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Original Article

Natural Airborne Dust and Heavy Metals: A Case Study for Kermanshah, Western Iran (2005-2011)

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Abstract

Background: Dust pollution has become a serious environmental problem especially in recent decades. The present study aim was the investigation of the levels of PM_{10} concentration in Kermanshah, western Iran and also measured five important heavy metals (Pb, Cd, As, Hg and Cr) in some samples during 2005 to 2011.

Methods: A total 2277 samples were collected from air pollution measurement station belonging to the Department of Environment in Kermanshah. Furthermore, four samples were collected during dusty days to determine the selected heavy metals concentration. The samples were analyzed statistically using the SPSS Ver.16

Results: The highest seasonal average concentration in spring was recorded in 2008 with 216.63μg/m^3, and the maximum values of 267.79 and 249.09μg/m^3 were observed in summer and winter in 2009, respectively. The maximum concentration of 127.11μg/m^3 was in autumn in 2010. The metals concentration (Pb, Cd, As, Hg and Cr) of samples were 42.32±5.40, 37.45±9.29, 3.51±2.07, 1.88±1.64 and 0μg/g in July, 2009, respectively.

Conclusion: According to National Ambient Air Quality of USEPA guidelines, the most days with non-standard, warning, emergency and critical conditions were related to 2009 (120 days) while the least polluted days were recorded in 2006 (16 days). There are concerns about the increasing frequency and intensity trend of dust storms in recent years as a result of special condition in neighboring Western countries which it could endanger public health and environment. All measured heavy metals except mercury was higher than the standard level of WHO and USEPA.

Keywords: Heavy metal, Dust, PSI, PM_{10}, Iran

Introduction

In recent years, air pollution has become a serious environmental problem especially in industrialized and populated cities (1-3). Some activities such as solid waste burning, industrial processes, motor vehicles, fossil fuel combustion and other human activities can cause air pollution (4-6). Air qualities indexes (AQI) have been made for classifying the air quality measurements of several air pollutants. The index used by the United States Environmental Protection Agency (USEPA), which is approved by part 319 of the Clean Air Act, called the Pollutant Standards Index (PSI) (4, 7). The PSI is one of the environmental indicators used to express air quality by pollutants concentrations in the air. Environmental Protection Agency (EPA) uses the PSI measurements to inform the public about potential health effects due to air quality. PSI has been used all over the world since 1978 (8). The PSI is defined by five pollutants e.g. ozone (O_3), particulate matter (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) in which the National Ambient Air Quality Standards (NAAQS) have been established by the USEPA (4, 7).

Atmospheric particles (PM_{10}) are significantly characterized by Air Quality Standards in many countries (9) (Table 1). It is clear that air quality can be influenced by the distribution of airborne ambient particulate matter in the environment. Therefore, the concentration of dust in the atmosphere is an essential parameter in climate variation. In Table 2, air quality is categorized into six types on the basis of dust concentration according to EPA guidelines (10). It is noted that air quality is also categorized into four groups on the basis of dust concentration according to the Environmental Protection Organization of Iran. In this basis, day of $PSI>100$ classified as non-standard quality, $100<PSI<250$ indicates as warning, $250\leq PSI<350$ classified as emergency while $PSI\geq 350$ shows critical condition.

There are numerous sources which release aerosols to the atmosphere. On global scale, the major part of dust emission comes from arid and semi-arid regions (with annual rainfall under 200–250 mm) which is called 'dust belt'(11) and it extends from the west coast of North Africa, the Middle East, central and south Asia to China(12). In recent years, the main sources of dust storms which influence the western and central regions of Iran are coming from the western and southern neighboring countries (Fig. 1) (13, 14).

Dust occurrences, are mostly the consequence of wind turbulent (16), which can move large amount of dust from arid regions and decrease visibility to less than 1km. This dust concentration can reach more than 6000 μg/m^3 (17). According to WHO reports, Ahvaz and Sanandaj with PM_{10} concentration annual average of 372 and 254 μg/m^3 were known as the first and the third polluted cities in all over the world, respectively (17).

