Levels of PM10, PM2.5 and PM1 and Impacts of Meteorological Factors on Particle Matter Concentrations in Dust Events and Non-Dusty Days

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Abstract

Background: *The aim of study was to measure particle matter concentration (PM1, PM2.5 and PM10) during normal, semi-dust and dust-event days. The impacts of some meteorological factors on particle matter concentrations were also investigated.*
Methods: *Samples were collected by Grimm aerosol technik (GmbH model 1/108 Germany) from November 2011 to May 2012. Temperature, humidity, wind speed and UV index were obtaind from the website (www.Weather.ir).*
Results: *The concentration of particulate matter PM1, PM2.5, PM10 in dust event days was 10, 6 and 2 times higher than normal days, respectively. The highest concentration of particle matter was February in winter. There was significant relationship between the particulate matter concentration with temperature and wind speed (P<0.05).*
Conclusions: *The concentration of particulate matter affected by traffic, crowded, humidity and temperature. These factors increased particulate matter concentration specially when was with inversion.*

Keywords: Particulate matter, Dust event day, Ahvaz, Meteorological parameters.
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Introduction

Ahvaz, the capital city of the Khuzestan zone, is one of the main cities of Iran. It is located in a dry area in southwestern Iran in the Adjacency of Iraq, Saudi Arabia, and Kuwait, the main sources of dust events in the Middle East. The geographical site of Ahvaz is located at latitude 31°32, longitude 48°68 and 18 m above sea level.

The presence of large industrial plants, including the South Oil-rich Zones Company, has made Ahvaz into one of the main industrial centers of Iran, attracting many immigrants to Ahvaz.[1] In recent years; dust storms have added an anthropogenic source of air pollution to this city. Dust storm frequencies were 29, 33, 55, 45, and 17 in 2005, 2006, 2007, 2008, and 2009, respectively. In some cases, storms lasted for 48-72 h.[2]

According to previous studies, the other main source of desert dust is assumed to be the Arabian Peninsula, Iraq, Kuwait, and parts of Iran, which contribute significantly to the total dust particles in the Middle East.[3,4] Contact to ambient PM has been linked to adverse health effects. The accurate constituents of PM that cause illness and the mechanisms involved remain unidentified. Studies to determine the components or characteristics of PM that contribute to airway irritation and annoyance have been attempted.[5] Aerodynamic size fractions of PM have been studied, including coarse (PM10-2.5) and fine (PM2.5) varieties; the particulate matter is a compound mixture, typically divided in fractions on the basis of the particle size. Particulates with an aerodynamic diameter of <10 μm (PM10) can enter conductive airways and badly affect the respiratory organism.[6,7] Findings show that an increase of 10 mg/m3 in particulate air pollutant was associated with a 4%, 6%, and 8% increase in cardiopulmonary, lung disease, and mortality, respectively.[7] The main purpose of this study was to measure the concentration of particulate matters (PM1, PM2.5, and PM10) during normal and dust-event days. The impact of numerous meteorological factors on particle matter concentrations was also investigated.

Materials and Methods

In this project, attempts were made to measure particulate concentrations in Ahvaz city. Sampling was performed at traffic (Behdasht Ghadim), high traffic and joinery (Naderi), low traffic (Havashenasi), and residential (Mohit Zist) stations.
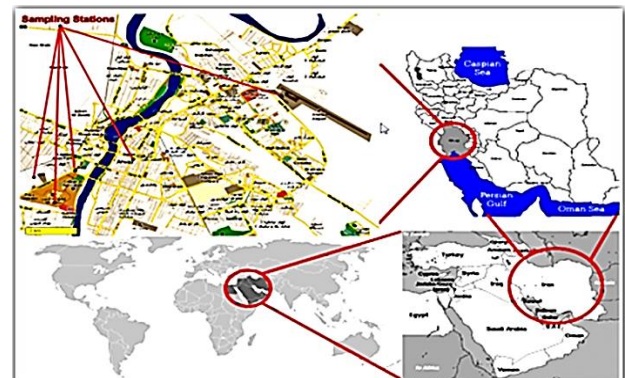

Figure 1. Location of the study area and sampling station, showing the nearby sources of dust storms

Air sampling was conducted for 7 months from November 2010 to March 2011 on normal and dusty days.

