Environmental Health Engineering and Management Journal 2019, 6(2), 129–137
http://ehemj.com
doi 10.15171/EHEM.2019.15
Environmental Health Engineering and Management Journal

Original Article

Ecological risk assessment of heavy metals from cement factory dust

Firouzeh Yadegarnia Naeini, Hamidreza Azimzadeh*, Asghar Mosleh Arani, Ahad Sotoudeh, Bahman Kiani

Environmental Science Department, Natural Resources School, Yazd University, Yazd, Iran

Abstract

Background: The release of metals from industrial factories is one of the most important sources of environmental pollution. The present study aimed to determine the concentration of heavy metals like cadmium (Cd), chromium (Cr), manganese (Mn), nickel (Ni), and lead (Pb) in dust around the cement factory.

Methods: A total of 22 dust samples were collected from areas around the cement factory in Isfahan province in spring and summer and transferred to laboratory for chemical digestion. Risk index (RI), integrated pollution index (IPI), mean of contamination degree (mC_d), and contamination factor (C_f^i) were calculated to determine the contamination status.

Results: The concentration of heavy metals in the falling dust around the factory was expressed as Cd <Ni <Pb <Mn <Cr. Pearson correlation showed that there is only a significant negative relationship between the concentration of Cd and the distance from the factory. By increasing the distance from the factory, the concentration of Cd in dust decreased. The results of falling dust analysis showed that Cr has a high-risk potential in two seasons of spring and summer and Cd has a middle level of pollution in spring.

Conclusion: According to the results, the deposited dust of study area is considered as a polluted dust and it is at higher risk of pollution with Cd and Cr.

Keywords: Cement factory, Dust, Environmental pollution, Heavy metals

Citation: Yadegarnia Naeini F, Azimzadeh H, Mosleh Arani A, Sotoudeh A, Kiani B. Ecological risk assessment of heavy metals from cement factory dust. Environmental Health Engineering and Management Journal 2019; 6(2): 129–137. doi: 10.15171/EHEM.2019.15.

Article History:
Received: 17 February 2019
Accepted: 9 April 2019
ePublished: 5 May 2019

***Correspondence to:**
Hamidreza Azimzadeh
Email: hazimzadeh@yazd.ac.ir

Introduction

A dust storm is a meteorological phenomenon and usually occurs when the wind speed exceeds the threshold value and particles are removed from the soil (1). In recent years, the rapid growth of industry and urbanization has produced dust, particulates, and million tons of pollutants which threat the environment and human health (2). One of the industries that produce alternative amounts of dust in most stages of the process is the cement industry (3). Dust particulates released from the cement industry, due to the size and composition with other air pollutants, in addition to soil contamination, have irreparable effects on plants (4). Generally, sedimentation of cement dust on plants reduces the energy stored in plant tissues, closes stomata, and decreases photosynthesis and the growth of plants (5). Depending on their origin and direction, these particulates have a high ability to carry heavy metals (6). Heavy metals are the most toxic pollutants that enter the environment through industrial and human activities (7,8). Cement industries as the most polluting industries in the world, are the main sources of heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), manganese (Mn), copper, and zinc (9,10), which create heavy metals with different physical and chemical properties at each stage of production including pre-heating, clinkering, clinker cooling, crushing, and storing (11).

Heavy metals are important due to their inherent microorganisms and their physiological effects on humans and other living organisms at low concentrations (12) and are considered as the most hazardous components of human-made contaminants because of their toxicity and environmental sustainability (13). Among all heavy metals, Cd, Cr, and Pb are of most concern due to high toxicity (14,15).

Several studies have been conducted on the pollution caused by the cement industry and determined the concentration of heavy metals like Cd, Pb, copper, zinc, Ni, Cr, and cobalt in limestone, particulates, and surface soil around the factory (5,7,8,10,11,16-19). Their results showed that the origin of heavy metals in soil depends on the dust rich in heavy metals from cement production (16). Evaluation of the effect of heavy metals on cement soil and vegetation showed that lead mobility in surface soil is more than 20 cm depth. In addition, heavy metals poisoning plays a role in reducing plant height, burning leaf margins, reducing leaf growth, and mostly the wilting of plants (17). Assessment of the heavy metals content in the dust generated by the Sagamu cement factory and its attendant health effects, especially on the inhabitants of the area. The results detected that the concentration of Cd, Pb, and zinc in all four sample types of limestone, shale, soil, and dusts were generally higher than their global means. In addition, the results of medical reports on the health of residents of the study area showed that the incidence of some diseases like cancer, respiratory, lung, heart, skin, kidney, and liver diseases are constantly increasing. Furthermore, the incidence of respiratory, lung, and heart diseases have doubled in this period (8). The evaluation of Ilam cement factory dust effects on the concentration of the heavy metals in soils in Karzan area, showed that the maximum concentration of Pb (96.40 ppm) was observed in April 2015 (18).

