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PATTERNS OF ANNUAL FLUCTUATION OF DUST CONCENTRATIONS ALONG WITH METEOROLOGICAL PARAMETERS: A CASE STUDY IN QOM PROVINCE, CENTRAL IRAN

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ABSTRACT:

Introduction: Concentration of Particulate Matters were measured for a one-year monitoring period from July 2011 through June 2012 in Qom, a city located in western part of Dasht-e Kavir, central Iran.

Materials and Methods: Some related meteorological parameters comprising wind speed, wind direction, rainfall, relative humidity (RH), temperature and sunshine hours were evaluated.

Results: PM_{10}, $PM_{2.5}$, and PM_1 maximum values were recorded as 1160.67, 242.92, 90.82 µg/m^3, respectively. The maximum number of days with peak concentration of PM was reported from July through November 2012. Obtained results represented that the winds are prevailed from southern and south-eastern sides of Qom with 24.5% and 24% of consequences, respectively. The correlation between PM_{10} concentration and relative humidity was moderate and indirect (r = - 0.340).

Conclusions: The coordination between governmental administrations of central provinces engaged with dust events is suggested to mitigate the health-related impacts using a long term control program.

INTRODUCTION

Only a few studies reveal some beneficial aspects of desert dust on oceanic and terrestrial processes [1-3]. In contrast, during recent decades, concerns arose on some negative effects of dust events [4]. The side effects of dust events can be divided in two main categories consist of environmental and human impacts. Altering the atmosphere temperature through scattering or absorption the solar radiation [5], changing the atmosphere convectional activity [6], affecting the cloud formation [7] are among impacts on environment. The impacts of dust loading on humans are noticeable in different ways such

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as respiratory complaints, transporting the allergens, asthma incidences, some bacterial outbreaks and so on [8-12].

The Sahara and Sahel regions of North Africa are the most important sources of dust events [13]. The Badain Juran, Taklamakan, and Gobi deserts are recognized as the second important atmospheric dust source in the world which have been known as "Asian Dust" [14, 15]. Although, dust events originated from the Arabian Peninsula, Kuwait and southern parts of Iraq are not as severe as Saharan and Asian sources, but those impacts on the western part of Asia are noticeable and are titled as "the Middle east dust (MED) event"[4, 16]. During recent years, the southwestern, western and even central parts of Iran have been affected extensively from Middle east dust (MED) events. It was reported a total of 72 dusty days and 711 dust hours with PM_{10} concentration more than 250($\mu g/m^3$) during a six month study period from April through September 2010 [17]. Over 30 percent of Iran is covered by deserts which are located mainly in central part of country. Some of most important population centers in Iran, such as Qom, Isfahan, Kashan, Yazd, Kerman and semnan have been located in central desert margins. Studies regarding to atmospheric dust problems which have been done in central cities of Iran, mainly focused on anthropogenic sources and desert dust events and those origins almost have not been considered yet [18-23]. There is no obvious evident that the source of dust events occurred in central Iran is due to Middle east dust (MED) or inland deserts.

This study was aimed to evaluate the PM_{10}, $PM_{2.5}$, and PM_1 concentrations in Qom from July 2011 through June 2012. The main targets of the research were to indicate the main trend of dust concentrations in Qom ambient air, determining the patterns of annual fluctuation of dust concentrations, to illustrate the amounts of PM ratios, to define the statistical properties of the dust events, and to evaluate the impacts of meteorological situations on the PM concentration.

MATERIALS AND METHODS

Study area

Qom is a semi-arid region located in central part of Iran (34°38′N 50°52′E) beside Kavir desert, the central and greatest desert of Iran which is one of the major source of dust events in areas located in central part of country [21, 22] The city has a population of 1.1 million and a total surface area of 185km^2. Fig.1 illustrates the location of the city almost in central part of Iran.

The sampling place was located on the roof of the faculty of Health. The site was at near the center of urban area. The reason for selection this sampling place was to represent human exposure to particulate matter in the area. The station was installed 12 m above the ground to minimize the effects of natural features, like trees and hills, and man-made structures, on PM concentrations. The location of the sampling station is also determined in Fig.1.

Time schedule of measurements

Measurements were lasted one year, from July 2011 through June 2012 .The time distance between two consequent sampling were almost one week. On all weekly measurements, the amounts of PM_{10}, $PM_{2.5}$ and PM_1 were determined every 30 min during 24 h period as was mentioned in other study [17].