The concentrations of particulate matter (PM1, PM2.5, and PM10) were measured using a transportable Aerosol Spectrometer (Grimm Aerosol Technik GmbH, model 1.108, Germany).

The Grimm tool is an optical particle counter and is used to measure particulate matter ranging from 1.0 to 10.0 μm. Sampling was based on the EPA standard. In this study, we measured 1.5 to 2 m above the ground, representative of human respiratory height. Sampling location was 20 m away from the street and plants were at a distance of 20 m from and twice the height of obstacles.

Sampling was conducted twice daily, morning (9:00-12:00) and afternoon (14:00-17:00). Moreover, in dust-event days, sampling was performed in the early hours of the afternoon (13:00-14:00). In accordance with the EPA standard, air sampling was conducted once every 6 days; during dust events days, sampling was performed on the same day.

Simultaneously, the temperature, relative humidity, wind speed and direction, and UV index in Ahvaz were obtained from the Iranian Meteorological Organization website (www.weather.ir).

Data were analyzed using SPSS version 17 and statistical techniques including the Kolmogorov-Smirnov test (for normality), Pearson rank correlation coefficient and linear regression measure, to determine the relationship between meteorological parameters and concentration of particulate matter during normal and dust-event days.

Results

The concentrations of PM10, PM2.5, and PM1 were calculated at three climate conditions (normal, semi-dust events, and dust-event days) from November 2011 to May 2012. Table 1 presents the summary statistics for concentrations of PM at dissimilar sampling stations during this study. The average concentrations of PM10, PM2.5, and PM1 for the entire study period were 598.92, 114.8, and 34.5 μg/m3, respectively.

The average concentrations of PM10 for normal, semi-dust events, and dust-event days were 144, 416.4, and 1365.43 μg/m3, respectively; the consequent values for PM2.5 were 42, 83, and 238 μg/m3, respectively (Figure 2).

The averages of the PM10, PM2.5, and PM1 concentrations above the sampling period are presented in Figures 3 and 4.

The average PM concentrations for different months over the study period are shown in Figure 4.

It is clear from the figure that the peak mean and maximum values of the PM10, PM2.5, and PM1 were observed in February and March 2011, while the lowest average concentrations were measured in November and January. The highest average PM concentration was recorded at Naderi station, while mean PM concentrations were lowest at Havashenasi station (Table 2).

The average concentrations of the PM10, PM2.5, and PM1 at Naderi station were 804.2, 141.5, and 37.2, respectively; corresponding values for Havashenasi station were 490.7, 95.6, and 33, respectively (Figure 5).

Environmental parameters are one of the main factors contributing to the air pollution crisis. In this research, the impact of environmental factors on the particle concentration was examined. The results are discussed below. Environmental factors have an important influence on human life and other living organisms, and intensive environmental changes, such as humidity, temperature, air stability, inversion, sunlight, rainfall and atmospheric precipitation rate, days of the week, and

seasons of the year, impact the amount of pollutants, leading to crisis situations and health threatening conditions.[8]

The trend of changes in aerosol concentrations and environmental parameters is shown in Figure 6. The average of relative humidity was <45% and the range of temperature was between 2°C and 41°C, with a total average of approximately 18°C. The UV index has high volatility and its range was between 0 and 9, with a wind speed range of between 0 and 43 km/h, with an average of 12 km/h. Maximum temperature, relative humidity, and wind speed were measured in April, October, and February, respectively. According to the results of this research, the most severe dust storms in Ahvaz, owing to the occurrence of the minimum recorded temperature (2°C) and the highest wind speed (43 km/h), was in February. The concentration of PM10 particles was enhanced by the increase of humidity percent and wind speed and the decrease in temperature (Figure 6).

