



## Spatial and Temporal Variations of PM<sub>2.5</sub> Concentration and Air Quality in Isfahan City in 2016

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### ABSTRACT

**Introduction:** Particular Mineral (PM) less than 2.5 (PM<sub>2.5</sub>) is considered as one of the most important pollutants with major health effects. Therefore, the aim of this study was to evaluate spatial and temporal variations of PM<sub>2.5</sub> concentration and air quality in Isfahan city in 2016.

**Materials and Methods:** In this cross-sectional study, spatial and temporal changes in PM<sub>2.5</sub> concentrations were evaluated. The concentrations of PM<sub>2.5</sub> in 6 stations in Isfahan were measured. Data were analyzed using Excel and SPSS software.

**Results:** The results of the study showed that PM<sub>2.5</sub> concentrations were higher in warm months than in cold months, and also in the early days of the week's PM<sub>2.5</sub> concentrations were higher than the weekends. The total average of concentration of PM<sub>2.5</sub> in Isfahan was  $29.87 \pm 10.9 \mu\text{g}/\text{m}^3$ . City of Isfahan was healthy for 296 days and was in an unhealthy condition for 70 days. Furthermore, concentration of PM<sub>2.5</sub> was higher in the central parts of Isfahan.

**Conclusion:** The present study showed that in most days and months of the year, the concentration of PM<sub>2.5</sub> in Isfahan was higher than the standard limit of World Health Organization ( $25 \mu\text{g}/\text{m}^3$ ), and PM<sub>2.5</sub> concentrations mean in the cold season was higher than the hot season. It seems that the growth, control and the management of this pollutant is essential for citizens' health and reduction of unhealthy effects.

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### Introduction

Nowadays most of the major cities in the world face with environmental problems, which are at the top of the unfavorable condition of air quality. As a result, the exposure of citizens to polluted air in large cities is unavoidable<sup>1</sup>.

The term PM indicates particulates or droplets transmitted through the air, which can have production sources and variable sizes<sup>2</sup>. Smaller

particles (especially PM<sub>2.5</sub>) have a greater penetrating potential in the lungs and may even reach the alveolus region, therefore, they can have more short-term and long-term effects, such as early death, increased symptoms of respiratory diseases, decreased lung function and changes in the pulmonary tissues<sup>3, 4</sup>. The diverse health effects of PM depend on the chemical and physical compositions (mostly its chemical composition)<sup>5</sup>.

Smaller particles comprise a small amount of PM but they are much more important in terms of health <sup>6</sup> because their number is high and have more surface area and can carry toxic pollutants such as heavy metals and organic compounds. These particles are largely produced by combustion engines <sup>7</sup>.

The effects of PM include irritation of the throat and nose, severe lung injury, bronchitis and asthma, allergies, and early death. According to WHO estimations, the mortality rate increases by 1 to 3 percent for every 10 µg/m<sup>3</sup> of PM. Therefore, the need to study the properties of PM and how they propagate along with the determination of the origin of these particles in different cities is one of the priorities of the air pollution control program in urban areas <sup>8-11</sup>.

Several studies have been done to investigate the air pollution situation in cities. Concluded that long-term exposure to inhaled small particles, increases the risk of lung cancer and death from cardio-pulmonary complications <sup>10</sup>. A study conducted by Chan C in Beijing found that 86% of PM<sub>2.5</sub> samples were found to exceed the EPA <sup>12</sup>. Another study in Delhi showed that maximum PM<sub>2.5</sub>, PM<sub>10</sub> particles concentrations occur at peak traffic levels <sup>13</sup>.

Mokhtari et al., in a study evaluated the health effects of exposure to PM<sub>2.5</sub> in the air of the city of Isfahan. Their study showed that 8.1% of all non-randomized deaths recorded in the year 2013 in the city of Isfahan were due to PM<sub>2.5</sub> <sup>14</sup>.

In another study Jafari et al., distributed the air pollutants and estimated the mortality rate in Isfahan. The results of this study showed that 15.8% of the total mortalities in Isfahan were related to the pollutants which were studied in this study <sup>15</sup>.