Meteorological data

Meteorological data were acquired from Qom Meteorological Organization. The temperature, wind direction, wind speed, relative humidity (RH), Rainfall and Sunshine hours in Qom were obtained data (gathered from Shokouhieh synoptic Meteorological station) that was also accessible in Iranian Meteorological Organization.

Sampling and instruments

A Grimm (model 1.177 aerosol spectrometer Grimm Aerosol Technik GmbH, Ainring, Germany) was used to measuring the concentrations of course, fine, and ultrafine particulate matter which can be represent with abbreviations PM_{10}

particulate matters (less than 10 µm), $PM_{2.5}$ particulate matters (less than 2.5 µm) and PM_1 particulate matters (less than 1 µm) respectively. The Grimm monitor is a non-gravimetric, low-volume sampler, which uses a light scattering technique to measure the number of particles in the air. The data was transferred online via RS-232 connection by the Grimm Windows Software on a computer for data presentation or analysis and be exported directly into Excel. The Grimm samplers operate on the principle of light scattering and the amount of light scattered from a particle of a given size depends on its refraction index. Several studies has evaluated the validity of instrument measurements regarding to correlation between its obtained data and standard methods based on gravimetric approaches [24, 25]. This instruments were tested at laboratory by running them in ambient air before the campaign.

Based on previous studies, Grimm model 1.177 has some benefits than similar real time measurement instruments like TEOM and DMA, such as; low maintenance needs, reliability during long-time run period without noticeable survey and its ability to measuring samples in time intervals varies from 1s to 60 min [26]. The device is consists of an optical particle counter (OPC) which is an instrument rely on real time measurement designed for particulate matter in the range 1.0 to 10.0 µm [17].

Data analysis

AQI values were computed based on PM_{10} and $PM_{2.5}$ concentrations, which were reported daily, during the study period [27]. The environmental data and measured concentrations of particulates (PM_{10} and $PM_{2.5}$) were analyzed using SPSS18.5. All graphs were plotted using Microsoft Excel 2007.

RESULTS AND DISCUSSION

Particulate matter concentrations

The PM_{10}, $PM_{2.5}$, and PM_1 concentrations were determined on 65 days from July 2011 through June 2012, almost according to weekly measurements. The sampling period was continuously lasted for one year. Tables 1, 2 and 3 depict the PM_{10}, $PM_{2.5}$, and PM_1 concentrations respectively, during 12 months of the study.

The overall average values of PM_{10}, $PM_{2.5}$, and PM_1 were calculated 207.3±136.7, 61.8 ± 38.1, and 21.3± 12.5 mg/m^3, respectively. Also, from

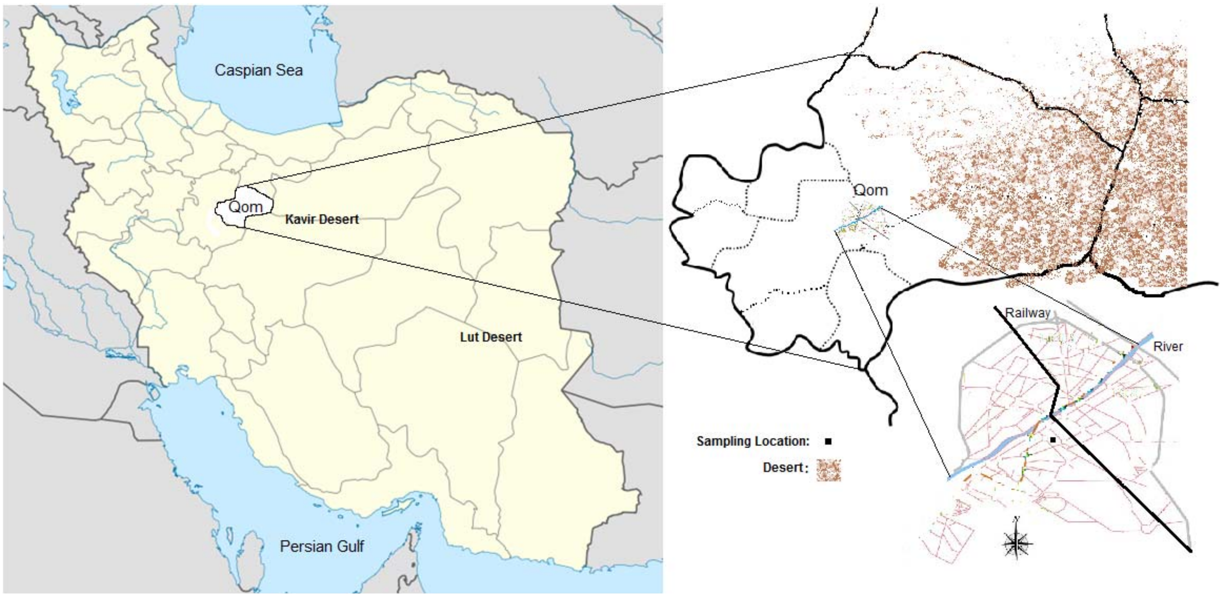

Fig. 1. Location of the study area and sampling place.

