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AIR QUALITY AND VARIATIONS IN PM₁₀ POLLUTANT CONCENTRATION IN WESTERN IRAN DURING A FOUR -YEAR PERIOD (2008-2011), KERMANSHAH - A CASE STUDY

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Abstract

The present study explored the quality of PM₁₀, over a four-year period in the western part of Iran. A total of 1334 samples were collected from air pollution measurement stations in Kermanshah. Statistical analysis was carried out using the SPSS ver.14. The results showed that the total percent change in PM₁₀ over a period of 4 years was 10.04%, 59.2%, 26.4%, 0.7% and 3.3%. The highest and the lowest frequencies of PM₁₀ occurred in February with 37.7%, June and July with 0%; winter and summer months with 21.96 and 4.81%, respectively. The results are depicted that the air quality in July, the summer months and 2008 was worst in terms of PM₁₀ concentration, which was mainly due to the fluctuations and acute entrance of dust particles into western Iran. Hence, the reduction in such emissions is indispensable and requires extensive and considerable cooperation between the government of Iran and the neighbouring countries.

Keywords: Concentration changes, Particular matter, PM₁₀, Iran, Kermanshah.

1. Introduction

Particulate matter (PM), which has adverse effects on human health [1], has become one of the most important issues and challenges associated with air

pollution in most parts of the world. Studies show that the air pollution in cities is linked to increased mortality rate, hospital admissions, and physiological changes in the body, especially the respiratory and cardiovascular system [2]. These effects are mostly linked to populated cities, where the PM_{10} concentration increases due to human activities [3]. Health impact assessment studies have shown that reducing the PM_{10} concentration to $5 \mu\text{g}/\text{m}^3$ could decrease the premature death rate (3-8 thousand) in European cities each year [4]. The particulate matter concentration is dependent on meteorological parameters such as humidity, wind speed, temperature and wind direction, all of which are effective in increasing particulate (PM_{10}) concentration [5].

The PM_{10} concentration in the urban atmosphere can be affected by the natural or man-made large area distribution of PM_{10} . For instance, in Greece the prevailing northerly winds transfer air pollution from Europe to the Eastern Mediterranean during the summer months [6]. On a global scale, the main proportion of mineral atmospheric dust comes from arid and semi-arid regions. The principal sources of dust within subtropical regions come from the Northern Hemisphere, a large part of North Africa, Middle East, South and Central Asia [7]. Furthermore, reduced rainfall and drought provide ideal conditions for increasing the concentration of PM_{10} particulates in the Mediterranean region [8].

In recent years, because of some issues including the extended drought phenomenon in the Middle East region, the desertification and loss of vegetation in large parts of the region, additionally dam construction and reduce rivers water, lack of long term policy-making plan and investments to deal with this phenomenon in neighbouring countries the intensity and frequency of dust particles (PM_{10}) from Arabian countries has increased, especially affecting the Western parts of Iran (Fig. 1). Considering that Kermanshah is an industrial city, the interaction between chemical pollutant and dust can be doubled concerning, especially in autumn and winter which inversion may occur frequently.

Accordingly, due to above mentioned factors and other parameters such as geographical position, dry climate conditions due to drought, population, industrial development, industrial facilities and proximity to Iraq, the present study explored the air quality, monthly, seasonal and annual changes in PM_{10} emission levels by collecting, comparing and analyzing samples over a four-year period (2008 to 2011) in Kermanshah, and also to determine the air quality, the reduction or increase trend of dust particles, sources of dust, deal management and reducing the harmful effects of dust particle in the western part of Iran.

2. Material and Method

2.1. Area and air quality data collection

Kermanshah located in western part of Iran with Latitude $34^{\circ}18'51''$ N and Longitude: $47^{\circ}03'54''$ E and elevation 1420 meters above sea level. The average, maximum, and minimum annual temperatures in this area are 14.2, 38 and 3.2°C , respectively.