Pearson correlation coefficients for the concentration of suspended particles (μg/m3), temperature, relative humidity, UV index, and wind speed, in dust and normal situations, were determined. Correlation coefficients are presented in Table 3.
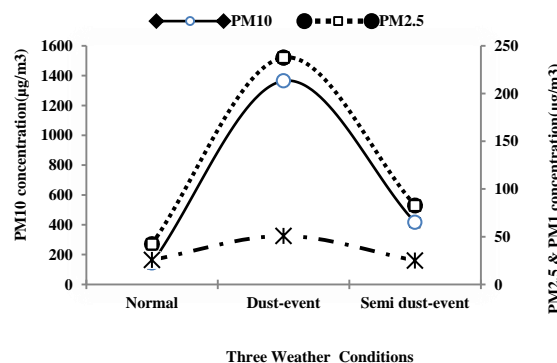

Figure 2. PM10, PM2.5, and PM1 mean concentrations during the study period for three weather conditions

Table 1. Summary statistics of PM_{10}, $PM_{2.5}$, and PM_1 concentrations during the study period for three weather conditions ($\mu g/m^3$)

Pollutant	Weather condition	N	Mean ±SD
PM_{10}	Normal	101	143.94±91.24
	Dust-event	64	1365.43±873.49
	Semi dust-event	17	416.4±227.3
$PM_{2.5}$	Normal	101	42.37±21.65
	Dust-event	64	237.74±150.23
	Semi dust-event	17	82.78±55.96
PM_1	Normal	101	25.74±15.65
	Dust-event	64	50.81±30.72
	Semi dust-event	17	25.11±18.43

Table 2. PM_{10}, $PM_{2.5}$, and PM_1 mean concentrations during the study period at different sampling stations

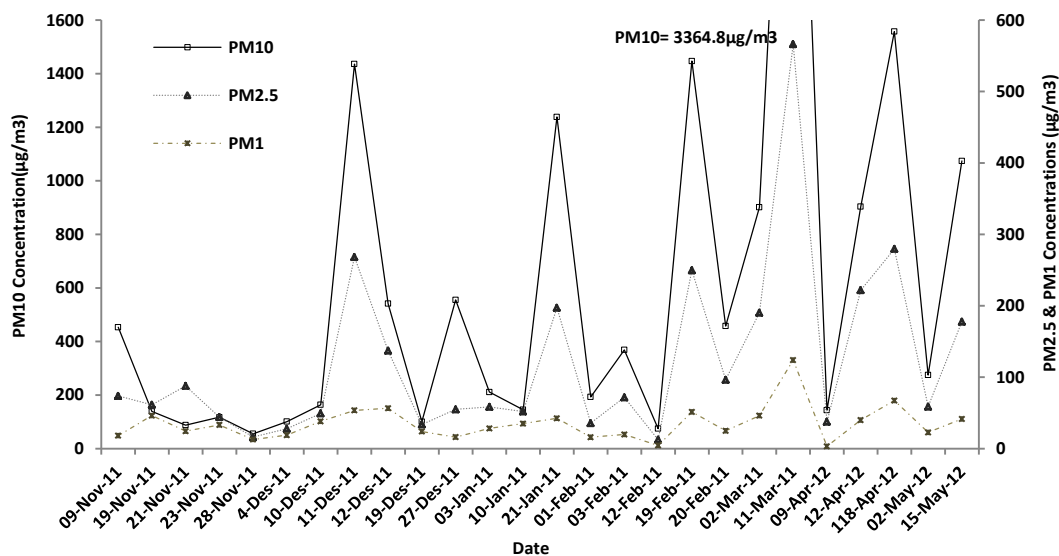| Station	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	PM_1 ($\mu g/m^3$)
Mohit Zist	629.85	119.84	35.28
Behdasht Ghadim	598.68	121.08	34.22
Naderi	804.22	141.5	37.11
Havashenasi	490.75	95.61	33.05