Table 1. Summary statistics of PM_{10} concentrations (μg/m^3).

Month	Average	Max	Min	Median	SD
Jul	336.4	591.3	166.3	355.5	±174.8
Aug	449.1	664.2	90.8	441.2	±226.2
Sep	465.2	1160.7	227.5	307.7	±392.5
Oct	234.8	417.7	116.9	203.9	±116.7
Nov	223.4	742.3	70.5	84.3	±291.7
Dec	172.7	247.2	93.3	174.2	±68.2
Jan	114.4	168.3	93.4	102.5	±31.0
Feb	151.4	240.5	58.4	150.4	±65.6
Mar	39.5	75.4	17.1	26.6	±26.4
Apr	74.1	261.0	17.9	28.6	±104.7
May	81.8	243.4	35.7	56.9	±65.8
Jun	144.9	256.9	51.6	145.8	±77.3
Overall	207.3	422.4	86.6	173.1	±136.7

Table 2. Summary statistics of $PM_{2.5}$ concentrations (μg/m^3).

Month	Average	Max	Min	Median	SD
Jul	109.7	152.5	62.1	123.3	±37.3
Aug	119.5	186.2	24.0	105.1	±66.8
Sep	108.3	242.9	48.1	63.6	±82.1
Oct	53.5	113.4	20.2	46.3	±35.2
Nov	68.8	192.6	29.1	41.2	±69.6
Dec	60.1	91.3	27.8	64.9	±30.0
Jan	47.6	81.0	23.4	36.5	±24.2
Feb	63.7	111.7	28.5	58.3	±30.9
Mar	17.2	35.3	4.8	15.7	±12.6
Apr	25.4	73.0	8.7	13.1	±26.9
May	26.9	51.4	14.9	22.9	±14.7
Jun	41.2	84.5	15.8	39.6	±27.2
Overall	61.8	118.0	25.6	52.5	±38.1

Table 3. Summary statistics of PM_1 concentrations (μg/m^3).

Month	Average	Max	Min	Median	SD
Jul	37.1	65.4	19.1	31.2	±19.7
Aug	34.8	70.3	7.7	31.3	±25.2
Sep	39.8	90.8	19.1	26.9	±29.7
Oct	16.7	37.3	7.1	12.8	±12.1

Table 3. Summary statistics of PM_1 concentrations (µg/m³).

Month	Average	Max	Min	Median	SD
Nov	30.8	68.3	17.3	22.4	±21.2
Dec	24.6	38.2	11.9	26.3	±11.3
Jan	15.9	28.3	8.6	12.3	±7.7
Feb	18.2	27.0	8.3	16.4	±7.5
Mar	9.3	16.1	2.1	8.1	±6.1
Apr	9.1	13.5	5.9	7.8	±3.1
May	8.6	10.9	6.4	7.8	±2.0
Jun	11.1	19.6	6.4	9.7	±5.0
Overall	21.3	40.5	10.0	17.7	±12.5

Tables 1, 2 and 3, the overall maximum amounts of PM_{10}, $PM_{2.5}$, and PM_1 were 422.4, 118, and 40.5 mg/m³), respectively.

The PM_{10} maximum concentration which occurred in 13 September 2011 was 1160 µg/m³. As shown in Table 1 and Fig. 2, during three consecutive months, from July through September 2011 which comprise summer season, the average monthly concentration of PM_{10} were higher than 250 µg/m³.

The overall average values and the overall maximum amounts of PM which were obtained from the experiment are similar to those found in previous study (regarding to measurement results of Afganistan Bagram and Khowst regions) [28]. But the average concentrations are less than those reported in Kuwait and Ahvaz areas in other studies [16, 17].

Occurring maximum dust events during summer which was reported in the study are in agreement with those reported by similar studies. These results can show that the role of the hot northwesterly wind that is dominant during the summer and transferred large amounts of dust from southern areas of Iraq. Also, High particle concentrations presented in this study have been happened during the Middle east dust storm [29, 30].