This research is a descriptive - analytical study. A total of 1334 samples were collected from air pollution measurement stations (HORIBA model). HORIBA's Ambient Air Pollution automatically measures and records airborne particulate concentration levels using the industry-proven beta ray reduction. This instrument

has advanced technology, field-proven reliability with excellent sensitivity & accuracy at ppb levels belonging to the Environmental Protection Organization over a four-year period. The measurement stations are included a mobile station which is located in the Environmental Protection Organization Department and three other stations is located in south, south east and central part of the city (Fig. 2). Each hour, a small carbon-14 element emits a constant of high-energy electrons (known as beta rays) through a spot of clean filter tape. These beta rays are detected and counted by a sensitive scintillation detector to determine a zero reading. It automatically advances this spot of tape to the sample nozzle, where a vacuum pump then pulls a measured and controlled amount of dust-loaded air through the filter tape. Hourly this dirty spot is placed back between the beta source and the detector thereby causing a decrease of the beta ray signal which is used to measure the mass of the particulate matter on the filter type [9].

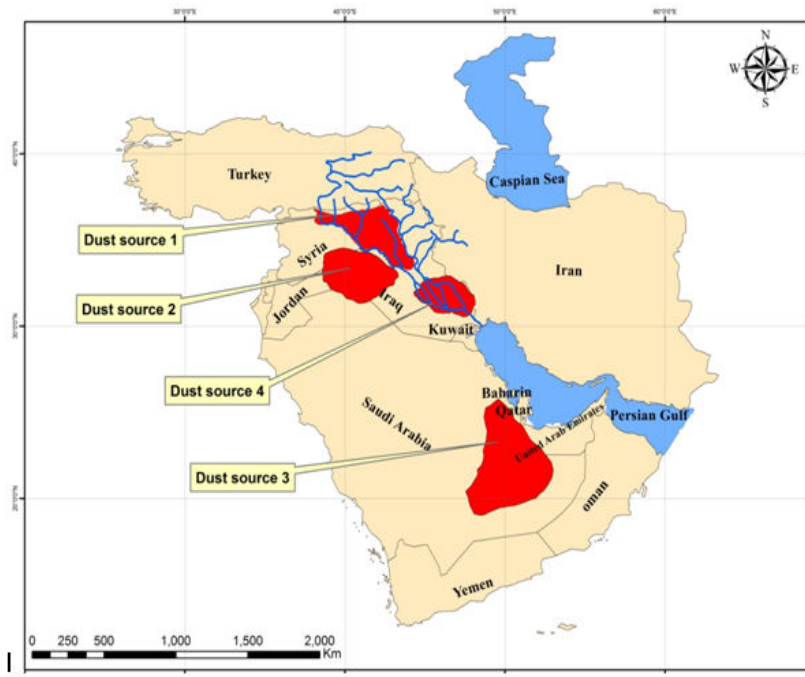


Fig. 1. Sources of dust in west part of Iran whiten 2008-2011.

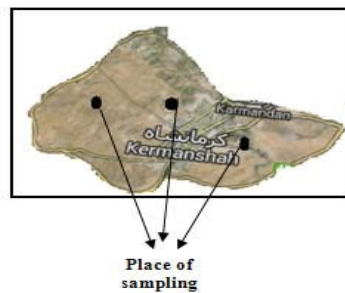


Fig. 2. Air pollution measurement stations in Kermanshah.

2.2. Data analysis

The data was analyzed statistically for correlation between meteorological parameters and air pollution levels using SPSS ver.14. Comparison of average frequency of different ranges during years, seasons and months carried out using (One-Way ANOVA). To estimate air quality based on PM₁₀ particulates, comparisons were made due to the Environmental Protection Agency (EPA) standard index of Iran, which includes the following: 0-50 µg/m³ (good), 51-150 µg/m³ (moderate), 151-350 µg/m³ (unhealthy), 351-420 µg / m³ (very unhealthy), and more than 420 µg/m³ as (hazardous). In addition, based on this classification the PM₁₀ concentration ranges (0-150 µg/m³) within the standard range and more than the 150 µg/m³ was out of standard level was considered [10].