A study on Cd and Pb concentrations of soils around the Kurdistan cement factory in western Iran, showed that Pb and Cd concentrations were weakly correlated with each other, indicating that Pb and Cd in soils may originate from different pollution sources. No distinct spatial trends of Pb with its low accumulation in the soils demonstrate that Pb content was mainly influenced by soil factors. The spatial pattern of Cd showed that the cement factory emission has an impact on the soil's Cd content, since the highest level in an area close to the cement factory. Estimated integrated pollution index (IPI) showed that the soils around the factory were practically uncontaminated by metals (19).

The most contaminated sites are found within the 0 to 3 km of the cement factory (20), so, the present study aimed to determine the concentration of heavy metals such as Cd, Cr, Mn, Ni, and Pb in dust around the factory and determine the contamination level using the contamination factor (C_f^i), IPI, risk index (RI), and mean of contamination degree (mC_d) at 0-3 km around the factory.

Materials and Methods

The study area

The cement factory is located at 53°8′ E and 32°40′ N in the east of Isfahan province with a hot and arid climate in the desert region with an altitude of about 1600 m above sea level. The study area is 3 km radius around the cement factory, which has no residential area and its distance to the city center is about 30 km. The closest residential areas are two villages of Benvid-e-Olia and Sofla located at 4 and 5 km from the factory in the north of the region, respectively. The dominant vegetation in this region includes *Artemisia sieberi*, *Fortuynia bungei*, and *Pteropyrum aucheri*. Figure 1 shows the location of the study area.

The executive operation of the factory was started in 2011 and the production and exploitation of cement was started in 2004. In this factory, 240 employees are working in the production line and administrative and technical departments. The total area of the factory is about 16 hectares and its nominal capacity is about 600 tons of cement per day.

Analysis of wind speed and direction in the region

In order to investigate the wind changes, the seasonal wind rose was plotted at the time of the trap placement (March-September 2017). Wind speed and direction data obtained from Naein station were analyzed. The data format was changed by visual basic (version 7) and used as the input of WRPlot (version 7) to plot the wind rose. Figures 2 and 3 present the seasonal wind rose of six months during spring and summer 2017. As shown in these figures, the dominant wind is in the west and northwest direction in spring and northwest in summer, which is effective in spreading dust pollution of the cement factory.

Sampling and laboratory analysis

Dust samples were taken seasonally in two seasons of spring and summer in 2017. The distribution of sampling points was designed to cover 11 sampling stations according to the topographic characteristics and the dominant wind direction up to 3 km from the factory (21,22). The dust

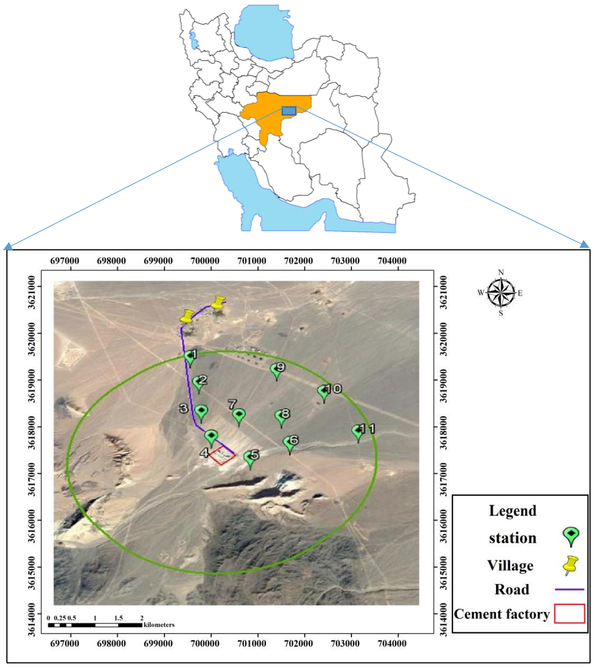

Figure 1. Location of the study area including the cement factory, sample points, and villages.

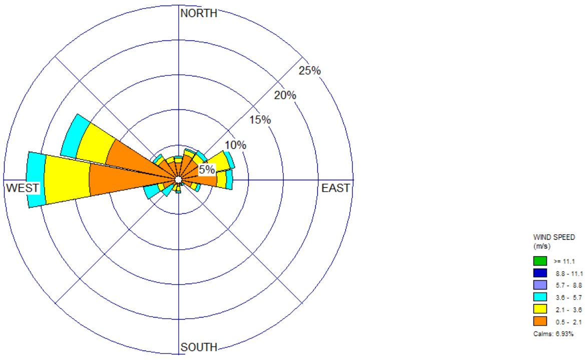

Figure 2. Wind rose of Naein weather station (spring 2017).