Figure 3. Daily average of PM10, PM2.5, and PM1 concentrations during the study period in Ahvaz
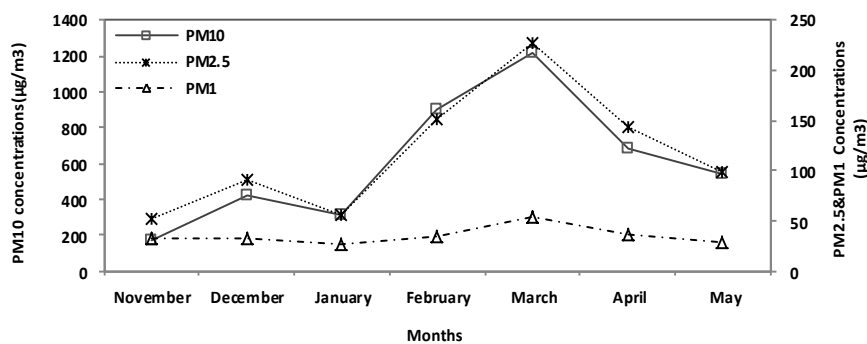

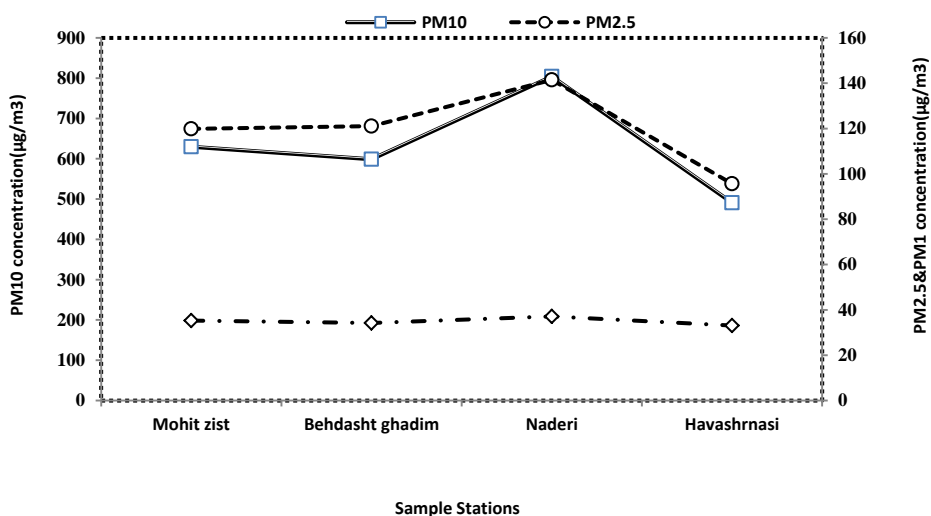Figure 4. Monthly average of PM10, PM2.5, and PM1 concentrations over the study period in Ahvaz