Moreover, Farrokhzadeh et al., estimated the spatial distribution of lead, radon and PM<sub>10</sub> in Sepahan, Isfahan, using GIS. The results of the study indicated a high concentration of PM<sub>10</sub> in this region <sup>16</sup>.

In another study, Jafari et al. evaluated the spatial and seasonal variations of air quality indicators in Isfahan using GIS. The results of this

study showed that Ahmedabad station has the highest rate of pollution in Isfahan. The rate of air quality index in Isfahan was only in a healthy condition for 4 days <sup>17</sup>.

Azizfar et al., in a study determined the concentration of PM<sub>2.5</sub> and calculated the air quality index in Qom. The results of this study showed that PM<sub>2.5</sub> contaminated with the average of 33 µg/m<sup>3</sup>, was the most polluted and August, September and October with average of 8 µg/m<sup>3</sup> were the clean months, as well as the rate of air quality index in most cases was less than standard <sup>18</sup>.

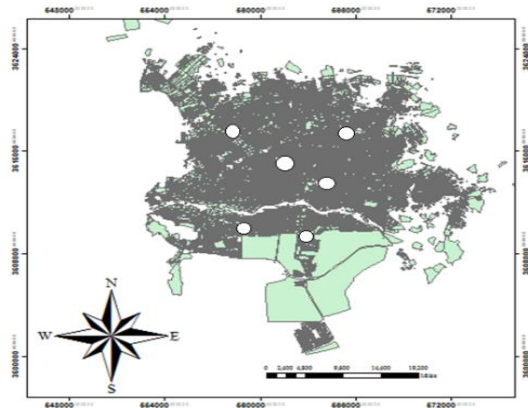
Gholampour, studied the concentration of PM in Tabriz, concluded that the concentration of PM<sub>2.5</sub> was 69% of the national standard (10 µg/m<sup>3</sup>) and the standard level (25 µg/m<sup>3</sup>) of EPA was 50% higher than the standard. The PM of Tabriz is often beyond the standard limits <sup>19</sup>.

The air pollution crisis has become a serious issue in some cities in Iran including Isfahan <sup>20</sup>. The city of Isfahan, with an area of about 106 km<sup>2</sup>, with a population of 2 millions, hundreds of thousands of cars, consumption of millions of liters of gasoline, polluting industries such as refineries, petrochemicals, industrial towns around, is one of the largest and the most polluted city in Iran <sup>21</sup>. Due to the importance of hygiene in PM in the air, present study addresses the temporal and spatial changes of PM of less than 2.5 (PM<sub>2.5</sub>) and air quality indicators in Isfahan in 2016. It is hoped that the results of this study could help policymakers design integrated air quality management and plan to prepare themselves to deal with the effects of this phenomenon.

## Materials and Methods

### The study area

City of Isfahan is located at 32 degrees and 38 minutes' north latitude and 51 degrees and 39 minutes' east longitude in central of Iran with an average elevation of 1570 meters above sea level on the Zayanderud coast. Figure 1 shows the studied area and air pollution sensing stations in Isfahan.



**Figure 1:** Geographical location of the city of Isfahan and the studied stations

### **Study Type and Time Range**

This descriptive-analytic, cross-sectional study was done in Isfahan in 2016. Due to the limited number of air pollution sensing stations, all the information obtained from all these centers is used. These include the stations of Ahmadabad square, University blvd, Rudaki street, Chaharbagh Khajoo, Kharrazi highway and Imam Hossein square. All of these stations are managed by Isfahan EPA. The measurement of PM<sub>2.5</sub> concentrations in the form of the hour is measured at pollution stations in the city of Isfahan. Data related to the meteorological variables including humidity and temperature was obtained from the meteorological organization.

### **Air Quality Index**

Air pollution index indicator was used to express air pollution in mass media. In 1999, the US Environmental Protection Agency (U.S.EPA) introduced the Air Quality Index (AQI) to express the severity of air pollution. The AQI has been shown to measure the effects of contaminated air on health. The index of this indicator, carbon monoxide, ozone, suspended particles, sulfur dioxide and nitrous oxide is converted to the air quality index using the formula. After the calculations, a number is obtained between 0-500 which is divided into different ranges and each range shows the amount of air pollution and provides the necessary advice.