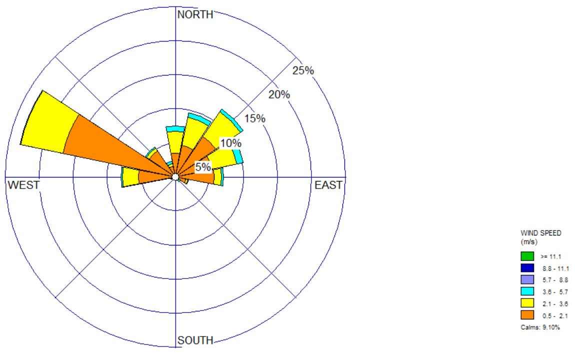

Figure 3. Wind rose of Naein weather station (summer 2017).

deposition trap was used to collect falling dust with 27 cm in diameter and 10 cm in depth covered by the stainless steel anti-bird thorns and artificial grass into the trap. The traps were installed at a height of 120 cm above the ground level in sampling sites (Figure 4).

The trapped dust samples were seasonally distilled by water twice, transferred to the laboratory, and heated at 70°C for 48 hours. Then, 1 g of dust was weighed with a precision of ±0.001 to measure the total concentration of heavy metals in accordance with ISO 11446 international standard procedure. According to the extraction procedure of trace elements, 7 mL of concentrated chloride acid plus 2.5 mL of concentrated nitric acid (1:3 ratio) and then, 5 mL of diluted nitric acid (0.5 M) drop by drop were added to each sample. The adsorption vessel and condenser were installed and rinsed with a further 10 mL of nitric acid after reaction time.

In the final step, after cooling the samples, 33.3 mL of diluted nitric acid was added and the solution was completely filtered by Whatman 42 filter paper and reached the volume of 50 mL by adding deionized distilled water. The concentration of heavy metals like Cd, Cr, Mn, Ni, and Pb was determined in digested solution by Analytic Jena 330 Flame Atomic Absorption Spectrophotometer (23).

Data analysis

Data were analyzed using SPSS (version 22). The descriptive statistics of variables were calculated. Then,

Figure 4. Dust deposition trap in a sample site.

paired t-test was used for comparison of the heavy metals in spring and summer. Pearson correlation coefficient was used to determine the relationship between the distance from factory and the amount of pollutant integration. The normality of data was also investigated using the Kolmogorov-Smirnov test. In addition, the spatial variations of heavy metals concentration around the cement factory were described using definite methods such as radial basis functions and local polynomial interpolation by ArcGIS software version 10.2.

The pollution indices used for heavy metals analysis

To determine the status of contamination in the study area in terms of pastures and environmental protection, the C_f^i, and in terms of integration, the IPI, RI, and mean of mC_d were calculated.

Contamination factor and mean of contamination degree

C_f^i can be used to indicate the environmental contamination of a specific metal. This factor is calculated by the Eq. (1) (24).

$$C_f^i = \frac{\overline{C}_{0-1}^i}{C_n^i} \quad (1)$$

Where C_f^i represents the contamination factor (mg/kg), $\overline{C}_{0-1}^i$ is the average metal concentration (mg/kg), and C_n^i is the concentration of the same metal in the reference sample (mg/kg).

$$C_d = \sum_{i=1}^{n} C_f^i \quad (2)$$

In Eq. (2), *Cd* is used for evaluating the overall pollution of the environment and calculated by the sum of the total contamination factor for all metals as follows. Due to the limitations of the degree of contamination index, the mean of contamination degree was used as Eq. (3) (25).

$$mC_d = \frac{\sum_{i=1}^{n} C_d}{n} \quad (3)$$

Where mC_d represents the mean of contamination degree and n is the number of examined trace elements (mg/kg). The standard value of trace elements was considered based on the standards of Soil and Water Research Institute of Iran (Table1).

Integrated pollution index

The pollution level was calculated using Eq. (5). In this equation, *PI* refers to the pollution index of the i-th pollutant, C_i is the concentration of the i-th pollutant (mg/kg), B_i represents the base concentration of pollutant of soil parent materials (mg/kg), and *n* is the number of pollutants (26). Table 1 shows the categories of level of IPI.

$$PI_i = \frac{C_i}{B_b} \quad (4)$$

$$IPI = (\prod_{i=1}^{n} PI_i)^{1/n} \quad (5)$$

In a recent study, the values of Iran's standard soil trace element were used for comparing rangeland and environmental protection land-use (27) as shown in Table 2 (28).