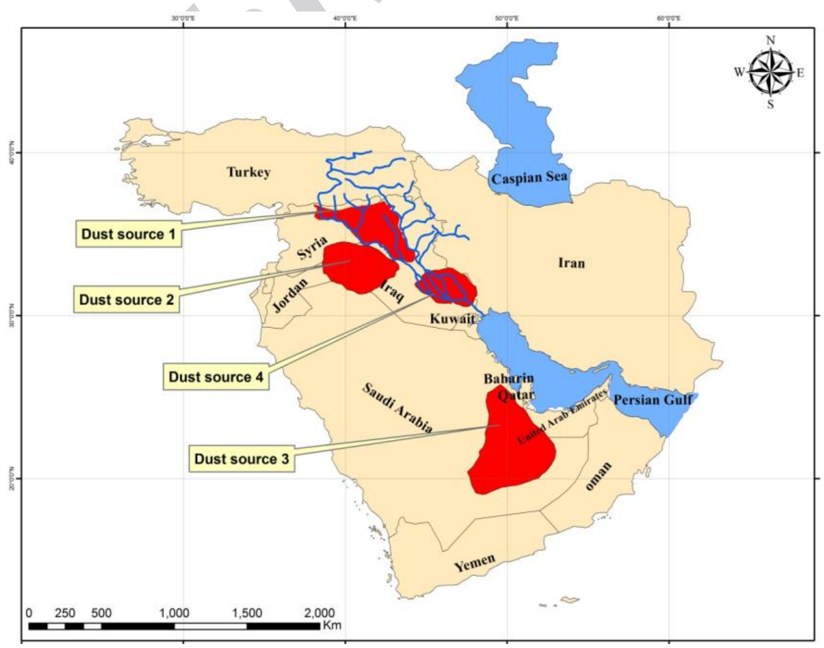

Fig. 1: Sources of dust events in the west of Iran from 2000 to 2008(14)

Dust plays an important role in the atmosphere due to it's severely effects on human health, environment and climate conditions (19-23). However, airborne dust is a significant issue in carrying and distributing pathogens, pollutants and heavy metals (5, 19-20).

Also it causes visibility reduction, possessions damage and human illnesses (24-25). Therefore, breathing dust particles can cause heart and respiratory troubles, acute and chronic headaches, allergies and skin diseases (23, 26). Some epidemiological studies revealed that the mortality rate in populated cities might be associated with PM_{10} and $PM_{2.5}$ particles. Usually, every 10 μg/m^3 increase in PM_{10} concentration could raise about 1% of the total daily mortality (9). Though, a certain level of heavy metals coupled with respirable PM_{10} is toxic and causes the health problems, because they can enter deeper parts of the lungs and are not washed out simply (21-22, 27). Thereby, some heavy metals, such as Pb, Co, Cd, Cu, and Cr, are recognized as a dangerous pollutant that it can accumulate in the body, a relatively long half-life. High concentrations of airborne heavy metals such as Pb, Cd, and certain persistent organic pollutants may also cause neurodevelopment and behavioral defects in children (23).

Therefore, the aim of this study was to investigate the levels of PM_{10} concentration in Kermanshah-Iran and compare the results with standard level, and also to measure five important heavy metals (Pb, Cd, As, Hg and Cr) in some samples, over a seven-year period (2005-2011).

Materials and Methods

Air quality data collection

A total 2277 samples (average of 24-hour) were collected daily from one air pollution measurement station (HORIBA model) inside Kermanshah City, Iran. The HORIBA's Ambient Air Pollution station automatically determines and reports airborne particulate concentration amount utilizing the industry-proven beta ray reduction. This equipment has superior technology, field-proven reliability with outstanding sensitivity & accuracy at ppb levels belonging to the Kermanshah's Department of Environmental protection placed in the central part of the city determining the air quality principle over a seven-year period (April 2005-October 2011). A Small carbon-14 element releases a constant of high-energy electrons (known as beta rays) via a spot of clean filter tape, hourly. These beta rays are detected and counted by a sensitive scintillation detector to determine a zero reading. It repeatedly advances this spot of tape to the sample needle, where a vacuum pump pulls a measured amount of the air throughout the filter tape. Hourly, this spot is sited back among 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 tape (28).