3. Results and Discussion

The results show that the percent change of air quality in terms of PM₁₀ concentration, based on satisfactory, moderate, unhealthy, very unhealthy and hazardous standard indexes within a four-year period was 10.4, 59.2, 26.4, 0.7 and 3.3, respectively (Table 1). So, the highest and lowest percentage frequencies based on the satisfactory standard index (0-50) were 15.9% and 6.4% in 2010 and 2008; and 21.9% and 4.81% in winter and summer; and 37%, 7%, 0.0%, 0.0% in January, May and June, respectively. The highest and lowest percent change relative to the highest and lowest percent change relative to the hazardous standard index, was 4.4% and 1.8% in 2008 and 2011, respectively; 6.3% and 0% in spring and autumn season; 12.4% in May; and in September, October and November 0% was reported. The average absolute range of PM₁₀ emission levels within the four-year period was 140.1 µg/m³. So, in accordance with monthly, season and year, the maximum and minimum mean values for PM₁₀ levels were related to June, 227.5 µg/m³ and November, 75.9 µg/m³; summer and autumn with 176; 1 and 102 (µg/m³); and 2009 and 2010 with 159.8 and 122.6 µg/m³, respectively. However, the aggregate percent frequency for days outside the standard level (>150 µg/m³) was 30.4% during the four-year period. However, the maximum and minimum frequencies of days outside the standard level, based on month, season and year were as follows: June and November with 54.9 and 3.5%; spring and autumn with 77.7 and 12.7%; and 2009 and 2010 with 39 and 20.3%, respectively, results of Seasonal and Monthly PM₁₀ and assessment of the air quality are represented in Tables 2 and 3.

Table 1. Levels of PM₁₀ and assessment of the air quality in Kermanshah over period of 4 years (2008-2011).

PM ₁₀ (µg/m ³)	Air quality (PM ₁₀)	2008		2009		2010		2011		Total	
		Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)
0-50	Good	22	6.4	21	7	57	15.9	39	11.7	139	10.4
51-150	Moderate	209	61.1	162	54	229	63.8	190	57.1	790	59.2
151-350	Unhealthy	94	27.5	98	32.7	62	17.3	98	29.4	352	26.4
351-420	Very Unhealthy	2	0.6	6	2	1	0.3	0	0	9	0.7
>420	Hazardous	15	4.4	13	4.33	10	2.8	6	1.8	44	3.3
Total		342	100	300	100	359	100	333	100	1334	100
P value		0.001>									

Table 2. Seasonal PM₁₀ levels and assessment of the air quality in Kermanshah

PM ₁₀ (µg/m ³)	Air quality (PM ₁₀)	Spring		Summer		Autumn		Winter	
		Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)
0-50	Good	27	7.4	17	4.8	38	10.7	57	21.9
51-150	Moderate	175	47.9	189	53.4	272	76.6	154	59.2
151-350	Unhealthy	139	38.1	125	35.3	44	12.4	44	16.9
351-420	Very Unhealthy	1	0.3	4	1.1	1	0.3	3	1.2
>420	Hazardous	23	6.3	19	5.4	0	0	2	0.8
Total		365	100	354	100	355	100	260	100
P value		0.001>							

Table 3. Monthly PM₁₀ particulate matter levels and assessment of the air quality of Kermanshah.

Month	PM ₁₀ concentration range									
	0-50		51-150		151-350		351-420		420>	
	Air quality in term of PM ₁₀									
Air Quality PM ₁₀	Good		Moderate		Unhealthy		Very unhealthy		Dangerous	
	Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)	Day	Frequency (%)
March	18	14.8	63	51.6	36	29.5	0	0	5	4.1
April	9	7.4	55	45.1	54	44.3	1	0.8	3	2.5
May	0	0	57	47.1	49	40.5	0	0	15	12.4
June	0	0	55	45.1	51	41.8	1	0.8	15	12.3
July	8	6.6	60	49.6	49	40.5	3	2.5	1	0.8
August	9	8.1	74	66.7	25	22.5	0	0	3	2.7
September	0	0	88	73.3	31	25.8	1	0.8	0	0
October	18	15	93	77.5	9	7.5	0	0	0	0
November	20	17.4	91	79.1	4	3.5	0	0	0	0
December	18	20	66	73.3	6	6.7	0	0	0	0
January	23	737.7	30	49.2	5	8.2	2	3.3	1	1.6
February	16	14.7	58	53.2	33	30.3	1	0.9	1	0.9
Total	139	10.4	790	59.2	352	26.4	9	0.7	44	3.3
P value	0.001>									