Risk index

The potential environmental risk factor has been calculated to assess the contamination of heavy metals in soil and the ecological and environmental effects of heavy metals. RI is calculated according to the Eq. (6) and (7):

$$E_r^i = T_r \times C_f \quad (6)$$

$$RI = \sum_{i=1}^{n} E_r^i \quad (7)$$

Where E_r^i represents the risk factor for each metal, T_r refers to the toxicity response to heavy metals (Table 3), and *RI* is the risk index. This index is calculated by the sum of several metals or various pollution factors under investigation (14). Table 4 shows the classification of the index and potential environmental risk levels.

Table 1. Standard classification of C_f^i, mC_d, and IPI

C_f^i and IPI	Class	mC_d	Class
C_f^i<1	Low	mC_d< 1.5	Nil to very low degree
1≤C_f^i <3	Moderate	1.5≤ mC_d< 2	Low degree
3≤C_f^i<6	High	2≤mC_d< 5	Moderate degree
Cif ≥6	Very high	5≤mC_d< 8	High degree
IPI <1	Low	8≤mC_d< 16	Very high degree
1≤IPI<2	Moderate	16≤mC_d< 32	Extremely high degree
C_f^i ≥2	High	mC_d≥32	Ultra high degree

Table 2. Standard reference value of some soil heavy metals of Iran for different land-use

Land-use	Cd (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
Pasture	8	15	950*	530	290
Environmental protection	3.9	0.4	950*	50	300

* The mean of earth's crust was used as the reference standard of manganese.

Results

Descriptive statistics on the concentration of trace elements including Cd, Cr, Mn, Ni, and Pb as well as the amount of dust in spring and summer are shown in Table 5. According to this table, Cr had the highest range of changes in spring and summer and Cd had the least change. In addition, Cr had the highest concentration in dust and Cd had the lowest concentration. Trace elements concentration was detected from the lowest to the highest Cd< Ni< Pb< Mn< Cr, respectively (Table 5).

The results of the paired t-test for comparison of the heavy metals concentration in spring and summer are shown in Table 6. As shown in this table, there is only a significant difference between the concentration of Cd and Ni in two seasons.

To determine the relationship between Cd, Cr, Mn, Ni, and Pb in dust in spring and summer and the distance from the factory, Pearson correlation coefficient was calculated. The results are presented in Table 7. As shown in this table, the relationship between the concentration

Table 3. Toxic-response factor (14)

Element	Cd	Cr	Mn	Ni	Pb
Toxic-response factor	30	2	1	5	5

Table 4. The potential ecological risk factor

Risk Degree	E_r^i	Ecological risk degree	RI
Low	E_r^i<40	Low	150<RI
Moderate	40≤E_r^i<80	Moderate	150≤RI<300
Considerable	80≤E_r^i<160	Considerable	300≤RI<600
High	160≤E_r^i<320	Very high	RI ≥320
Very high	E_r^i≥320		

Table 5. Descriptive statistics for heavy metals concentration (mg/kg) in the cement factory during spring and summer 2017

Variable	Season	Min	Max	Mean ±SD
Cd	Spring	4.60	9.26	6.16± 1.74
	Summer	2.16	7.48	3.84±1.69
Cr	Spring	12590.00	53083.33	26196.65±11218.2
	Summer	14582.14	36733.33	21570.53±6284.69
Mn	Spring	282.5	525.61	409.14±80.94
	Summer	351.8	532.5	431.63±53
Ni	Spring	10.03	15.46	13±1.93
	Summer	10.67	19.79	15.20±3.04
Pb	Spring	42.63	73.55	59.3±10.88
	Summer	40.94	67.93	51.34±8.52

of Cd and the distance from the factory was significant ($P<0.01$), indicating that with a probability of 99%, by increasing the distance from the factory, the concentration of Cd decreases. The correlation between the distance from the factory and dust deposited Cd concentration was negative (r= -0.863, $P<0.01$) in spring. There is also a significant negative correlation between the distance from the factory and concentration of dust Cd (r= -0.784, $P<0.01$) in summer.

The spatial variations of heavy metals in deposited dust were interpolated by inverse distance weighting and polynomial function methods (Figure 5). According to this figure, high concentrations of Cd and Pb in the study area were measured in spring and summer 2017. Spatial distribution of other elements shows that the hot spots were located far away from the factory and almost in the north, northeast, and east of the factory. The heavy metals content of the sampling site No.11 shows the highest concentration of Cr. The dust deposition sampler No.11 was located near the tailings and mining waste materials of the factory.

Table 8 indicates the results of the contamination factor (C^i_f) of each heavy metal based on Iranian soil standard for pasture and environmental protection land-use. The results show that the dust deposited around the cement factory area by considering pasture land-use standards in terms of Cr is polluted. Cd is in the moderate level of pollution in spring and Cr is in high pollution level in spring and summer seasons, by assumed the standard reference of environmental protection. However, it has less contamination in terms of other metals.