The data files were collected through two-way serial port common terminal programs. Then, they were analyzed statistically for correlation between meteorological parameters and air pollution levels using SPSS Ver.16. To estimate air quality based on PM_{10}, comparisons were performed with the USEPA standard index for month, season and year periods. Fluctuations in air quality indicated a significant difference ($P<0.05$) in PM_{10} emissions.

Analytical procedure

Four samples were collected during dusty days utilizing polyethylene wraps for determining the selected heavy metals concentration. The samples transferred to the laboratory in Public Health Faculty (Kermanshah Medical Sciences University) in order to analyze the heavy metals according to USEPA method for determining inorganic compounds in ambient air (29). Samples were digested on a hot plate for extracting heavy metals by adding 10 ml concentrated H_2SO_4 and 5 ml concentrated HNO_3. Then, they were heated for 2 hours until the solution was cleared.

A blank filter paper was digested in the same way. The samples were filtered and diluted for measuring heavy metals using Inductive Coupled Plasma (ICP) (Perkin Elmer Inc, USA, Optima 7300 DV, optical Emission Spectrometer, serial number 077C9081402).

Results and Discussion

Figures 2-5 depicts the number of non-standard, warning, emergency and critical days during 7 years (2005-2011), respectively. As shown in Table 5, according to National Ambient Air Quality Standards (NAAQS) USEPA, the most days with non-standard, warning, emergency and critical conditions were related to 2009 by 120 days which is one third days of the year while the least polluted days were recorded for 2006 by 16 days. The results showed that from 2006 onwards, the intensity and frequency of non-standard days have been increased. Universally, many cities regularly monitor the air quality using accurate devices to measure and record air pollution concentrations every moment to show the level of population exposure to the pollutants. This strategy helps us to compare the air quality with standards, find a proper plan for pollution reduction and provide long term and short term controlling approaches, (30-32). However, the increased dust storm and intensification of the number of warning, emergency and critical days in western provinces particularly Kermanshah, have made living conditions difficult, which has caused an increase in migration from Kermanshah to the central regions and neighboring provinces that subsequently causes other social and economical problems.

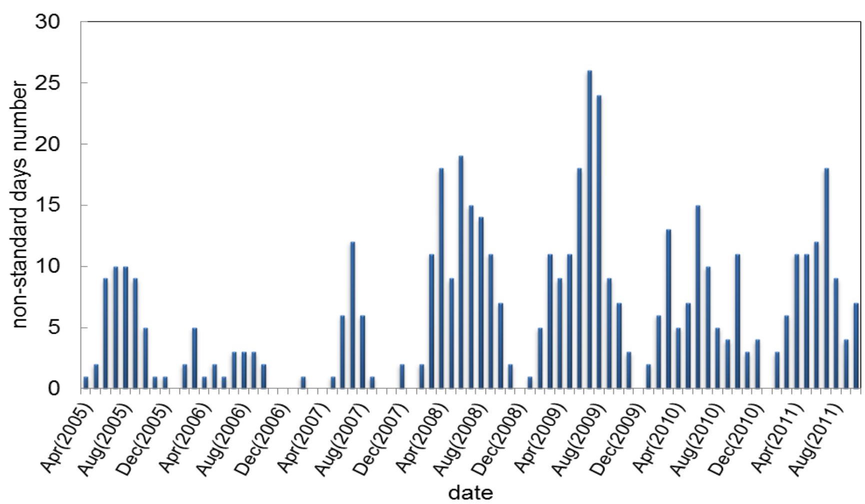

Fig. 2: Number of non-standard days during 2005-2011.

