of public health. The World Health

* Corresponding author Email: mashaykhan@gmail.com

Organization has estimated that 500,000 people per year die of exposure to airborne particulate matter in the open air. Particulate matter increases the risk of respiratory death, affects the function of the lungs, exacerbates asthma and causes other respiratory symptoms such as coughing and bronchitis, while these particles also increase the risk of other respiratory diseases. Exposure to Air pollution caused by particulate matter causes spontaneous heart reactions such as increased heart rate, reduced cardiac flexibility and increased cardiac arrhythmias. Among other effects of particulate matter are global warming, degradation of properties and effects on plants (Lily *et al.*, 2009).

City of Shiraz, the capital city of Fars province, has a length of 40 km and a width between 15 to 30 km with an area of 1268 km^2 and a rectangle shape and is geographically located in the southwest of Iran in the central part of Fars province. The geographical coordinates of Shiraz are: 29° 36´ N and 52° 32´ E with an elevation ranges between 1480-1670 m in different parts of the city. This city has a Mediterranean climate. The average annual temperature is 18 °C and the annual rainfall is 337.8 mm. The total population of Shiraz in 2011 was 1,460,665 and including the population living in the suburbs reaches 1,700, 687. Nowadays, Shiraz is called Electronic Center of Iran. Currently, there are about 40 major active industries in the city. Manufacturing industries in Shiraz have a very small contribution to the air pollution due to the accurate control of activities of these industries. However, the main factor creating particulate matter into the air of Shiraz is related to traffic and vehicles, which its volume is increasing every day. Regarding the specific topographical and climate conditions, traveling over 500,000 vehicles in this city as one of the seven major polluted cities in Iran is the source of these particles and other pollutants. A large part of this pollution is due to the poor performance of vehicles' engine.

Since one of the main causes of air pollution in Shiraz is particulate matter, monitoring of these particles and the continuous determination of air quality in order to develop control programs is necessary; therefore the aim of this study was to measure the concentration of airborne particulate matter and to compare them with the standards.

MATERIALS AND METHODS

This study was a descriptive-cross sectional one in Shiraz during June, July and August 2015. Sampling was done in mornings and afternoons based on EPA guidelines for particulate matter. In this study, 45 stations were selected for sampling. Thus, during the sampling period, 90 samples were taken for PM$_{2.5}$ (45 in mornings and 45 in afternoons) and 90 samples for PM$_{10}$ (45 in mornings and 45 in afternoons) and a total of 180 samples were taken. The following statistical relationship known as the Cochran formula was used to determine the sampling points:

$$n = \frac{Z^2\ pq}{d^2} \qquad (1)$$

Where n = sample size or number of points; Z^2 = a constant value that depends on the confidence interval and the error level, and is equal to 1.96; q = p = ratio of observations = 0.5; and d = confidence level or desirable probability = 1.0. Finally, 45 stations were selected for sampling after some modifications.

To measure the concentration of particulate matter (PM$_{10}$ and PM$_{2.5}$), sampling device of Dust Trak model 85100 (TSI Co., Ltd., USA) was used. Using this device, the average, maximum and minimum values were calculated in mg/m3 and after the sampling period, these values were converted to μg/m3 for statistical analysis by computer. SPSS and Excel programs were used for statistical analysis of particles' concentration and drawing charts and tables.

RESULTS AND DISCUSSION

The maximum and minimum daily concentration of PM$_{10}$ was observed in June equal to 49 μg/m^3 and in June equal to 3μg/m^3, respectively. The maximum and minimum average of daily PM$_{10}$ concentration was observed in July equal to 1.17 μg/m^3 and in August equal to 13μg/m^3, respectively. The maximum and minimum daily concentration of PM$_{2.5}$ was related to July equal to 31μg/m^3 and in this month equal to 1 μg/m^3, respectively. The maximum and minimum average of daily PM$_{2.5}$ concentration was related to July equal to 11μg/m^3 and in August equal to 8.67μg/m^3, respectively.

According to graph 1 for June, the maximum and minimum average of PM$_{10}$ concentration was 25 and 6μg/m^3, respectively and for PM$_{2.5}$ concentration was 18 and 4μg/m^3, respectively. As it can be seen in graph 2 for July, the maximum and minimum average of PM$_{10}$ concentration was 30 and 11μg/m^3, respectively and for PM$_{2.5}$ concentration was 24 and 5μg/m^3, respectively. According to graph 3 for August, the maximum and minimum average of PM$_{10}$ concentration was 19 and 6μg/m^3, respectively and for PM$_{2.5}$ concentration was 16 and 5μg/m^3, respectively. The phenomenon of air pollution in urban and industrial areas is one of the most important environmental problems and threatens human health. Among these pollutants is particulate matter and the

mortality rate increases by 1 to 3% per an increase of 10 µg/m^3 of particulate matter (Hatami *et al*., 2012). The present study was conducted to determine the concentration and pollution of airborne particulate matter in Shiraz. To assess the status and extent of pollution, the measured concentrations can be compared with the reference and standard values, which were done in the current study. National and international standards are presented in tables 1 and 2 and then the results are mentioned:

Table 1: EPA standard for particulate matter at three time intervals

average of 24-hour PM$_{2.5}$ concentration	average of 24-hour PM$_{10}$ concentration	time	Standards
65	150	1997	EPA
35	150	2006	
35	150	2012	

Table 2: Clean Air (National) Standards for particulate matter at three time intervals

average of 24-hour PM$_{2.5}$ concentration	average of 24-hour PM$_{10}$ concentration	time	Standards
150	150	1388	National
30	90	1389	
25	50	1390	

Comparison of particulate matter concentrations with EPA and national standards showed that fortunately, the concentrations measured throughout the sampling period were less than the standards. The maximum daily concentration of PM$_{10}$ in June, July and August was less than the standard limit, while the maximum daily concentration of PM$_{2.5}$ in June and July was greater than the national standard in 2011 and then the national standard in 2010 and 2011, respectively. One of the most important causes of air pollution in large and densely populated cities is permanent atmospheric conditions, especially temperature inversion in winter. Since the study was conducted in June, July and August, i.e. in the spring and summer, it can explain the low concentration of particles in the aforementioned period. Dust storms and haze are other factors in increasing the particulate matter, which has occurred in the west, southwest and most recently in the center of Iran in recent years. These dust storms have been occurred in springs and summers just a few years ago, but nowadays they cover eight months of the year and in addition to the southwestern regions of the country, they have become widespread in most provinces of the country and metropolitan areas such as Tehran, Isfahan and Shiraz (Arfaeinia *et al*., 2014). Of course, there was no dust storm at the time of the current study; therefore, it can be considered another reason of low concentration of of particles in the study period. In a study conducted by Lily *et al*. (2009) in the central area of Tehran in the mornings and

evenings, they found that PM$_{10}$ concentrations measured during the whole sampling period were lower than the standard limit (According to the 1997 standard and the new 2006 standard of United States Environmental Protection Agency). According to the 1997 standard, the average measured concentrations of PM$_{2.5}$ were below the standard limits, while were more than 2006 standard. Results of Azizifar *et al*. (2011) also showed that the concentration of particulate matter was less than standard limit in most cases.

Table 3: Statistical description of airborne particulate matter in Shiraz

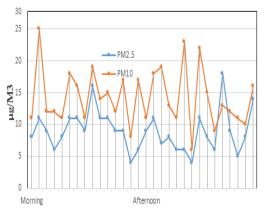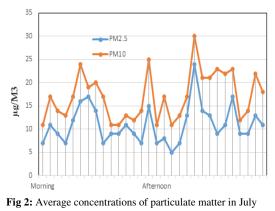| August	July	June		
13	17.1	14.23	average	PM$_{10}$
3.43	5.1	4.5	standard deviation	
25	44	49	maximum	
4	4	3	minimum	
8.67	11	8.97	average	PM$_{2.5}$
2.94	4.07	3.23	standard deviation	
22	31	29	maximum	
2	2	1	minimum	

Fig 1: Average concentrations of particulate matter in June

In general, it can be said that, during the sampling period for PM$_{10}$, July with an average of 1.17 µg/m^3 was the spottiest month and August with an average of 13µg/m^3 was the cleanest month. For PM$_{2.5}$, July with an average of 11µg/m^3 was the spottiest month and August with an average of 8.67µg/m^3 was the cleanest month. Azizifar *et al*. (2011) studied the concentration of particulate matter in the air of Qom during summer and autumn seasons. During the sampling period for PM$_{10}$, October with an average of 117µg/m^3 was the spottiest month and September with an average of 83µg/m^3 was the cleanest month. For PM$_{2.5}$, November with an average of 33µg/m^3 was the spottiest month and August, September and October with an average of 8µg/m^3 were the cleanest months. In addition, Houthuijs *et al*. (2001) measured the concentrations of PM$_{2.5}$ and PM$_{10}$ in Poland and results showed an increase in the concentration of PM$_{10}$ during the warm season from 18 to 45µg/m^3.

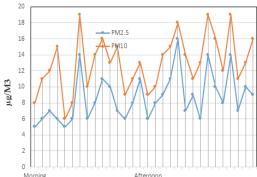**Fig 2:** Average concentrations of particulate matter in July

Fig 3: Average concentrations of particulate matter in August

In general, it has been found that there were high levels of particulate matter pollution probably due to local warming and season change in this region. In another study, Chaloulakou *et al*. (2003) measured the concentration of particulate matter (PM_{10} and $PM_{2.5}$) in the central part of Athens, Greece. Sampling site was selected close to a busy street with high traffic. Finally, the average of 24-hour PM_{10} concentration during the whole sampling period was 75.5µg/m^3 and the average concentration of $PM_{2.5}$ was 40.2µg/m$^{3.}$ Generally, it can be said that concentrations of $PM_{2.5}$ and PM_{10} were below the standard limit in most cases. Given the fact that this study was done in spring and summer seasons, it is suggested to routinely conduct such studies other seasons of the year to better understand the concentrations of these pollutants. It is also necessary that the Environmental Protection Agency consider the establishment of more fixed stations around the city to measure air pollutants (currently there are only two pollution control stations in Shiraz) and in addition to determining the size of air pollutant particles, similar investigations should be done to assess the type of particles and sources of air pollutants in Shira
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