The risk factor of each heavy metals (E^i_r) and integrated RI of the dust deposited around the cement factory are shown in Table 9. The Cr of falling dust causes high risk for pasture and environmental protection land-use in spring and summer while the Cd is in moderate risk for the protection of the environment land-use in spring.

The results of RI also indicate that the overall risk of heavy metals in the dust deposited around the factory in both seasons is very high for pasture use and environmental protection. IPI was obtained 1746.44 and 1438.03 in spring and summer, respectively, for pasture land-use and 321.61 and 53926.32 in spring and summer, respectively, for environmental protection, indicating that the pollution level of falling dust around the factory is high. In addition, mC_d was obtained 349.57 and 287.84 in spring and summer, respectively, for pasture use and 13098.82 and 10785.65 in spring and summer, respectively, for environmental protection, indicating that the dust is severely polluted. The results of RI, IPI, and mC_d analysis indicated that measurement of the risks caused by heavy metals pollution in the dust deposited around the cement factory can be useful and each of these three indices can be a good alternative for each other in terms of pollution measurement in such environments. Cd and Cr has a main role in the pollution of dust deposited around the factory.

Table 6. The results of comparison of heavy metals concentration (mg/kg) in the dust using paired t-test during spring and summer 2017

Variable	Season	Mean	T
Cd	Spring	6.16[a]	-9.196[d]
	Summer	3.84[b]	
Cr	Spring	26196.65	-1.131[ns]
	Summer	21570.53	
Mn	Spring	409.14	0.923[ns]
	Summer	431.63	
Ni	Spring	13[b]	2.806[c]
	Summer	15.20[a]	
Pb	Spring	59.3	-2.096[ns]
	Summer	51.34	

[a] larger than mean; [b] smaller than mean; ns, not significant; [c] Significant at $P \leq 0.05$; [d] significant at $P \leq 0.01$.

Table 7. Correlation coefficients between heavy metals concentration (mg/kg) and distance from the factory (m) during spring and summer

		Cd	Cr	Mn	Ni	Pb
Distance	Spring	-0.863[a]	0.530[ns]	0.161[ns]	0.288[ns]	-0.315[ns]
	Summer	-0.784[a]	-0.181[ns]	0.279[ns]	0.459[ns]	-0.506[ns]

ns=not significant; [a] significant (P value < 0.01).

Discussion

According to the results, dust deposition of cement factory increases the ecological risk due to trace elements such as Cd and Cr. Cd content in the dust deposited around the factory increased ecological risk in spring but Cr increased ecological risk in two seasons of spring and summer. Cr is not only abundant in the earth's crust, it also enters the environment during the mining process and cement production. Mousavi et al evaluated the concentration of heavy metals in the dust caused by Karun cement factory and concluded that Cr had the highest concentration while Cd had the lowest concentration (16), which is consistent with the results of the present study and a study by Ogunkunle and Fatoba (10). There was no difference in the concentrations of Cr, Mn and Pb between two seasons of spring and summer. However, the concentration of Cd and Ni differed in two seasons. Cd concentration was higher in spring while Ni concentration was higher in summer.

The analysis of the correlation between the concentration of heavy metals and the distance from the factory showed that there is only a correlation between the concentration of Cd and decreased distance from the factory, which indicates the man-made origin and the role of the cement factory in producing Cd as well as the effects of occupational exposure groups, soil, and surrounding plants.

The overall contamination status of the study area, using integrating indices (IPI, mCd, and RI), showed that the pollution level of cement factory is high. Cd and Cr are