It was found that the concentration of 69.5 µg/m³ for the average $PM_{2.5}$ concentration in Ahvaz, southwestern of Iran [17, 31]. The average $PM_{2.5}$

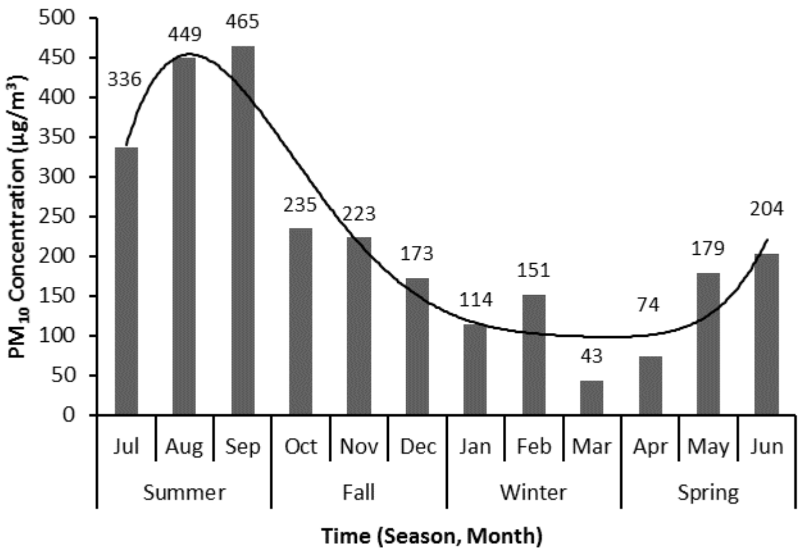

Fig. 2. PM_{10} average monthly concentrations from July 2011 through June 2012 in Qom ambient air, Iran.

concentration of 61.8 µg/m^3 was measured in this study which was comparable with the results of other studies. According to the results of another study that was focused on "Asian Dust" in china, 67.6 µg/m^3 was recorded for the average $PM_{2.5}$ concentration [31]. The acquired average $PM_{2.5}$ concentration was obviously higher than the findings of previous study in Tehran during 2007 and also, the results of PM_{10} and $PM_{2.5}$ compositions in California [20, 32].

In comparison with other study that was found average $PM_{2.5}$ concentrations of 216 µg/m^3 in December which was near fourth times more than our findings in December measurements which was represented in Table 2 [33].This significant discrepancy may be due to the effect of anthropogenic factors such as vehicles in Meng et al study.

PM ratios

Ratios of $PM_{2.5}/PM_{10}$, PM_1/PM_{10}, and $PM_1/PM_{2.5}$ can be illustrated based upon attributed trends along with the period of study in Qom as depicted in Fig.3. The ratio of $PM_{2.5}/PM_{10}$ was ranged from 0.2 to 0.6.

The average amounts of $PM_{2.5}/PM_{10}$ ratios during the summer, autumn, winter and spring were 0.29, 0.31, 0.41 and 0.37, respectively. As represents from Fig 3, similar trends can be observed for PM_1/PM_{10} and $PM_1/PM_{2.5}$. The entire annual ratios for PM_1/PM_{10} and $PM_1/PM_{2.5}$ were 0.15 and 0.38, respectively.

As can be recognized from Fig.3, a slow decrease was detected from July through October. In spite of this; a steady increasing trend is noticeable from October through March. Again, it can be shown a gradually decrease of $PM_{2.5}/PM_{10}$ ratio from March through June.

During a study regarding to PM_{10} and $PM_{2.5}$ Compositions in California's San Joaquin Valley, it was reported an obvious increase in $PM_{2.5}/PM_{10}$ ratio from October through February up to 0.85 and decreasing this ratio down to 0.09 from April through June [32]. The average ratio of $PM_{2.5}/PM_{10}$ for the entire period of study (entire year was reported 0.34) that is significantly more than 0.23 which was founded in previous study [17]. It may be due to the $PM_{2.5}/PM_{10}$ ratio determining only for six months, from April through September, and the ratios attributed to autumn and winter have not been considered. Whereas, in studies which was worked the entire year and the result of present study, it can be identified the higher ratios of $PM_{2.5}/PM_{10}$ or $PM_{2.5}$/TSP [31,34]. Findings reported in another research in Tehran, represented $PM_{2.5}/PM_{10}$ ratios 0.37, 0.15 and 0.15 for summer, autumn and winter, respectively. The results

