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Spatial and Temporal Variations of $PM_{2.5}$ Concentration and Air Quality in Isfahan City in 2016

Hossein Jadidi [1], Abbas Shahsavani [2], Behzad Mahaki [3, 4*]

[1] Student Research Committee, Department of Biostatistics, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran.
[2] Department of Environmental Health, School of Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[3] Department of Biostatistics, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran.
[4] Department of Biostatistics, School of Health, Kermanshah University of Medical Sciences, Kermanshah, Iran.

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***Corresponding Author:**
Behzad Mahaki

Email:
Behzad.Mahaki@gmail.com

Tel:
+989128077960

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ABSTRACT

Introduction: Particular Mineral (PM) less than 2.5 ($PM_{2.5}$) 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 $PM_{2.5}$ concentrate and air quality in Isfahan city in 2016**.**

Materials and Methods: In this cross-sectional study, spatial and temporal changes in $PM_{2.5}$ concentrations were evaluated. The concentrations of $PM_{2.5}$ in 6 stations in Isfahan were measured. Data were analyzed using Excel and SPSS software.

Results: The results of the study showed that $PM_{2.5}$ concentrations were higher in warm months than in cold months, and also in the early days of the week's $PM_{2.5}$ concentrations were higher than the weekends. The total average of concentration of $PM_{2.5}$ in Isfahan was 29.87 ± 10.9 μg/m^3. City of Isfahan was healthy for 296 days and was in an unhealthy condition for 70 days. Furthermore, concentration of $PM_{2.5}$ 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 $PM_{2.5}$ in Isfahan was higher than the standard limit of World Health Organization (25 μg/m^3), and $PM_{2.5}$ 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 [1].

The term PM indicates particulates or droplets transmitted through the air, which can have production sources and variable sizes [2]. Smaller particles (especially $PM_{2.5}$) 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 [3, 4]. The diverse health effects of PM depend on the chemical and physical compositions (mostly its chemical composition) [5].

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Smaller particles comprise a small amount of PM but they are much more important in terms of health [6] 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 [7].

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^3 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 [8-11].

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 [10]. A study conducted by Chan C in Beijing found that 86% of $PM_{2.5}$ samples were found to exceed the EPA[12]. Another study in Delhi showed that maximum $PM_{2.5}$, PM_{10} particles concentrations occur at peak traffic levels [13].

Mokhtari et al., in a study evaluated the health effects of exposure to $PM_{2.5}$ 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 $PM_{2.5}$ [14].

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 [15].

Moreover, Farrokhzadeh et al., estimated the spatial distribution of lead, radon and PM_{10} in Sepahan, Isfahan, using GIS. The results of the study indicated a high concentration of PM_{10} in this region [16].

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 [17].

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

Gholampour, studied the concentration of PM in Tabriz, concluded that the concentration of $PM_{2.5}$ was 69% of the national standard (10 μg/m^3) and the standard level (25 μg/m^3) of EPA was 50% higher than the standard. The PM of Tabriz is often beyond the standard limits [19].

The air pollution crisis has become a serious issue in some cities in Iran including Isfahan [20]. The city of Isfahan, with an area of about 106 km^2, 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 [21]. 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 ($PM_{2.5}$) 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.

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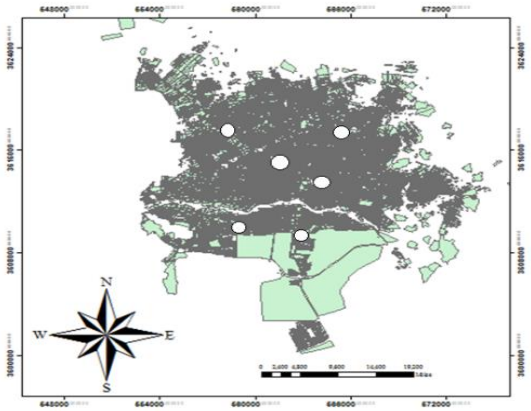

Figure 1: Geographical location of the city of Isfahan and the studied stations

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 $PM_{2.5}$ 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 ($PM_{2.5}$ 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 $PM_{2.5}$ concentrations at air pollution monitoring stations in Isfahan, $PM_{2.5}$ concentrations are available at all stations for/ (during) 365 days of the year. The average concentration of $PM_{2.5}$ and its changes according to month in year 2016 are presented in the table. As table 1 shows, the maximum monthly $PM_{2.5}$ concentrations equal to 92.43 and 117.89 $\mu g/m^3$ recorded in October rand February, and the minimum monthly $PM_{2.5}$ concentrations equal to 14.82 and 15.91 $\mu g/m^3$ recorded in March and November respectively. Besides, October and December with the average of 38.20 and 35.60 µg/m3 have the highest monthly $PM_{2.5}$ concentrations respectively. In addition, April and March with a mean of 21.02 and 23.48 µg/m3, have the lowest $PM_{2.5}$ monthly concentrations respectively. The mean and standard deviation of total $PM_{2.5}$ concentrations over the 365 days is 29.87 ± 10.95 $\mu g/m^3$ (Table 1).