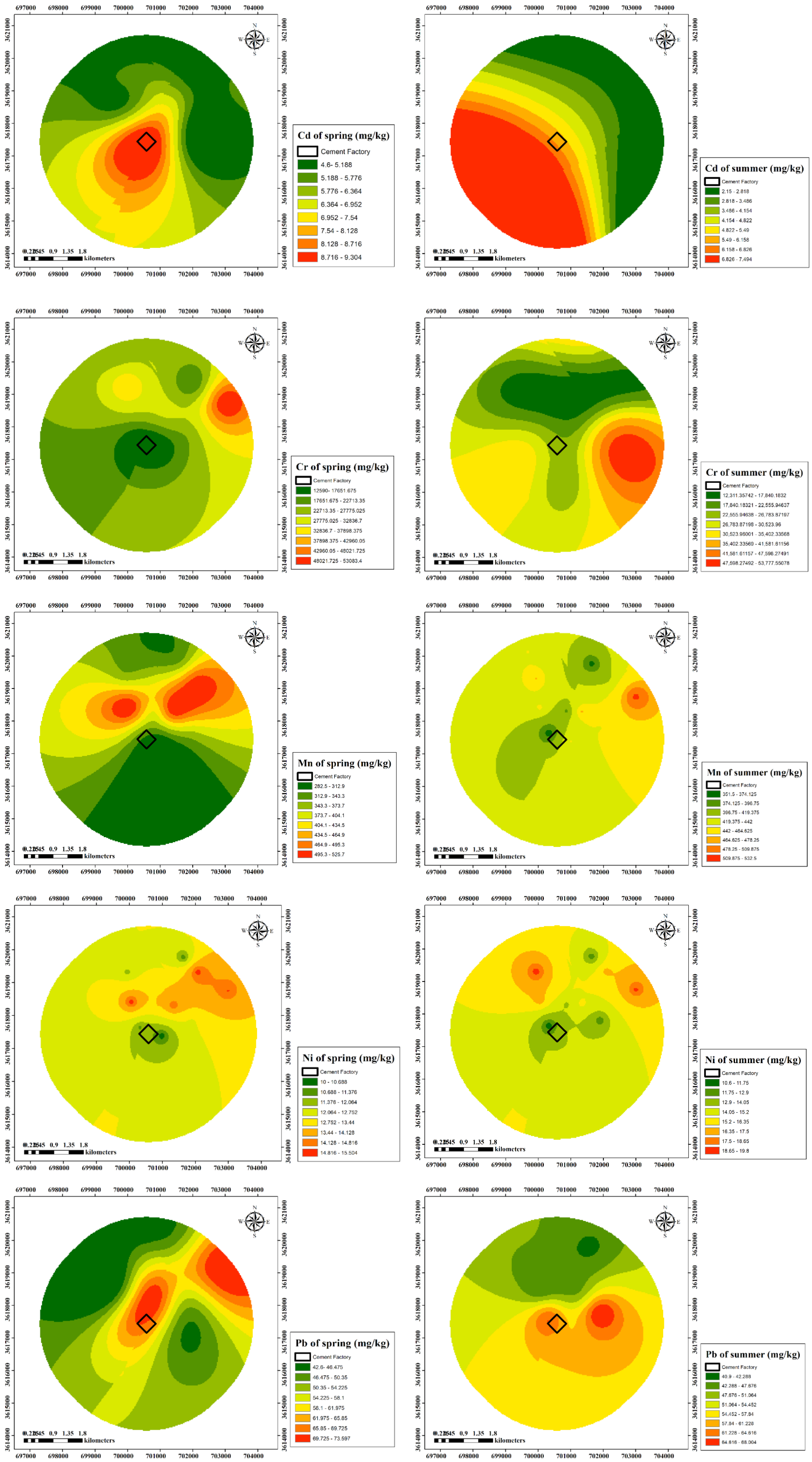

Figure 5. Spatial distribution of Cd, Cr, Mn, Ni, and Pb of the dust deposited during spring and summer 2017.

Table 8. Contamination factor of heavy metals concentrations in the falling dust for pasture and protection land-use

Variable	Season	Land-use	Value	Contamination Factor Level
Cd	Spring	Pasture	0.77	Low
	Summer		0.48	Low
	Spring	Environmental protection	1.58	Moderate
	Summer		0.99	Low
Cr	Spring	Pasture	1746.44	Very high
	Summer		1438.04	Very high
	Spring	Environmental protection	65491.64	Very high
	Summer		53926.32	Very high
Mn	Spring	Pasture	0.43	Low
	Summer		0.45	Low
	Spring	Environmental protection	0.43	Low
	Summer		0.45	Low
Ni	Spring	Pasture	0.02	Low
	Summer		0.03	Low
	Spring	Environmental protection	0.26	Low
	Summer		0.3	Low
Pb	Spring	Pasture	0.2	Low
	Summer		0.18	Low
	Spring	Environmental protection	0.2	Low
	Summer		0.17	Low

the main pollutants. Khaksarnejad et al investigated the contamination index of Cr, Ni, and aluminum in the dust of Ghaen cement factory and reported that the contamination index for all three elements was in the middle class and the IPI was in polluted level (29,30). In addition, the concentration of Cr, Ni, and aluminum in the dust of Ghaen cement factory was assessed and it was concluded that the potential ecological risk of heavy metals in all stations was low, which is inconsistent with the results of this study (21,30).