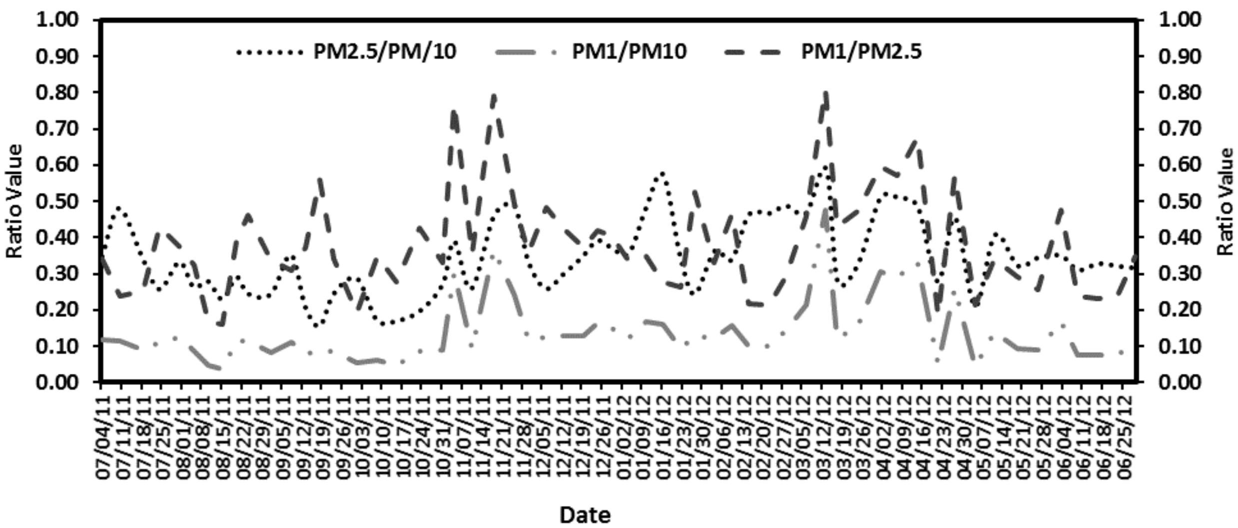

Fig.3. Trends in daily average $PM_{2.5}/PM_{10}$, PM_1/PM_{10}, and $PM_1/PM_{2.5}$ ratios during the study period in Qom.

of previous studies support the results obtained from the present study especially those reported for summer $PM_{2.5}/PM_{10}$ ratio. Obtaining higher ratios of $PM_{2.5}/PM_{10}$ in studies performed for entire year comparing with those only cover spring and summer months, probably may be due to the higher portion of fine fraction of particulate matters in wintertime (i.e., $PM_{2.5}$) because of various sources primarily release finer particles.

Meteorological parameters

As can be implied from Fig. 4, the wind rose of Qom during this study, represents that the southern (24.5% of consequences) and southeastern (24% of consequences) winds are the most frequent in this region, although the frequency of western (17% of consequences) and southwestern (17.5% of consequences) winds were also significant.

Fig.5 illustrates the PM_{10} rose of the study area during the sampling period. As can be inferred from Fig.5, the impact of southeastern winds on "dust evens" is noticeable.

The relationship between meteorological parameters and PM concentrations during the study period were also investigated. Meteorological parameters comprise; temperature, relative humidity, wind speed, rainfall and solar exposure (daily sunshine hours). Table 4 represents the results of Spearman correlation coefficient analysis for PM concentrations and meteorological parameters.

Fig.6 has illustrated obviously the trends of daily average relative humidity RH% and PM concentrations (μg/m^3) during the study period. Also, the direct relationship between PM concentrations (μg/m^3) and daily average temperatures (°C) are apparent in Fig.7.

Various studies have reported the Middle east dust (MDE) events which are originated from Kuwait, Arabian Peninsula [35-37] and southern part of Iraq [4, 38]. It was found that the Middle east dust MDE is the main source of dust events in Ahvaz [17].

From Figs.1 and 4, it seems that, because of the significant consequences of west and southwest winds, some dust events occurred in Qom during the study period may be attributed to Middle east dust MDE events. But findings illustrated in