Changes in air quality showed a significant difference in PM₁₀ levels over a period of four years based on season, month and year ($p < 0.001$) (Table 4). The size differences indicated that the rise and fall in pollution levels were different according to month, season and year, which were mostly due to the abnormal fluctuations in dust pollution entering the Kermanshah province from Iraq. In spring and early summer season, non-desire of air quality in terms of PM₁₀ which may have been due to more dust particles being transferred from Iraq to Iran during spring. This result is similar to the results of that study by Lelieveld et al. [6]. The percent frequencies of days outside the standard level, based on the year, were found to increase from 2008 to 2009 and decrease from 2009 to 2010 and increasing again from 2010 to 2011, which it was again due to dust particles entering the western part of Iran in 2009. Based on the season, the descending and rising trend of PM₁₀ is taking place from spring to autumn and from autumn to winter, respectively. With regard to the month, this tendency increased from March to June and decreased from June to November and also increased again from November to February. Dust particles entering Kermanshah were the main reason behind the increase in the trend of PM₁₀ during the March to June period, but the reason for the rise in the trend from November to February was more likely due to the humidity and an inversion phenomenon present in Kermanshah during the cold season, seasonal, monthly and four year period air quality due to PM₁₀ according to the number of days outside the standard level are revealed in Figs. 3 to 5. However, the main cause of this change cannot be associated with differences of atmospheric

pressure. Therefore, it can be concluded that the transfer of dust particles was restricted according to the continual occurrence of inversion due to lack of sunlight during the brief duration of the day. As a consequence of the fine dust particles are trapped by a stable layer of the atmosphere and maintaining these particulate matters for a long period.

Table 4. PM₁₀ µg/m³ concentration range determined according to months, seasons and years.

Parameters	Samples	Mean	Standard Deviation	Maximum	Minimum	
Month	March	122	143.3	125.4	890.1	29.7
	April	122	146.3	94.3	725.3	21
	May	121	213.6	176.8	1003	55.9
	June	122	227.5	184.3	1125	80.7
	July	121	153.2	82.8	550.3	7.4
	August	111	144.7	120.2	1061	6.9
	September	120	138.5	56.7	416.2	50
	October	120	91.2	42.6	223.1	19.9
	November	115	75.9	33.4	182.4	14.7
	December	90	80	48	319.5	13.2
	January	61	85.1	87.4	455.7	0
	February	109	134.9	97.3	1125	0
Season	Spring	365	167.6	139.8	1003	21
	Summer	354	176.1	141	700	6.9
	Autumn	355	102.2	52.6	416.2	14.7
	Winter	260	104.2	84.8	700	0
Year	2008	342	153.4	134.8	1061	21
	2009	300	159.8	125	921	14.7
	2010	359	122.6	111.5	1125	0
	2011	333	127.7	93.2	1003	13.2
Total	1334	140.1	118	1125	0	

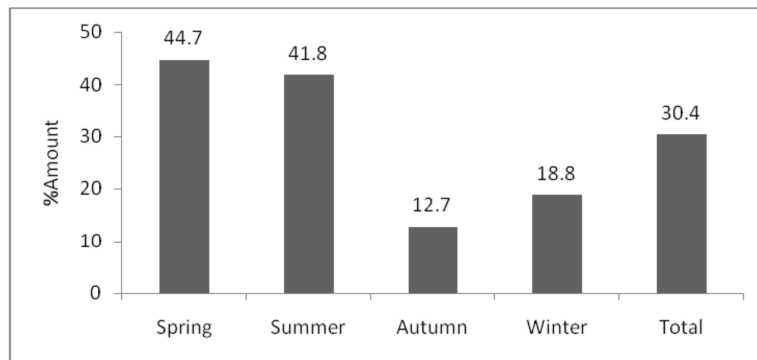


Fig. 3. Air quality of Kermanshah due to PM₁₀ according to the number of days with emissions outside the standard level ($150 > \mu\text{g}/\text{m}^3$) and season.