Figure 5. PM10, PM2.5, and PM1 mean concentrations during the study period at different sampling stations
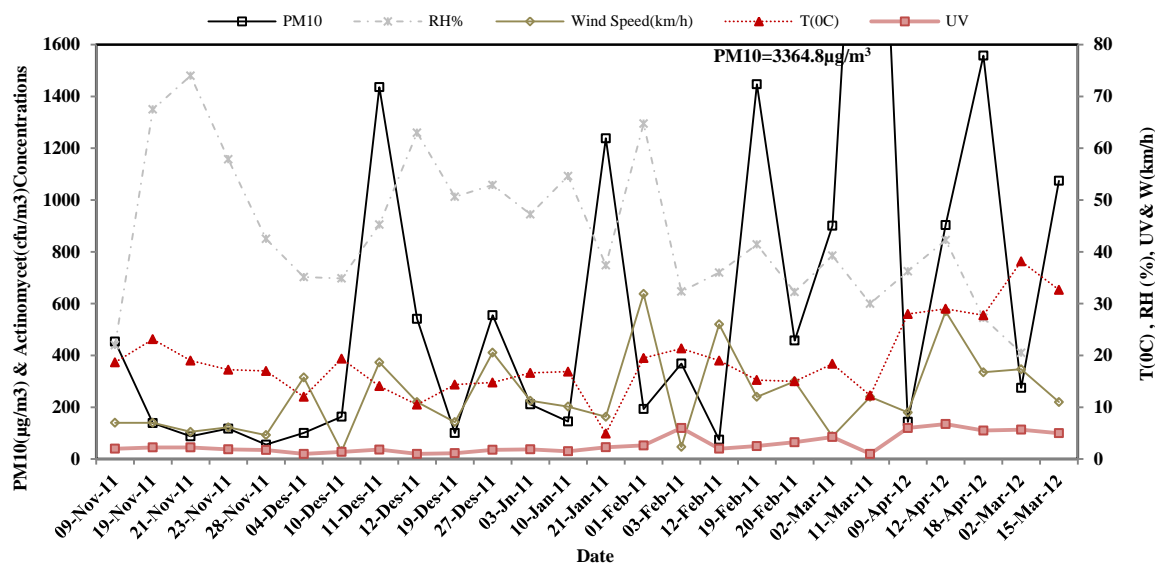
Figure 6. Temporal trends of PM10 average daily concentrations and RH (%), UV index, Wind speed (km/h) and Temperature (0C) during the study period in Ahvaz

Table 3. The correlation between the concentration of suspended particles and environmental parameters

Pollutant	Weather condition	Correlation							
		Wind speed		UV index		RH		Temperature	
		P.V	R	P.V	R	P.V	R	P.V	R
PM10	Normal	0.519	-0.065	0.053	0.193	0.056	-0.190	0.107	0.162
	Dust-event	0.073	0.565	*0.018	-0.296	0.593	0.068	0.101	-0.207
	Total	0.09	0.126	0.92	-0.007	*0.015	-0.181	**0.001	-0.245
PM2.5	Normal	*0.023	-0.226	0.584	0.055	**0.007	0.265	0.825	-0.022
	Dust-event	0.565	0.073	0.172	0.174	0.969	-0.005	0.388	-0.110
	Total	0.246	0.086	0.746	0.024	*0.05	-0.146	**0.003	-0.218
PM1	Normal	**0.000	-0.378	0.21	0.126	**0.000	0.481	*0.045	-0.200
	Dust-event	0.900	0.016	0.188	-0.168	0.529	-0.08	0.473	-0.091
	Total	0.235	-0.088	0.306	-0.076	0.362	0.068	**0.002	-0.223

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Discussion

Over the last few decades, various studies have been conducted to investigate the concentrations of bacteria, fungi, and particulate matter in different environments.[9-11] In this study, the concentrations of airborne particulate matter (PM10, PM 2.5, and PM1) and its relation to environmental conditions, such as humidity, temperature, wind speed, and UV index, were examined. There is a significant increase in the average concentration of dust particles in dusty circumstances as compared to when the air is pure and semi dusty (Table 1 and Figure 2). Average concentrations of particulate PM10, PM 2.5, and PM1 on dusty days compared to on ordinary days increased by 10, 6, and 2 times, respectively. Similar studies conducted in Iran and other parts of the world, such as that by Shahsavani et al. (2010) in Ahvaz, have yielded results consistent with the present study.[1] Meng and et al. (2007) studied Asian dust and found that during the dust-event of 2000, the concentration of PM10 and PM2.5 particles was >1500 and 230 (μg/m3). The concentration of PM10 on dusty days compared with normal days has increased by five to ten times; the annual average concentration of PM10 particles in