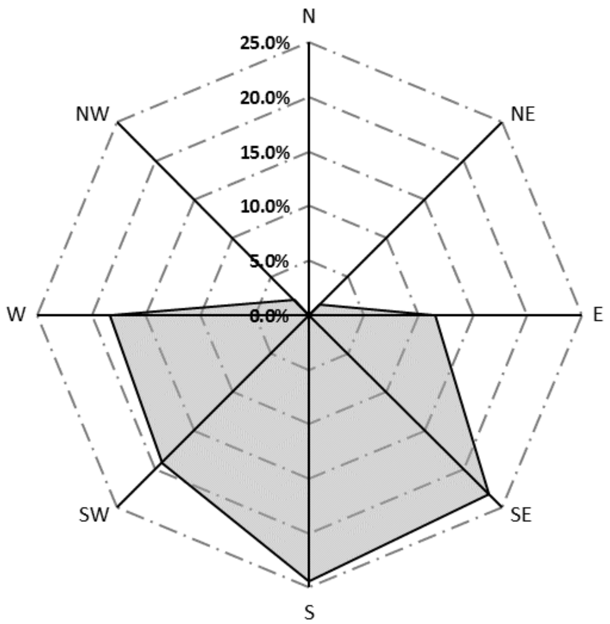

Fig.4. Windrose during the study period in Qom

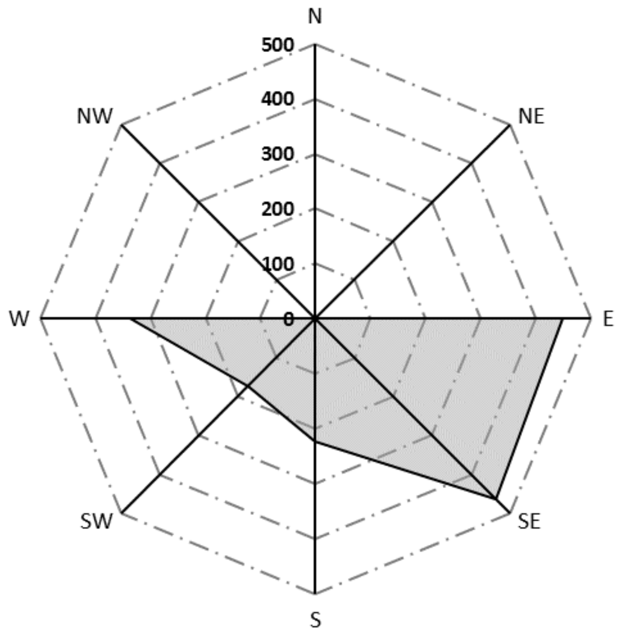

Fig.5. PM_{10} rose during the study period in Qom Values are according to (μg/m^3).

Table 4. Results of Spearman correlation coefficient analysis for PM concentrations and meteorological parameters

	PM_{10}		$PM_{2.5}$		PM_1	
	r[1]	P_{value}	r	P_{value}	r	P_{value}
WS[2]	0.018	0.894	0.101	0.451	-0.120	0.369
SE[3]	0.158	0.235	0.144	0.282	-0.024	0.856
RH[4]	-0.340	0.009	-0.368	0.005	-0.092	0.493
Temperature	0.452	0.000	0.400	0.002	0.216	0.103
Rainfall	-0.203	0.126	-0.140	0.295	-0.162	0.225

1. Correlation coefficient, 2. Wind speed, 3. Solar exposure, 4.Relative humidity

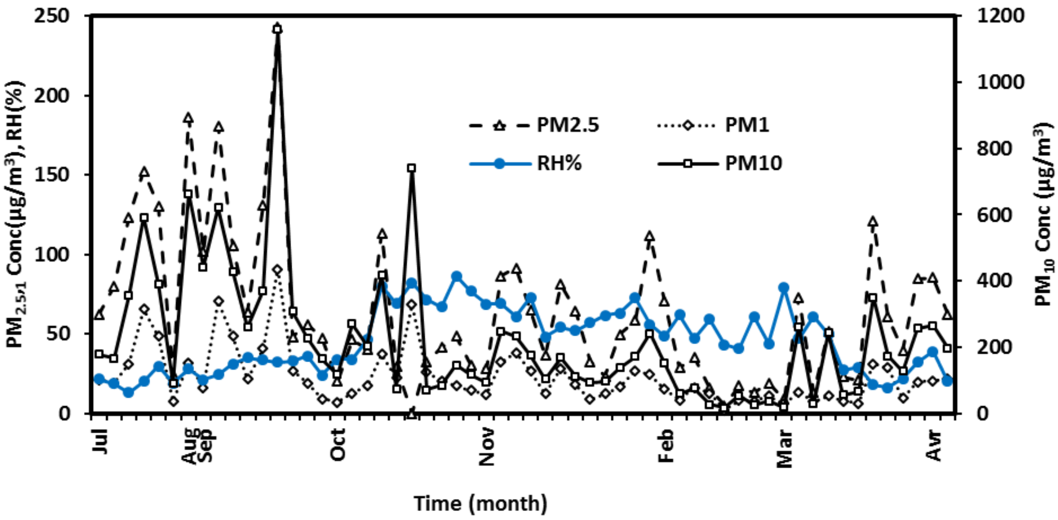

Fig. 6. Trends of daily average relative humidity (RH%) and PM concentrations (µg/m³) in Qom, from July 2011 through June 2012