### **Analysis**

Descriptive indicators of pollution were determined using mean and standard deviation. Charts were plotted using SPSS and Excel software.

In this study, the frequency of the desired variable (PM<sub>2.5</sub> contaminant concentration and air quality index proportional to it) was investigated based on the days of the week, season, and month.

### **Ethical issues**

This article is derived from the master thesis of Biostatistics, with the code of ethics "IR.MUI.REC. 1396.3.577".

### **Results**

According to the hourly measurement of PM<sub>2.5</sub> concentrations at air pollution monitoring stations in Isfahan, PM<sub>2.5</sub> concentrations are available at all stations for/ (during) 365 days of the year. The average concentration of PM<sub>2.5</sub> and its changes according to month in year 2016 are presented in the table. As table 1 shows, the maximum monthly PM<sub>2.5</sub> concentrations equal to 92.43 and 117.89  $\mu\text{g}/\text{m}^3$  recorded in October and February, and the minimum monthly PM<sub>2.5</sub> concentrations equal to 14.82 and 15.91  $\mu\text{g}/\text{m}^3$  recorded in March and November respectively. Besides, October and December with the average of 38.20 and 35.60  $\mu\text{g}/\text{m}^3$  have the highest monthly PM<sub>2.5</sub> concentrations respectively. In addition, April and March with a mean of 21.02 and 23.48  $\mu\text{g}/\text{m}^3$ , have the lowest PM<sub>2.5</sub> monthly concentrations respectively. The mean and standard deviation of total PM<sub>2.5</sub> concentrations over the 365 days is  $29.87 \pm 10.95 \mu\text{g}/\text{m}^3$  (Table 1).

Figure 2 shows the daily change in PM<sub>2.5</sub> concentrations. The highest daily concentration of PM<sub>2.5</sub> is equal to 117.89  $\mu\text{g}/\text{m}^3$  on 2nd October and the lowest daily PM<sub>2.5</sub> concentrations is equal to

14.82 on the 20th April. The total number of 242 days (66.3%) is higher than the daily standard.

Figure 3 shows seasonal mean PM<sub>2.5</sub> concentrations in the seasons of spring, summer, autumn and winter. The average PM<sub>2.5</sub> concentrations in these four seasons are 24.53 and 27.59, 34.03 and 33.54, respectively. The results indicate that winter has the highest and that the spring has the lowest concentration of PM<sub>2.5</sub>.

Figure 4 also provides a weekly overview of the PM<sub>2</sub> concentration. This chart shows that the highest concentration of PM<sub>2.5</sub>, is on Saturdays and Sundays and the lowest concentration of PM<sub>2.5</sub>, is on Fridays and Tuesdays.

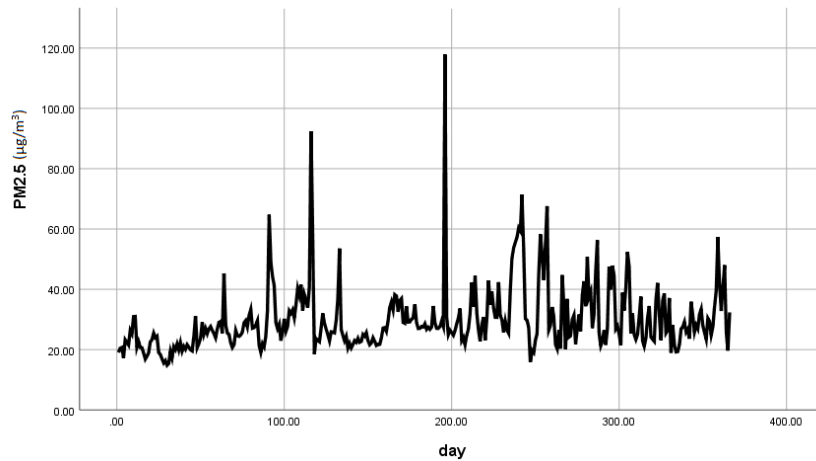
In table 2, the air quality of the city of Isfahan over the entire sampled days in 2016 is categorized according to AQI Index.