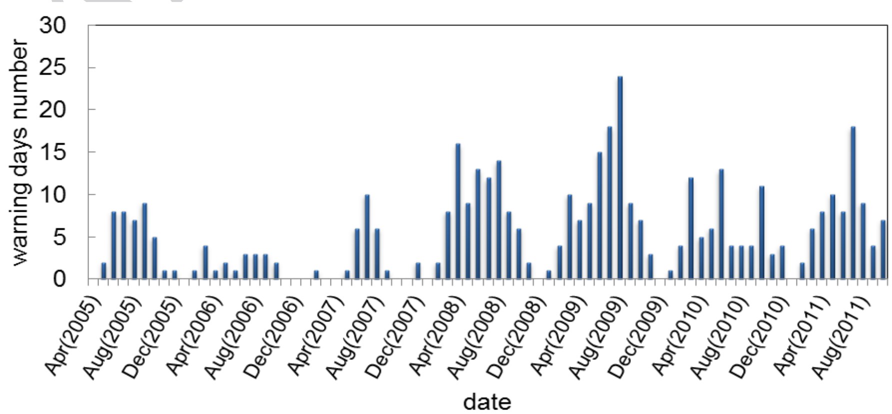

Fig.3: Number of warning days during 2005-2011

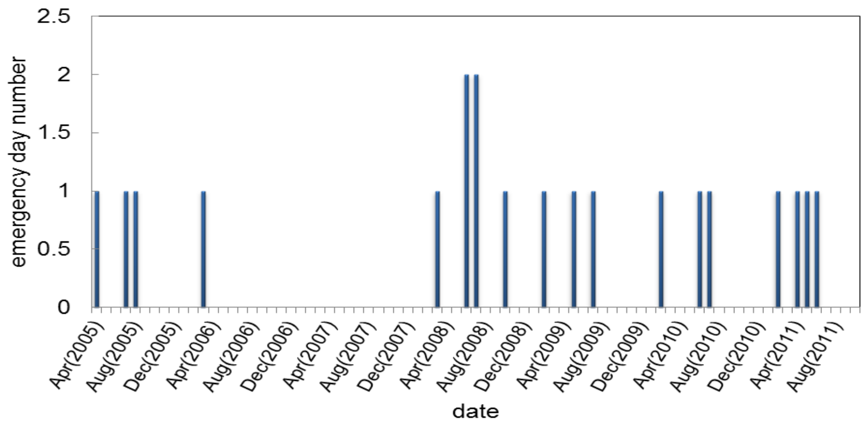

Fig.4: Number of emergency days during 2005-2011

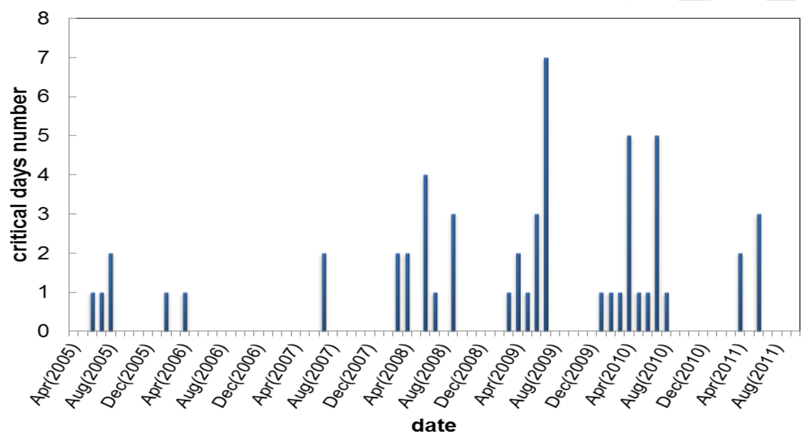

Fig.5: Number of critical days during 2005-2011

Table 3 shows monthly PM_{10} average concentration during a 7-year period. The PM_{10} daily mean concentration ranged from 6.96 in 2010 up to 2817 μg/m^3 in 2009. Average monthly concentrations of particles showed that the dust concentration began to increase in late March so that its maximum level reached in July and gradually begins to decline and the lowest was observed in January (Table 4). The seasonal average concentration of dust also represented in Table 4. According to dust concentration changes from 2005 up to 2011 and seasonal mean concentration, the highest seasonal average concentration of dust in the spring recorded in 2008 with the concentration of 216.63μg/m^3. In summer and winter seasons, the maximum values were related to year 2009 with the concentration of 267.79 and 249.09 μg/m^3 respectively, while the maximum concentration in autumn was obtained 127,11 μg/m^3 for 2010. The maximum seasonal mean concentration of dust occurred in summer, which was attributed to turbulent in the atmosphere, reduced precipitation and drought. So that strong winds transported the dust from Iraq and Kuwait to the west and south parts of Iran. Minimum dust concentration in terms of PM_{10} has been observed in autumn. It might be due to an increase in air relative humidity and rainfall. Statistic analysis also indicated that there were significant differences between dust concentration and saturated air humidity ($P<0.05$). According to NAAQS, annual maximum permissible concentration of PM_{10} is 50 μg/m^3 (32).