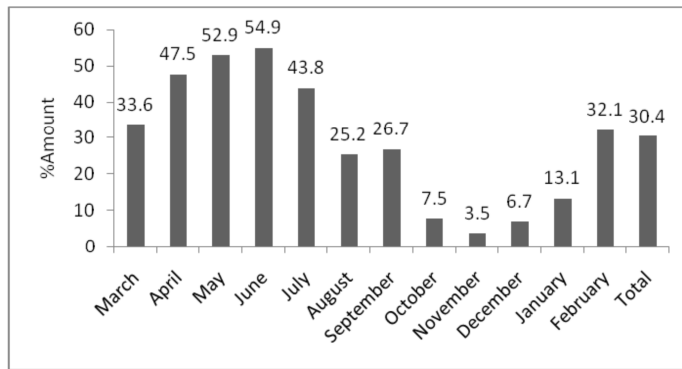


Fig. 4. Air quality of Kermanshah due to PM₁₀ according to the number of days outside the standard level ($150 > \mu\text{g}/\text{m}^3$) and month.

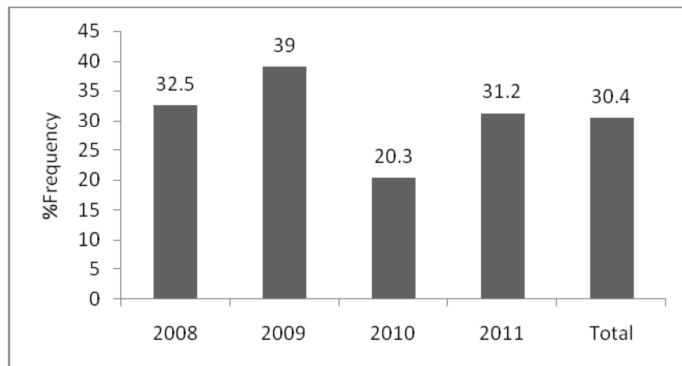


Fig. 5. Air quality of Kermanshah due to the PM₁₀ according to number of days outside the standard level ($150 > \mu\text{g}/\text{m}^3$) and year.

The changes in PM₁₀ levels reported in this study are different from those of other studies which have been carried out elsewhere in the world and also Iran, based on their geographic and climatic conditions, the PM₁₀ concentration was found to be low during summer, which was mostly caused by removal of particles from the atmosphere through intense rainfall. However, during the winter season, due to increasing wind speed, inversion phenomenon, humidity, and significant industrial and commercial activities, the PM₁₀ levels were found to increase in such countries [1, 5, 6, 9, 11-13].

Jenny et al. have studied the PM₁₀ in the Tianjin region of China. Their results showed that the PM₁₀ level was approximately $196.2 \pm 86.1 \mu\text{g}/\text{m}^3$, and the seasonal average concentrations of PM₁₀ during, spring, summer, autumn and winter were 196.5 ± 77 , 156.6 ± 55.1 , 203.4 ± 98.5 and $228.1 \pm 113.8 \mu\text{g}/\text{m}^3$, respectively. The highest and lowest average concentrations of PM₁₀ were reported during the winter and summer seasons, respectively. It is claimed that these differences are due to the synergistic effects of changes in the distribution of PM₁₀ and seasonal atmospheric conditions (mixing the upper layers of the atmosphere – constant occurrence of the inversion phenomenon) [1]. Also,