The results show that the weather conditions in Isfahan city (80%) were 299 days moderate (18%), 66 days in an unhealthy condition for sensitive groups, and (2%) 4 days in unhealthy conditions for all groups.

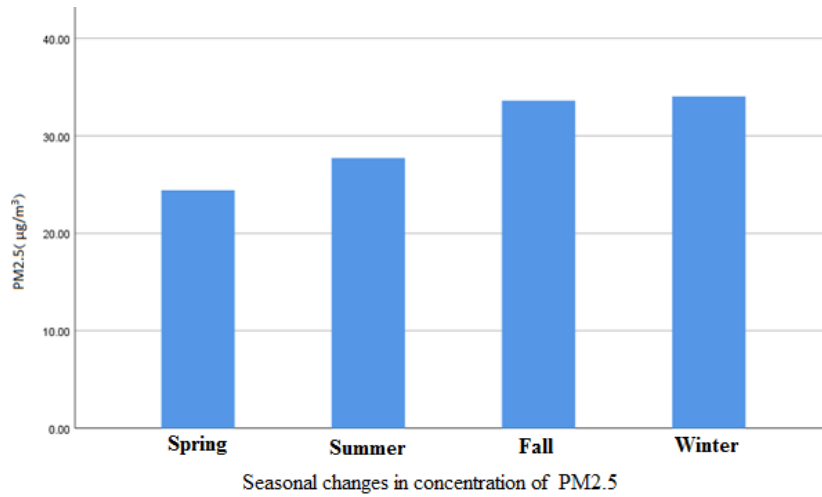
Also Table 3 shows monthly meteorological data. The results recorded show that the minimum temperature was in February and the maximum temperature was in July. Also, the minimum humidity level was recorded in December and maximum humidity level was recorded in September. The overall average temperature and humidity in Isfahan in 2016 was 15.60 degrees and 26.98 percent respectively. The dispersion map of PM<sub>2.5</sub> concentrations in Isfahan city was drawn in Figure 5 which shows that PM<sub>2.5</sub> concentrations in the center of Isfahan is more than other areas.

**Table 1:** The mean concentration of PM<sub>2.5</sub> in different months in Isfahan (2016)

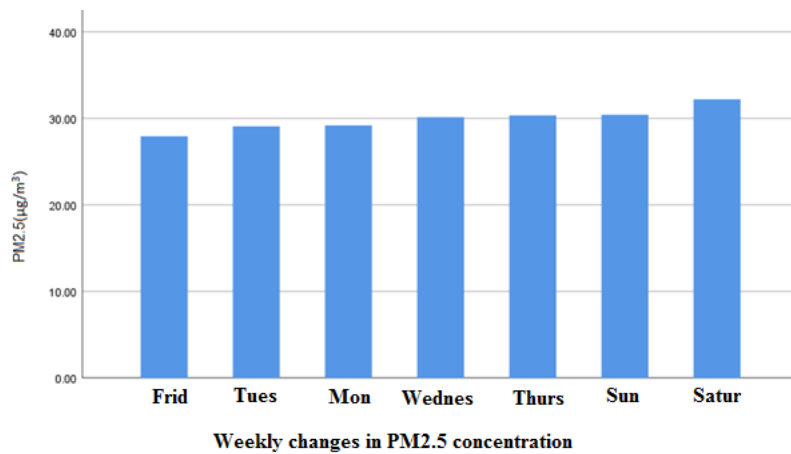
Month	Number of sample days	PM <sub>2.5</sub> ( µg/m <sup>3</sup> )			Standard Deviation
		Minimum	Maximum	Mean	
April	31	14.82	31.01	21.02	4.11
May	31	17.25	31.12	23.48	3.64
June	31	19.11	64.73	29.09	9.65
July	30	18.96	42.10	27.64	6.58
August	31	20.55	53.53	25.15	6.09
September	31	21.76	38.26	29.97	4.42
October	30	21.61	117.89	31.93	17
November	30	22.76	71.43	38.20	13.24
December	30	15.91	67.58	31.95	13
January	30	21.29	56.30	35.60	10.40
February	30	18.49	92.43	33.85	13.27
March	30	19.67	57.38	31.16	7.8
Total	365	14.82	117.89	29.87	10.95