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

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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 $PM_{2.5}$ concentrations in the seasons of spring, summer, autumn and winter. The average $PM_{2.5}$ 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 $PM_{2.5}$.

Figure 4 also provides a weekly overview of the PM_2 concentration. This chart shows that the highest concentration of $PM_{2.5}$ is on Saturdays and Sundays and the lowest concentration of $PM_{2.5}$ 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 $PM_{2.5}$ concentrations in Isfahan city was drawn in Figure 5 which shows that $PM_{2.5}$ concentrations in the center of Isfahan is more than other areas.

Table 1: The mean concentration of $PM_{2.5}$ in different months in Isfahan (2016)

Month	Number of sample days	$PM_{2.5}$ ($\mu g/m^3$)			
		Minimum	Maximum	Mean	Standard Deviation
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

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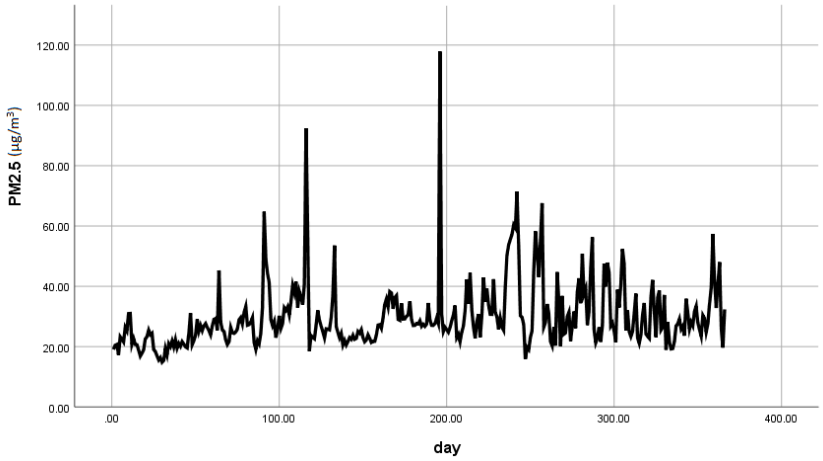

Figure 2: Daily changes of $PM_{2.5}$ concentration during 365 days in Isfahan (2016)

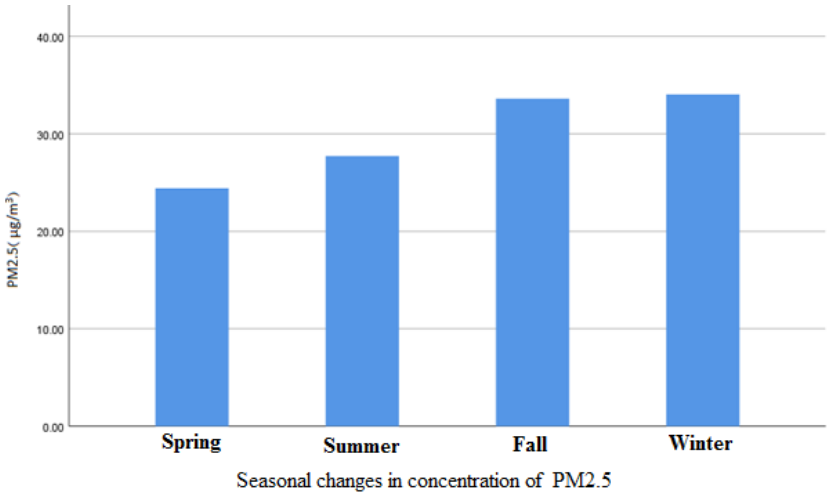

Figure 3: Seasonal variation of $PM_{2.5}$ concentrations over 365 days in Isfahan (2016)