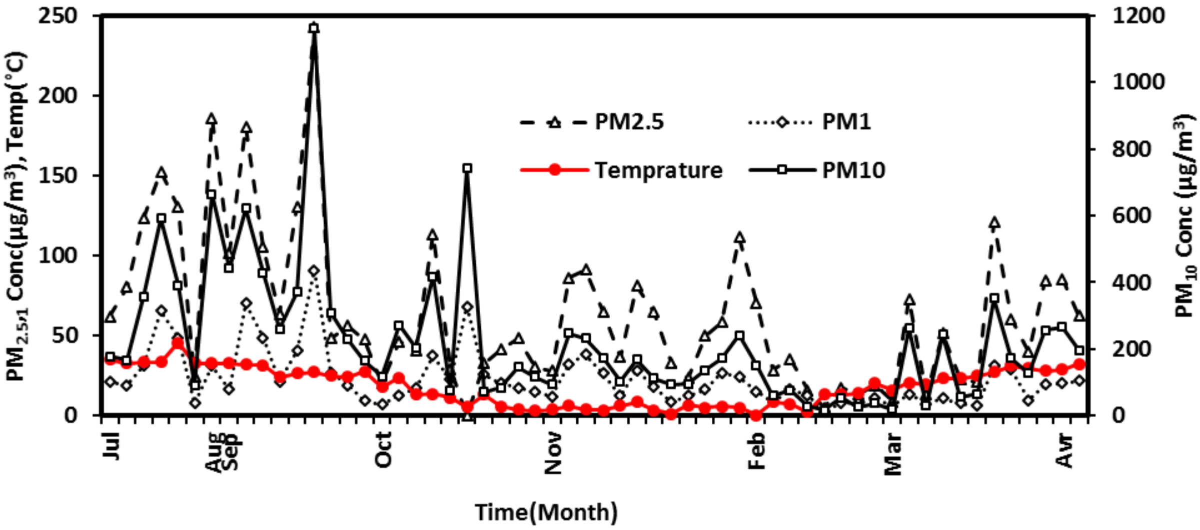

Fig. 7. Trends of daily average temperatures (°C) and PM concentrations (µg/m³) in Qom, from July 2011 through June 2012

Fig.5, also indicated that, the southern and southeastern winds have loaded the most portions of PM_{10} amounts.

So, it can be inferred that the central desert known as Kavir which is just located beside the city and extended from eastern to southeastern parts of Qom Fig.1. may be the principal origin of dust events. However, the results are in agreement with those studies performed in areas located in marginal parts of Iran central desert [21, 22].

As indicated in Table 4, regarding to PM_{10} concentration, only the relationship with relative humidity (RH% (P=0.009) and temperature (P = 0.00) was significant. Furthermore, the correlation between PM_{10} concentration and RH% was moderate and indirect (R=-0.340), but the correlation between PM_{10} concentration and temperature was reported moderate and direct (R=0.452). As also can be inferred from Table 4, for $PM_{2.5}$ concentration, only the relationship with temperature is significant (P = 0.002), with moderate direct correlation (R = 0.40) which can be inferred from Fig.8 Finally, according to Spearman correlation coefficient analysis, there were no significant relationships between meteorological parameters and PM_1 concentration that may represents the impact of man-made factors contributing to PM_1 emissions than the natural parameters [39].

Air quality index (AQI) attributed to PM_{10} and $PM_{2.5}$

Fig.8 illustrates the AQI values for PM_{10} concentrations in Qom which are consist of Daily reports from July 2011 through June 2012. Fig. 9 represents the AQI values for $PM_{2.5}$ concentrations. For $PM_{2.5}$, the highest AQI value was reported 296.

As shown from Fig.8, from July through November, five days with AQI PM_{10} up to 500 can be detected that means hazardous impacts on human health [27].

Fig.9 also depicted that unless 5 successive months from July through November, in the other days of study period, from December through June, (the AQI PM_{10} values more than 150 unhealthy for sensitive groups were not occurred).

The index values attributed to $PM_{2.5}$ was generally lower than those of PM_{10} but in more days it ranged between 100 and 150 which is unhealthy and according to USEPA: “may cause the aggravation of cardiovascular and respiratory diseases, increase premature mortality in sensitive groups, and increase hospital admissions for respiratory diseases in the general population”[27].