Table 1: Annual mean PM_{10} of Iran cities in 2009, by WHO (http://envis.tropmet.res.in/Data_depository/annua_%20mean_concentrations)

Annual mean PM10 (Particulate matter with diameter of 10 µm or less), by city							
Region	**Country**	**City**	**Annual mean PM10 (ug/m3)**	**Year**	**Number and location**	**Temporal coverage**	**Reference**
EmrLMI	Iran	Tabriz	82	2009	2 urban traffic, 2 residential and commercial	67	Department of Environment (DOE)
EmrLMI	Iran	Mashhad	87	2009	3 urban trafiic, 2 residential and commerial, 1 urban and suburban	100	Department of Environment (DOE)
EmrLMI	Iran	Tehran	96	2009	9 urban traffic, 10 residential and commercial, 6 urban and suburban, 1 industrial	100	Department of Environment (DOE)
EmrLMI	Iran	Arak	102	2009	3 urbantraffic, 2 residential and commercial, 1urban and sub-urban	83	Department of Environment (DOE)
EmrLMI	Iran	Hamedan	103	2009	1 residential and commercial	57	Department of Environment (DOE)
EmrLMI	Iran	Esfahan	105	2009	2 urban traffic, 2 residential and commercial	100	Department of Environment (DOE)
EmrLMI	Iran	Qazvin	112	2009	1 urban traffic	20	Department of Environment (DOE)
EmrLMI	Iran	Kerman	125	2009	1 urban traffic, 1 residential and commercial	100	Department of Environment (DOE)
EmrLMI	Iran	Bushehr	125	2009	1 residential and commercial	20	Department of Environment (DOE)
EmrLMI	Iran	Ilam	129	2009	1 residential and commercial	100	Department of Environment (DOE)
EmrLMI	Iran	khoramabad	168	2009	1 urban traffic, 1 residential and commercial	48	Department of Environment (DOE)
EmrLMI	Iran	Qom	176	2009	1 urban traffic, 1 residential and commercial	15	Department of Environment (DOE)
EmrLMI	Iran	Uromiyeh	183	2009	1 urban traffic, 1 residential and commercial	100	Department of Environment (DOE)
EmrLMI	Iran	Yasouj	215	2009	1 urban green area	20	Department of Environment (DOE)
EmrLMI	Iran	Kermanshah	229	2009	1 residential and commercial	62	Department of Environment (DOE)
EmrLMI	Iran	Sanandaj	254	2009	1 urban traffic, 1 residential and commercial	35	Department of Environment (DOE)
EmrLMI	Iran	Ahwaz	372	2009	1 urban traffic and 3 residential and commercial	100	Department of Environment (DOE)

Table 2: PM_{10} concentrations and its corresponding to PSI & Air Quality categories (15)

PM_{10}(µg/m^3)	PSI	Category
0-54	0-50	Good
55-154	51-100	Moderate
155-254	101-150	Unhealthy for sensitive Groups
255-354	151-200	Unhealthy
355-424	201-300	Very Unhealthy
425-604	301-500	Hazardous