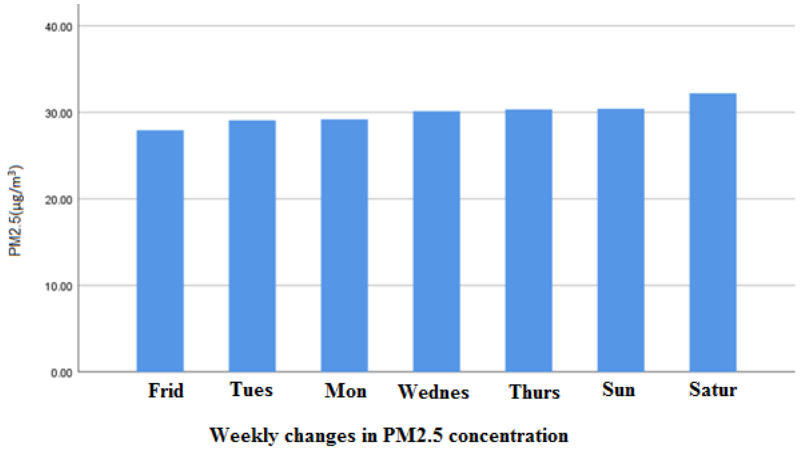

Figure 4: Weekly changes in $PM_{2.5}$ concentrations over 366 days in Isfahan (2016)

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

Air quality classification	AQI	$PM_{2.5}$	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^3)	-	-	242

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

	Minimum		Maximum		Mean	
Month	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

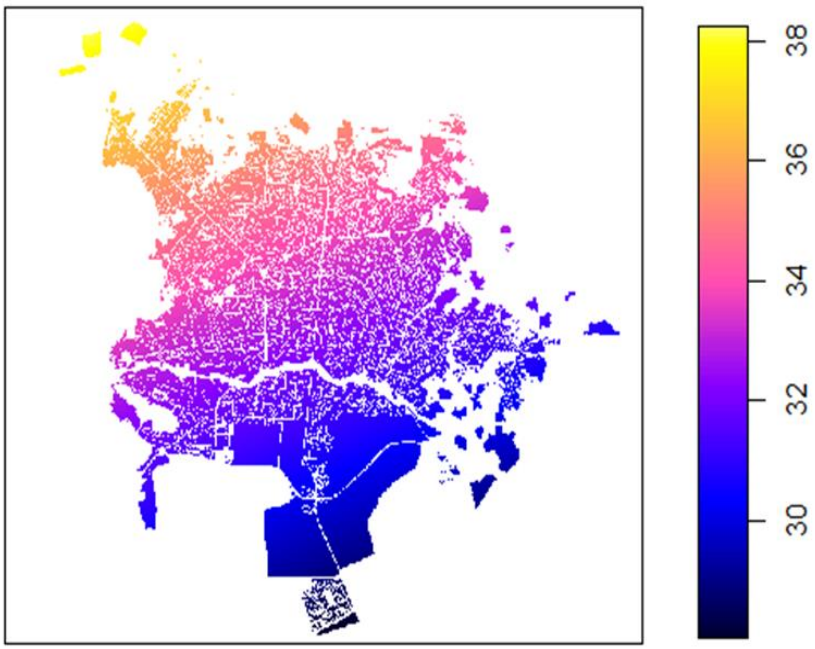

Figure 5: Distribution map of $PM_{2.5}$ in Isfahan in 2016

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Discussion

$PM_{2.5}$ 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 $PM_{2.5}$ 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 $PM_{2.5}$ concentration, December was the most polluted month with average 33 $\mu g/m^3$ and August, September and October were the most cleanest months with the average of 17 $\mu g/m^3$ [22].

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 [23, 24].

While studies by Islami and colleagues in Kermanshah [25] and Ammar Luie et al [26] 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 $PM_{2.5}$ 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 $PM_{2.5}$ concentrations in the whole period of 2016-2017 was 29.87 ± 10.9 $\mu g/m^3$.

Furthermore, the $PM_{2.5}$ concentration dispersion map shows that $PM_{2.5}$ concentrations in the central parts of the city of Isfahan have the highest concentrations. Mokhtari et al [14] also studied the changes in $PM_{2.5}$ concentrations in Isfahan in 2013, which showed that the highest concentration of $PM_{2.5}$ 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 $PM_{2.5}$ concentration in urban environments is high traffic and vehicle combustion [27]. Chart of daily changes in $PM_{2.5}$ 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 (25$\mu g/m^3$). 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 [19]. 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 $PM_{2.5}$ in Isfahan was higher than the WHO (25 $\mu g/m^3$), and the mean $PM_{2.5}$ concentrations in the cold seasons was higher than the mean $PM_{2.5}$ 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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