Conclusion

The single and integrating indices of heavy metals of the cement factory deposited dust detected that the moderate to high risk of pollution. Most risk factors were related to Cr and Cd. Because of the high concentration of Cr in the dust around the factory, there is no significant correlation between the distance from the factory and Cr content of dust deposited at 3 km away from the factory. By increasing the distance from the factory more than 3 km, the concentration of Cr in falling dust decreases. It is concluded that the Cd pollution is due to cement

Table 9. Risk factor (E^i_r) and risk index (RI) of heavy metals concentrations in the falling dust for pasture and protection land-use

Index	Variable	Season	Land use	Value	Class
E^i_r	Cd	Spring	Pasture	23.1	Low
		Summer		14.42	Low
		Spring	Protection	47.38	Moderate
		Summer		29.58	Low
	Cr	Spring	Pasture	3492.89	Very high
		Summer		2876.07	Very high
		Spring	Protection	130983.3	Very high
		Summer		107852.6	Very high
	Mn	Spring	Pasture	0.43	Low
		Summer		0.45	Low
		Spring	Protection	0.43	Low
		Summer		0.45	Low
	Ni	Spring	Pasture	0.12	Low
		Summer		0.14	Low
		Spring	Protection	1.3	Low
		Summer		1.52	Low
	Pb	Spring	Pasture	1.02	Low
		Summer		0.89	Low
		Spring	Protection	0.99	Low
		Summer		0.86	Low
RI	Integrated	Spring	Pasture	3517.56	Very high
		Summer		2891.97	Very high
		Spring	Protection	131033.4	Very high
		Summer		107885	Very high
IPI	Integrated	Spring	Pasture	1.18	Moderate
		Summer		1.11	Moderate
		Spring	Protection	4.71	High
		Summer		4.15	High
mCd	Integrated	Spring	Pasture	349.57	Ultra high degree
		Summer		287.84	Ultra high degree
		Spring	Protection	13098.82	Ultra high degree
		Summer		10785.65	Ultra high degree

production process and the Cr pollution is due to mining and transportation of the primary materials from the mine to the factory. Range management and animal grazing preservation are necessary surrounding the cement factory due to increase the heavy metals of Cr and Cd by falling dust. Cr concentration is high and the kind of oxidation of Cr (Cr-III or Cr-VI) around the factory is very important. Further studies are recommended to analyze plant species at different distance from the factory and soil to determine the level of contamination.

Acknowledgements

This study is extracted from the master thesis of environmental sciences of Yazd University and the authors would like to gratitude all people who contributed in this study.

Ethical issues

The authors have thoroughly observed ethical issues and no data from the study has been or will be published separately elsewhere.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors participated in the data collection, analysis, and interpretation. All authors critically reviewed, refined, and approved the manuscript.

References

1. Rezaei S, Naddafi K, Hassanvand MS, Nabizadeh R, Yunesian M, Ghanbarian M, et al. Physiochemical characteristics and oxidative potential of ambient air particulate matter (PM10) during dust and non-dust storm events: a case study in Tehran, Iran. J Environ Health Sci Eng 2018; 16(2): 147-58. doi: 10.1007/s40201-018-0303-9.
2. Rai PK. Biomonitoring of particulates through magnetic properties of roadside plant leaves. In: Tiwari. Advances in Environmental Chemistry. India: Mizoram University; 2011.
3. Zeleke ZK, Moen BE, Bratveit M. Cement dust exposure and acute lung function: a cross shift study. BMC Pulm Med 2010; 10: 19. doi: 10.1186/1471-2466-10-19.
4. Mosavi Z, Motassadi S, Jozi A, Khorasani NA. Investigating the effects of the dust from cement industry on vegetation diversity and density, case study: Shahroud cement industry. Journal of Health 2015; 6(4):429-38. [In Persian].
5. Sadeghiravesh M, Khorasani N. Effects of dust from the cement industry on vegetation cover case study: Abiek cement factory. Journal of Environmental Sciences and Technology 2009; 11(1): 107-19. [In Persian].
6. Rajabi M, Souri B. Evaluation of heavy metals among dustfall particles of Sanandaj, Khorramabad and Andimeshk cities in western Iran 2012-2013. Iranian Journal of Health and Environment 2015; 8(1): 11-22. [In Persian].
7. Ogunkunle CO, Fatoba PO. Pollution loads and the ecological risk assessment of soil heavy metals around a mega cement factory in southwest Nigeria. Pol J Environ Stud 2013; 22(2): 487-93.
8. Abimbola AF, Kehinde-Phillips OO, Olatunji AS. The Sagamu cement factory, SW Nigeria: is the dust generated a potential health hazard? Environ Geochem Health 2007; 29(2): 163-7. doi: 10.1007/s10653-006-9068-7.
9. Yahaya T, Okpuzor J, Ajayi T. The protective efficacy of selected phytonutrients on liver enzymes of albino rats exposed to cement dust. IOSR J Pharm Biol Sci 2013; 8(3): 38-44.
10. Ogunkunle CO, Fatoba PO. Contamination and spatial distribution of heavy metals in topsoil surrounding a mega cement factory. Atmos Pollut Res 2014; 5(2): 270-82. doi: 10.5094/APR.2014.033.
11. Saeb K, Ghorbanzadeh S, Kardar S, Khademi R. Survey the amount of heavy metals in species leaf around cement production industries (Case study: Payvand Golestan cement factory). Agronomic Research in Semi Desert Regionns 2015; 11(4): 245-54. [In Persian].
12. Wang G, Oldfield F, Xia D, Chen F, Liu X, Zhang W. Magnetic properties and correlation with heavy metals in urban street dust: A case study from the city of Lanzhou, China. Atmos Environ 2012; 46: 289-98. doi: 10.1016/j.atmosenv.2011.09.059.
13. Salamatian S. The studying of falling dust quantitative changes and determination of some physical and chemical properties during winter 2012 and spring 2013 (Case study: Isfahan) [dissertation]. Yazd: Yazd University; 2013. [In Persian].
14. Wan D, Han Z, Liu D, Yang J. Risk assessments of heavy metals in house dust from a typical industrial area in Central China. Hum Ecol Risk Assess 2016; 22(2): 489-501. doi: 10.1080/10807039.2015.1080593.
15. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ. Heavy metal toxicity and the environment. Exp Suppl 2012; 101: 133-64. doi: 10.1007/978-3-7643-8340-4_6.
16. Mousavi MH, Poornia M, Amiri F. Distribution of heavy metals in agricultural soils near the Karoun cement factory, south east of Masjed Soleyman. Geochemistry 2013; 1(3): 215-26. [In Persian].
17. Gupta S, Sharma S. Effect of heavy metal present in cement dust on soil and plants of Nokha (Bikaner). Curr World Environ 2013; 8(2): 299-303. doi: 10.12944/CWE.8.2.16.
18. Amirinejad A, Gholamian N, Parvaz G, Rostamynia M. The effect of dust of Ilam cement factory on the