Minqin city in China were>300 (μg/m3).[12] The results of another study by Hong et al. (2010) in South Korea showed that the average concentration of PM10 from the cities of Lashn, Beijing, and Seoul were approximately 361, 217, and 62, respectively, and that the concentration of PM2.5 was 107, 101, and 36 (μg/m3). According to this study, the air condition of Lashn and Beijing will be affected by Asian dust; during this event the concentrations of PM10 and PM2.5 particles reached up to 1100 and 450 (μg/m3).[13] The greatest average concentration of particles was observed from "Naderi station," located in the city center with high traffic volume and high population density (Table 2). In similar studies from other parts of the world, parts of a city with high activity, such as city centers, contained more air contaminant and air pollution in urban areas than in outside areas.[14-16] The lowest concentration is related to the meteorological station, probably owing to the special circumstances of such stations, such as lack of bustle and congestion and presence of vegetation in such areas. Generally, the regions with a lower density, less industry, and traffic, have a lower average concentration of particles.[17,18] The maximum amount of average concentrations (μg/m3) was

determined in winter at 801.8 μg/m3, which could be because of commercial and industrial activities and traffic or because of special weather conditions during the winter, such as inversion. Most dust storms occurred during the winter and the least during fall. In studies in other parts of the world, whenever air temperature and the amount of UV radiation increases, the concentrations of pollutants in ambient air will be reduced.[19] Shahsavani et al. observed a significant difference between aerosol concentrations and different seasons and the outdoor air pollutant concentrations in winter were higher than in other seasons.[1] Evaluation of the average monthly number of the dusty days in Ahvaz (Iran) in the past 50 years shows that in recent years (2001-2010), the occurrence of dust storms has been rising in autumn and winter because of more active atmospheric flows in these seasons.[20] Statistics of Iranian Meteorology Organization show that, in recent years (2001-2008), the dusty days, in the months of February and March (winter) and April and May (spring) have increased dramatically between 1971 and 2001. Therefore, the dusty days are not limited to late spring and summer and these phenomena occur most of the year in Ahvaz. The main cause of this event is the increasing risk of land erosion with wind and loss of land cover for plants, so that with the lowest wind speed this phenomenon occurs in this city.[4] Considerable changes in ambient temperature and relative humidity values were observed during the sampling period. In this study, according to calculated correlation coefficients in Table 3, the concentration of particles PM10, PM2.5, and PM1 have a significant inverse correlation with temperature. With an increase in temperature, the air will become drier and humidity will be reduced so that the concentration of particles (PM10, PM2.5, and PM1) will decrease in the air. Similar studies from Iran drew identical conclusions.[7,21] Generally, there is a significant inverse correlation between PM10 concentration and humidity (in regular and dusty condition); namely, PM10 particle concentration increases with decreasing humidity. However, there is a significant positive correlation in normal conditions between the concentration of PM2.5 and PM1 with relative humidity. This means that the concentration of the particles decreases with increasing humidity. Furthermore, a significant inverse relationship exists between the concentration of PM10 dust and UV-index, whereby the concentration of PM10 increased with reduced UV intensity. On the other hand, under normal circumstances, there is an inverse relationship between wind speed and concentrations of PM2.5 and PM1, meaning that the concentration of particles decreases with increasing wind speed. Qian et al. (2002) studied the relationship between weather parameters and dust in China during 1948-1999, and demonstrated a strong relationship (r=0.66) between the frequency of extreme dust and heat loss, particularly in winter. Indeed, their study shows that the cold and dry weather is a crucial factor for creating dust.[22] Wang et al. (2005) showed that a dust storm in China occurred with the passing of a mass of cold air, with low humidity and high wind speed; in fairly dry conditions.[23] With regard to normal and dusty conditions by calculating the correlation coefficient between the concentration of PM10 with PM2.5 and PM1, P=0.0001, indicating a significant linear correlation between PM2.5 and PM1 with PM10 concentration. By increasing PM10 concentration, the particle concentration

of PM2.5 and PM1 is thus also increased. Consistent with Rocco et al., there was a positive correlation between concentration of bacteria and suspended particulate pollutants (r=0.56).[24]

Conflict of Interest

The authors declare that they have no conflict of interest.

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