**Figure 2:** Daily changes of PM<sub>2.5</sub> concentration during 365 days in Isfahan (2016)



**Figure 3:** Seasonal variation of PM<sub>2.5</sub> concentrations over 365 days in Isfahan (2016)



**Figure 4:** Weekly changes in PM<sub>2.5</sub> concentrations over 366 days in Isfahan (2016)

**Table 2:** Air quality classification in Isfahan during one year based on AQI (2016)

Air quality classification	AQI	PM <sub>2.5</sub>	Frequency (days)
Clean	0-50	0-12.5	0
Healthy	51-100	12.6-35	296
Unhealthy for sensitive groups	101-150	35.1-65.4	66
Unhealthy	151-200	65.5-150.4	4
Very Unhealthy	201-300	150.5-250.4	0
Dangerous	301-500	250.5-500	0
The number of days, in which the air quality was above the daily standard (25µg/m <sup>3</sup> )	-	-	242

**Table 3:** Monthly changes in humidity and temperature in Isfahan in 2016-2017

Month	Minimum		Maximum		Mean	
	Temperature(°C)	Humidity(%)	Temperature(°C)	Humidity(%)	Temperature(°C)	Humidity(%)
April	-2.4	11.22	30.8	40.06	16.5	23.22
May	5	18.9	36.5	55.03	22.3	34.52
June	11	23.3	40.2	64	27.5	42.56
July	12	26.2	40.6	72.9	28.4	48.27
August	7.4	22.6	38.4	72.4	26.4	45.24
September	4.6	22.9	36	73.4	22.3	45.39
October	0.6	18.1	31.2	58.3	16.1	36.03
November	-7.4	14.3	25.4	48.9	8.4	29.65
December	-10.4	6.3	21.4	24.3	3.7	13.72
January	-12	8.3	19.4	27.5	2.69	16.03
February	-13.6	9.3	17.2	28	3.30	16.35
March	-4	8.9	23.4	33.9	9.7	18.25
Total	-13.6	6.3	40.6	73.4	15.60	26.98

## Discussion

PM<sub>2.5</sub> pollutants are one of the main air pollutants in the city of Isfahan and has severe damaging effects on human health.

The results of this study showed that the highest mean of PM<sub>2.5</sub> concentrations in Isfahan was observed in cold months of the year; November, December and February, and the lowest mean of concentration in the warm months of the year was in April, May, and August.

Aziz far et al., in a study in Qom in 2011, studied the amount of PM in Qom in different months of the year, based on PM<sub>2.5</sub> concentration, December was the most polluted month with average 33 µg/m<sup>3</sup> and August, September and October were the most cleanest months with the average of 17 µg/m<sup>3</sup> .

The average concentration of PM in winter and autumn is higher than the average PM in the spring

and summer. Because of the presence of air inversion in the cold months of the year and the increased use of fossil fuels for fuel vehicles and heating of homes, concentration of pollutant particles in the city of Isfahan have been increased. It is consistent with the results of the Gholampour study in Tabriz and Mokhtari's study in Yazd<sup>23, 24</sup>.

While studies by Islami and colleagues in Kermanshah<sup>25</sup> and Ammar Luie et al<sup>26</sup> in Ilam reported the highest concentrations of PM in the summer, the reason for this is that the incidence of entrapment neighboring countries in the western part of the country. According to the results of this study and monthly calculation of PM<sub>2.5</sub> contamination and air quality index, it was found that Isfahan, in 2016, had 296 days of healthy and 70 days of unhealthy conditions. Mean and standard deviation of PM<sub>2.5</sub> concentrations in the whole period of 2016-2017 was 29.87±10.9 µg/m<sup>3</sup>.