In this basis, during the years 2005-2011, respectively 55, 16, 41, 112, 120, 73 and 79 days have been reported as un healthy monitoring period, the dust concentration was reported 2 to 3 times more than the annual maximum primary standard. However, it should be noted that PM_{10} 24-Hour primary concentration was 10 to 20 times more than NAAQS (150 µg/m^3). The records imply high air pollution level in Kermanshah. From an assessment reported in the literature, the rank of Kermanshah between 10 polluted cities in the world is 6th after Ahwaz (Iran), Ulan Bator (Mongolia), Sanadaj (Iran), Ludhiana (India), Quetta (Pakistan) (34).With a closer look it becomes clear that 4 cities from 10 polluted city in the world belongs to Iran. 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. Also as showed in Table 1 from the WHO database, annual mean PM_{10} concentration in 2009 in Kermanshah has been 229 $\mu g/m^3$ (18). The world average PM_{10} levels by region ranged from 21 to 142 $\mu g/m^3$, by the way world average is 71 μg/m3. Hence Kermanshah is 3.2 times more polluted than the world average (35). Most dust storms in south-west of Iran are originated from Iraq, Syria and north of Saudi Arabia during the recent decays (13). In addition they approved that from 2005 up to now, the frequency and the intensity of dust storms are increasing about 20 to 30 percent as a result of drought phenomenon, abuse of natural sources and dam construction on Tigris and Euphrates, especially in neighboring countries such as Iraq (36). Similar findings were reported from different researches (36-39). Sudan, Iraq, Saudi Arabia and the Persian Gulf, are the areas that stated the most reported incidence of dust storms event. Dust storms in Iran, north-eastern of Iraq and Syria, the Persian Gulf and southern Arabian Peninsula are more common in summer (13). Dust storms originated from the north of Africa are increasing in the north of Saudi and Iraq and their developments reach the north of Persian Gulf and Khuzestan Province in Iran. Iraq and Turkey are the generation source of the dust storms which affect the west of Iran. The storm following a cold winter through Turkey entered Iraq and Kuwait and after it was greatly intensified, afflicted the western portions of Iran. Storms come from northern Africa and Saudi in summer and early autumn and affect the Khuzestan Province and the south of Iran (40).

According to the Zeng and Yoon forecasting, Central Africa, southwest of Saudi, northwest of Iran, the west of Caspian Sea, Iraq, Kuwait, and the east of Mediterranean Sea and some other areas of the world will transform into desert in the future. Therefore, dust storms from the west will be more in the future with many effects upon the western provinces of Iran (41).

Dust has a substantial role in the atmosphere; it intensely affects human health, natural ecosystems and climate. Wind-blown dust is an effective factor for the transport of pathogens and pollutants (18, 19). Another important aspect associated with the dust phenomenon which may be noticed less is the heavy metals contents of the particulate matters. They can diffuse into the lungs along with dust and seriously endanger people's health. The metals concentration (Pb, Cd, As, Hg and Cr) of the dust samples in July of 2009 is shown in table 6. From the Table 6, average concentrations of the metals in the dust samples were 42.32±5.40, 37.45±9.29, 3.51±2.07, 1.88±1.64 and 0μg/g. It can be noted that the concentration of lead and chromium of all collected samples were the most whereas, the concentration of mercury was zero which it could be due to the volatility of this metal. The concentrations of all measured heavy metals except mercury were higher than the standard levels determined by WHO and USEPA (30-32, 36-39). Concentration of lead was very high among all measured metals that could be due to the area with lead background or Euphrates and Tigris rivers sediments with industrial origin or fertilizers and pesticide residues in farm land. Figure 6 shows the rate of intake for the heavy metals (μg/h) received by humans.

From an estimation reported, 3.2 million people died in 2010 have been because of the poisonous effects of outdoor air pollution. Two-thirds of those killed by air pollution lived in Asia, where air quality continues to get worse (42). Thereby, uptake these toxic metals (Pb, Cr and Cd) through inhalation could be very harmful for human health especially in vulnerable groups (children and elderly people).These effects were discussed only on dust and heavy metals, but the effects of these particles and associated metals and other contaminants such as radioactive materials, bacteria, fungi and ... on the human health, economic, environmental, social (such as migration) and the psychological people need to be precisely studied.