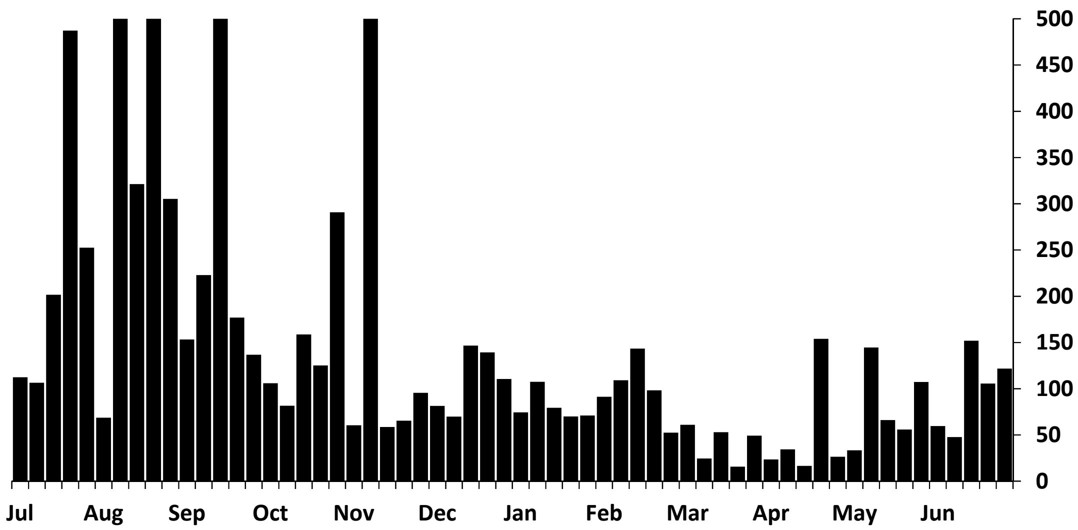

Fig. 8. AQI values for PM_{10} concentrations in Qom; Daily reports from July 2011 through June 2012

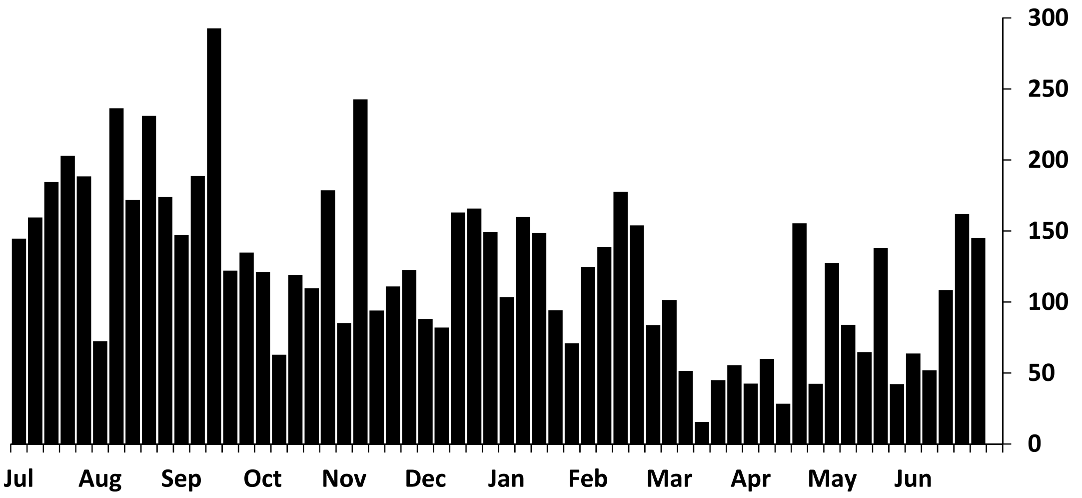

Fig.9. AQI values for $PM_{2.5}$ concentrations in Qom; Daily reports from July 2011 through June 2012.

CONCLUSIONS

The central desert of Iran, known as Kavir, which has been located beside Qom and extended from eastern to southeastern parts of the city, probably have more impact on dust events than Middle east dust (MED) events. High concentration of particulate matter may cause the aggravation of cardiovascular and respiratory diseases, increase premature mortality in sensitive groups, and increase hospital admissions for respiratory diseases in the general population. The study, also represents the importance of governmental coordination between provinces engaged with dust events regarding to side effects reduction in mid-term and long term scheduled process.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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ETHICAL CONSIDERATIONS

This study is original and has not been published elsewhere in any language. Also, the Authors are aware of publication ethics specifically related to authorship, dual submission, manipulation of figures, and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work.

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