heavy metals density of field soils in Karzan area. 15th Iranian Soil Science Congress; 2017 Aug 28-30; Isfahan: Isfahan University of Technology; 2017. [In Persian].
19. Solgi E. An investigation on Cd and Pb concentrations of soils around the Kurdistan cement factory in Western Iran. Journal of Chemical Health Risks 2015; 5(3): 179-91. doi: 10.22034/jchr.2015.544107.
20. Lafta JG, Fadhil HS, Hussein AA. Heavy metals distribution and the variation of soil properties around Alqaim cement factory in Anbar Governorate-Iraq. Int J Eng Adv Technol 2013; 3(1): 289-91.
21. Akbari A, Azimzadeh H. Soil chromium concentrations spatial changes around Behbahan cement factory. Journal of Natural Environment 2013; 66(2): 137-46. doi: 10.22059/jne.2013.35846. [In Persian].
22. Montazeri F, Tamrtash R, Tatian MR, Hojati SM. Investigating the concentration of lead, zinc and copper in soil and rangeland species Kochia prostrate (L.) Schrad around Firuzkouh cement factory. Journal of Plant Ecosystem Conservation 2016: 4(8): 145-58. [In Persian].
23. International Organization for Standardization. ISO 11466:1995. Soil quality -- Extraction of trace elements soluble in aqua regia. ISO; 1995.
24. Qingjie G, Jun D, Yunchuan X, Qingfei W, Liqiang Y. Calculating pollution indices by heavy metals in ecological geochemistry assessment and a case study in parks of Beijing. Journal of China University of Geosciences 2008; 19(3): 230-41. doi: 10.1016/S1002-0705(08)60042-4.
25. Abrahim GM, Parker RJ. Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Environ Monit Assess 2008; 136(1-3): 227-38. doi: 10.1007/s10661-007-9678-2.
26. Dolezalova Weissmannova H, Pavlovsky J, Chovanec P. Heavy metal Contaminations of Urban soils in Ostrava, Czech Republic: Assessment of Metal Pollution and using Principal Component Analysis. Int J Environ Res 2015: 9(2): 683-96.
27. Department of Environment, Human Environment Deputy. [cited 2019 Feb 5] Available from: https://www.doe.ir/portal/file/?977240/soil-standard-1.pdf.
28. Estifanos S, Degefa A. Assessing the effect of cement dust emission on the physicochemical nature of soil around Messebo area, Tigray, North Ethiopia. International Journal of Economic and Environment Geology 2012; 3(2): 12-20.
29. Khaksarnejad M, Rezaei MR, Sayadi Anari MH. Assessment of heavy metal pollution indices chromium, nickel and aluminum in dust around Ghaen cement factory. Third International Conference on Environment, Energy and Bio-Defense; 2015 Jun 5; Tehran: Mehr Arvand University; 2015 [In Persian].
30. Khaksarnejad M, Rezaei MR, Sayadi Anari MH. Investigating the indexes of heavy metals, chromium, nickel and aluminum in dust in the vicinity of the Qain Cement Factory. Third International Conference on Environment, Energy and Bio-Defense; 2015 Jun 5; Tehran: Mehrarvand University; 2015.