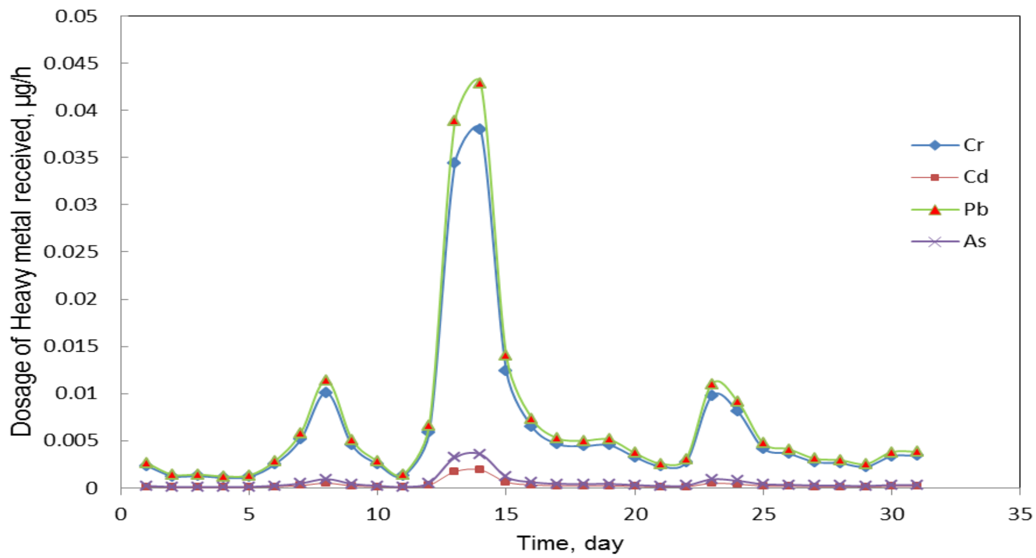

Fig.6: Intake rate for heavy metals (April 2011)

Table 3: Seasonal PM_{10} average concentration during a 7-year period

Season	Year							Total
	2005	2006	2007	2008	2009	2010	2011	
Spring	110.68	91.64	127.86	216.63	166.80	130.32	178.35	164.04±43.29
Summer	163.76	117.63	136.50	200.68	267.79	149.33	143.42	168.44±50.86
Autumn	111.69	76.29	102.61	101.45	96.54	127.11	84.02	99.95±16.88
Winter	84.70	66.83	121.07	111.51	249.04	83.55	102.15	116.98±61.05
Yearly Average	117.7± 33.14	88.09± 22.18	122.01 ±14.39	157.56 ±59.49	195.04 ±78.69	122.57 ±27.80	126.98 ±42.32	132.85±30.41

Table 4: Monthly PM_{10} average concentration during a 7-year period

Month	Sample frequency	Average	Maximum concentration	Minimum concentration
April	186	139.94±194.10	1953	24.41
May	186	124.68±88.15	725.3	21.01
June	208	175.71±152.56	1003	54.01
July	209	222.12±291.67	2817	56.05
August	214	148.21±92.484	925.4	7.40
September	204	134.90±94.66	1061	6.96
October	210	128.05±47.73	416.2	50.06
November	210	91.11±37.92	223.1	19.99
December	205	80.20±39.68	384.1	14.71
January	155	66.26±24.74	152.7	18.11
February	122	88.92±76.57	464	13.25
March	168	157.72±217.23	2500	32.26
Total	2277	129.82±44.28	2817	6.96

Table 5: Number of non standard daysduring a 7-year period

Year	Spring	Summer	Autumn	Winter	Total
2005	12	29	7	7	55
2006	4	9	2	1	16
2007	7	19	2	13	41
2008	46	40	9	17	112
2009	38	59	10	13	120
2010	27	19	18	9	73
2011	34	31	8	6	79
Total	168	206	56	66	496

Table 6: Heavy metal concentration in the dust samples

Metal	Sample	µg/l	Average±δ	µg/g	Average±δ
Cr	1	869.5	936.2±2.33	34.78	37.45±9.29
	2	693.3		27.73	
	3	1250		50	
	4	932		37.28	
Cd	1	13.47	47.09±41.09	0.54	1.88±1.64
	2	10.3		0.41	
	3	75.5		3.02	
	4	89.1		3.56	
Pb	1	992.5	1058.12±134.96	39.7	42.32±5.40
	2	915		36.6	
	3	1099		43.96	
	4	1226		49.04	
As	1	34.15	87.78±51.97	1.36	3.51±2.07
	2	54		2.16	
	3	120		4.8	
	4	143		5.72	
Hg	1	0	0	0	0
	2	0		0	
	3	0		0	
	4	0		0	

Conclusion

The highest seasonal average concentration of PM_{10} pollutant was in the spring season in 2008, summer and winter in 2009 and autumn in 2010, respectively. Therefore, the decline in such releasing is crucial and requires extensive and substantial collaboration between the government of Iran and the neighboring countries to control dust in west part of the Iran by using suitable methods to maintaining soil moisture and lessen the spread of desertification.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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