Furthermore, the PM<sub>2.5</sub> concentration dispersion map shows that PM<sub>2.5</sub> concentrations in the central parts of the city of Isfahan have the highest concentrations. Mokhtari et al.<sup>14</sup> also studied the changes in PM<sub>2.5</sub> concentrations in Isfahan in 2013, which showed that the highest concentration of PM<sub>2.5</sub> concentrations in the center of Isfahan is consistent with the present study.

The reason is the high traffic volume and high population density in these areas. One of the most important factors in increasing of PM<sub>2.5</sub> concentration in urban environments is high traffic and vehicle combustion<sup>27</sup>. Chart of daily changes in PM<sub>2.5</sub> concentration showed that in most days of the year 2016, almost among the most stations of the city of Isfahan, it was higher than the WHO standard (25µg/m<sup>3</sup>). The results of the study by Gholampour et al. in Tabriz, which investigated the changes in PM in the city, showed that the amount of PM in Tabriz city is more than the WHO standard for most days of the year<sup>19</sup>. It can be said that increase in population, vehicles, tourism and industries around Isfahan is not reasonable.

### Conclusion

The present study showed that in most days and months of the year, the concentration of PM<sub>2.5</sub> in Isfahan was higher than the WHO (25 µg/m<sup>3</sup>), and the mean PM<sub>2.5</sub> concentrations in the cold seasons was higher than the mean PM<sub>2.5</sub> concentrations in the warm seasons. It seems that the growth, control and management of this pollutant are essential for the health of citizens and reduction of unhealthy effects.

### Limitations

Among the limitations of the study, a few number of pollutant stations in the city of Isfahan were noted. The most pollutant stations in the city of Isfahan were focused in the center of the city and in close proximity. Likewise, the lack of measurement of meteorological variables in each station is another limitation of this study.

### Suggestions

Finally, it is suggested that the results of this study should be used to monitor air pollution in Isfahan and other important contaminants of Isfahan in the future should be studied simultaneously using spatial-temporal models and its relation to diseases in Isfahan in future research should be investigated.

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### Conflict of interest

The author has no conflict of interest to declare.

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### References

1. Nevers ND. Air pollution control engineering: Waveland press; 2010.
2. Amir Beighi H, Ahmadi Asor A. Air health and methods to combat with its pollutants. Tehran, Iran: Andisheh Rafi Publications. 2008.
3. Shi Q. Particulate suspended matter PM<sub>10</sub> and cases of respiratory diseases in Shenyang China [Thesis]. Rotterdam, Netherlands: Institute for Housing and Urban Development Studies. 2011.
4. Kavooosi, Z. Ghaderi, A. Moeiniazadeh, M. Relationship between psychological wellbeing with job performance of nurses and compare them in intensive care and general units. Research in Clinical Psychology and Counseling. 2014; 4(1): 175-94.
5. Sharma M, Maloo S. Assessment of ambient air PM<sub>10</sub> and PM<sub>2.5</sub> and characterization of PM<sub>10</sub> in the city of Kanpur, India. Atmospheric Environment. 2005; 39(33): 6015-26.