because of the wind and dry weather in the spring, the conditions for the distribution of PM_{10} particles were desirable. Furthermore, the low humidity is not suitable for secondary particle formation. Heavy rainfall during the summer season has largely washed away the PM_{10} particles. Increasing emissions from the burning of biomass have led to high the formation of high concentrations of PM_{10} in autumn, but the high concentrations of PM_{10} in the winter were mainly due to burning coal and seasonal atmospheric conditions (reduced mixing the upper layer of the atmosphere- the occurrence of inversion) [11]. The investigation carried out by Baraldo in Italy indicated that the level of particulates was 36 and 69 $\mu\text{g}/\text{m}^3$ in the summer and winter seasons, respectively, which was due to a constant inversion phenomenon during winter [14]. In addition, Horak showed that the PM_{10} levels were 17.36 and 21.03 $\mu\text{g}/\text{m}^3$ in the summer and winter, respectively [16]. The study carried out by Triantafyllo and Biskos [1] showed that the highest and lowest monthly average PM_{10} concentrations in Athens were detected during the autumn and winter; and summer months, respectively. However, Vassilakos [15] showed that the highest and lowest monthly average concentrations of PM_{10} in Athens were in the spring and summer months, respectively, and the variable trend of PM_{10} decreased from 2001 to 2010. The results of Vassilakos's research showed that the PM_{10} concentration in March was more than the other months in all the years, and there were significant differences between monthly and annual average PM_{10} concentrations [16]. Another study by Querol et al. [13] showed that the concentration of PM_{10} was 5-10 $\mu\text{g}/\text{m}^3$, with the highest rate being present in the eastern Mediterranean due to high levels of human activity in nature and the marine spray amount in the air, when compared to the Western Mediterranean. The process of seasonal variations showed that due to the dust movement in the African, the PM_{10} levels increased in the in eastern and western regions during the spring season and early summer months, respectively. In another study by Joksic et al. [11] in Belgrade was revealed that in the autumn and winter seasons, when the southwestern wind dominates, the PM_{10} concentration would increase, which may be due to the burning of coal 30 km away from Belgrade City. Joksic also showed that the PM_{10} levels during the spring and summer months were several times less than those of the autumn and winter months. This may be the result of increasing humidity that follows the formation of secondary aerosols under highly humid conditions during the autumn and winter months [13].

Mohammad [17] discovered that January in 2005, showing a PM_{10} level of 66.5 $\mu\text{g}/\text{m}^3$ was the most polluted month and April, 2005 with a PM_{10} level of 42.1 $\mu\text{g}/\text{m}^3$ was the cleanest month within the four -year period in Iran. In 98% of cases, the PM_{10} emission levels were less than the standard Air Quality Index (AQI <100)), and in 2% of the cases, they were higher than the standard (AQI>100). The reason for the reduction in PM_{10} emission levels during April was a decrease in business activities and the Iranian new-year holidays. However, significant increases took place in January, based on commercial and industrial activities, traffic jams and stable atmospheric conditions, such as the inversion phenomenon.

In research by Shariipour and Bidakhti [18], the maximum monthly PM_{10} concentration was detected in July 2002 in Tehran. In another study that was conducted by Prashant [19] in India the maximum concentration of PM_{10} was detected in Delhi during the peak traffic jam. Azizifar et al. [5] showed that the most polluted month in the city of Qom was November, with an average PM_{10} level

of 117 $\mu\text{g}/\text{m}^3$, and the cleanest month was in October with an average 83 $\mu\text{g}/\text{m}^3$). A study by Kermani et al. [20] showed that the most polluted and the cleanest months in Tehran regarding to PM₁₀ levels were March and April in 2001, and also showed that with respect to the days during the week, Saturday and Monday were found to be the most polluted days, and Friday was the cleanest day. According to the Air Quality Index (AQI), 75.5% of PM₁₀ concentration were less than the standard (AQI <100), and 24.5 was more than the standard (AQI).

4. Conclusions

The results showed that the worst air quality in terms of PM₁₀ pollutant concentrations was in the summer season (June) 2009, which is due to the intensity and frequency of entered dust particle to western part of Iran. Considering the geographical location of Kermanshah, the cause for the rise in PM₁₀ concentration in this region is primarily due to the transfer of these particles from Iraq to this city during the summer months. It can be concluded that, the reduction in such emissions is indispensable and requires extensive and considerable cooperation between the government of Iran and the neighbouring countries to control dust in west part of the Iran by using appropriate methods to maintaining soil moisture and lessen the spread of desertification.

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