6. Krzyzanowski M. WHO air quality guidelines for Europe. *J Toxicol Environ Health*. 2008; 71(1): 47-50.
7. WHO. Health aspects of air pollution: results from the WHO project "Systematic review of health aspects of air pollution in Europe", 2004.
8. WHO. Global Environment Monitoring System (GEMS): urban air pollution 1973-1980: World Health Organization; 1984.
9. Jamshidi A, Karimzadeh Shirazi K, Raygan Shirazi A. Particulate air pollution concentration in the city of Gachsaran, 2005-2006. *Armaghane Danesh*. 2007; 12(2): 89-97. [In Persian]
10. Pope CA, Burnett RT, Thun MJ, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA Netw Open*. 2002; 287(9): 1132-41.
11. Dehghani M, Saeedi AA, Zamanian Z. A study of the relationship between indoor and outdoor particle concentrations in Hafez Hospital in Shiraz, Iran. *Health System Research*. 2012; 8(7): 1348-55.
12. Chan C, Xu X, Li Y, et al. Characteristics of vertical profiles and sources of PM<sub>2.5</sub>, PM<sub>10</sub> and carbonaceous species in Beijing. *Atmospheric Environment*. 2005; 39(28): 5113-24.
13. Kumar P. Mass and number concentration of Respirable suspended PM (RSPM) on selected corridors of Delhi city. [Thesis], Delhi, Indian Institute of Technology; 2005.
14. Mokhtari M, Jafari N, Hajizadeh Y, et al. Estimation of health effects of PM<sub>2.5</sub> exposure using Air Q model in Isfahan during 2013. *Journal of Health and Development*. 2017; 6(1): 74-84.
15. Jafari N, Mohammadi A, Nemati S, et al. Spatial analysis and attributable mortality to outdoor air pollutants in Isfahan. *Journal of Community Health Research*. 2017; 2(4): 11-25.
16. Farrokhzadeh H, Jafari N, Sadeghi M, et al. Estimation of spatial distribution of PM<sub>10</sub>, lead, and radon concentrations in Sepahanshahr, Iran using Geographic Information System (GIS). *Journal of Mazandaran University of Medical Sciences*. 2018; 27(159): 84-96.
17. Jafari N, Ebrahimi A, Mohammadi A. Evaluation of seasonal and spatial variations of Air Quality Index and ambient air pollutants in Isfahan using Geographic Information System. *J Environ Health Sustain Dev*. 2017; 2(2): 261-70.
18. Azizifar M, Naddafi K, Mohammadian M, et al. Air Pollution Quality Index (AQI) and density of PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> in the air of Qom. *Qom University of Medical Sciences Journal*. 2011; 5(2): 59-63.
19. Gholampour A, Nabizadeh R, Hassanvand M, et al. Investigation of the ambient PM concentration changes and assessing its health impacts in Tabriz. *Iranian J Environ Health Sci Eng*. 2015; 7(4): 541-56.
20. Goudarzi G, Geravandi S, Forouzanmehr, et al. Cardiovascular and respiratory mortality attributed to ground-level ozone in Ahvaz, Iran. *Environmental monitoring and assessment*. 2015; 187(8): 487.
21. Geravandi S, Zalaghi E, Goudarzi G, et al. Exposure to PM of less than 10 microns and its effect on respiratory and cardiovascular diseases in Isfahan, Iran in 2013. *Health System Research*. 2016; 11(4): 725-30.
22. Azizifar M, Mohammadian M, Safdari M., Investigation of the air quality index and the concentration of suspended particles in the air of Qom. *Journal of Qom University of Medical Sciences*. 2011; 5(2): 59-63.
23. Gholampour A, Nabizadeh R, Naseri S, et al. Exposure and health impacts of outdoor PM in two urban and industrialized area of Tabriz, Iran. *J Environ Health Sci Eng*. 2014; 12(1): 27.
24. Mokhtari M, Miri M, Mohammadi A, et al. Assessment of air quality index and health impact of PM<sub>10</sub>, PM<sub>2.5</sub> and SO<sub>2</sub> in Yazd, Iran. *Journal of Mazandaran University of Medical Sciences*. 2015; 25(131): 14-23.
25. Eslami A, Atafar Z, Pirsaeheb M, et al. Trends of PM (PM<sub>10</sub>) concentration and related Air Quality Index (AQI) during 2005-2012 in Kermanshah, Iran. *Journal of Health in the Field*. 2017; 2(1): 150-61.
26. Amarloei A, Jonidi JA, Asilian MH, et al. The evaluation of PM<sub>10</sub>, PM<sub>2.5</sub> and PM<sub>1</sub> concentration during dust storm events in Ilam city, from Mar 2013 through Feb 2014. *Journal of Ilam*



University of Medical Sciences. 2014; 22(4): 240-59.  
27. Boldo E, Linares C, Lumbreras J, et al. Health

impact assessment of a reduction in ambient PM<sub>2.5</sub> levels in Spain. Environment International. 2011; 37(2): 342-8.