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Assessment of Environmental Pollution of Heavy Metals Deposited on the Leaves of Trees in Yazd Bus Terminals

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Abstract

There is a lack of information about urban transport activity in adding heavy elements to the environment. This research assesses concentration some of heavy elements in the deposited atmospheric dust in Yazd bus terminals. Dust samples were collected from the green space in the bus terminals of urban transportation. Following the digestion by nitric acid, determination of the total metal concentration of cadmium(Cd), cobalt(Co), copper(Cu), nickel(Ni), lead(Pb), zinc(Zn), chromium(Cr), and manganese(Mn) in the dust were performed via Atomic Absorption Spectrometry. The map representing the spatial distribution of metals was plotted and their source was identified using Pearson correlation coefficients, Principal Component Analysis(PCA), and Cluster Analysis(CA). The findings indicated that the mean concentration of heavy metals in the deposited dust on the leaves of the trees was in the following order; Cd<Co<Ni<Pb<Cu<Zn<Cr<Mn. The map representing the spatial distribution of heavy metal concentrations indicated that the abundance of metals in different stations varies according to their location. Two important sources for the concentration of heavy metals in the deposited dust on the leaves were identified. The sources of Co, Cd, Mn, and Ni were anthropogenic and lithogenic, and the sources of Pb, Zn, Cr and Cu were the traffic and industrial activities. The amounts of EF, CF, IPI and, RI Indicators in residential, commercial, green space and environmental uses were estimated at low to extremely high levels of pollution. The findings showed that the growth of industrialization and human activities had caused contamination of the environment by heavy metals emitted into the atmosphere of Yazd.

Keywords: Heavy metals; Pollution index; Falling dust; Cluster Analysis; Bus terminals; Yazd.

1. Introduction

Heavy metals cause and severely impact on the health of local residents (Ahn et al. 2020). The prolonged exposure to the various well-known environmental factors including heavy metals, air pollutants (particulate matter), nanoparticles containing metals, results in accelerating the progression some of diseases such as Alzheimer (Mir et al. 2020). Air pollution is becoming an increasingly essential environmental issue in today's societies, particularly in developing countries. It poses severe risks to the environment (Esfandiari et al., 2020). In recent decades, increasing population density and economic and industrial activities in cities have increased the volume of traffic and, in turn, increased air pollution. The leading cause of air pollution in growing large cities is the mass transportation of cars that consume more than the standard, fuel, and energy. The heavy traffic load on the streets of these cities is often rooted in problems such as poor traffic management, and it has a traffic culture (Esfandiari et al. 2019). Of significant contributors to urban air pollution are motor vehicles and road traffic (Bucko et al. 2011). Road and roadsides in urban areas are usually polluted with fine particles caused by traffic (Addo et al. 2012). Once emitted into the atmosphere, these particles may remain in the atmosphere for a long time and eventually deposited in the form of street dust on soils of roadsides, buildings and vegetation (Zhang et al. 2006). Most of these dust particles contain heavy metals. Environmentally, the metal contaminants are usually stable and can cause environmental damage through the food chain. Pollutants and particulate matter in the air, including metal particles, cause damage to the environment and plants (Sawidis et al. 2011).

Urban dust is currently used as an indicator of heavy metal pollution in the urban environment. Recently, due to the emissions of various environmental pollutants and their impacts on human health and other organisms, much attention has been paid to recognizing pollutants, how they are transported, function, and availability.

Studies show that the leaves are the most sensitive part of a plant and are useful in absorbing and retaining environmental dust on the leaf surface. Tree leaves are of low sampling costs, most useful and most widely used as bio-collectors for monitoring pollutants in urban and industrial environments (Kardel et al. 2010; Balasooriya et al. 2009). Recently, various investigations have been conducted on the concentration of heavy metals, related to developed countries (Fu et al. 2020; Esfandiari et al. 2020; Sabouhi et al. 2020; Qadeer et al. 2020).

Alsbou and Al-Khashman, (2018), collected samples of falling dust deposited on the palm leaves in Bosnia and Herzegovina and concluded that in terms of the abundance of heavy metals in the dust, Fe, Mn, Zn and Pb have the highest amounts respectively, and Cd has the lowest. Cai and Li, (2019), a detailed investigation to determine levels and sources of HMs contamination in street dust from, China. The results showed that the mixed (traffic and industry) group contributed were the highest of HMs in dust obtained.

Qadeer et al., (2020), measured concentrations, pollution indices of HMs in road dust from two urbanized cities of Pakistan (Lahore and Faisalabad); their result showed that among sites, concentrations of HMs were the highest in dust obtained from the general bus stand in both cities. Xiao et al., (2019), used an environmental index and assessed the HMs pollution risks in urban soils of the steel industrial city of Liaoning Anshan, China. The results indicated that urban soils were at moderate to the high levels of contamination with Cd and Pb. Rapid industrialization has made Yazd, a city in the center of Iran, to face sever air, soil and water pollutions, which can be a serious threat to the health of residents and employees working in the area. No information is available on the status of pollution caused by urban transportation in atmospheric dust of Yazd. Identifying the source and amount of pollutant is useful and effective in managing air pollutants. Therefore, the purpose of this research is to determine the concentration of some the most critical HMs in deposited atmospheric dust and evaluate air pollution that came from urban transportation in city of Yazd.

2. Materials and Methods

2.1 Study Area

Yazd has a cold and dry climate and is with 31° N and 54° E, located in the Pediment of Yazd- Ardakan Plain. The region is at an average altitude of 1216 meters above sea level. According to the 15-year data of Yazd Synoptic Station, the mean precipitation, average temperature and relative humidity in this period are 67.7 millimeters, 19.9 and 27%, respectively (Fathizad et al, 2020). Yazd covers an area of 6336 square kilometers. The population of Yazd is 586,276 people.Yazd can be considered as one of the cities with high traffic. The following seven bus terminal located for transportation inside and outside the city of Yazd are: Emam Ali, Atlasi, Shohaday-e Mehrab, Doulat Abad, Golzar-e Shohada, Quran Gate and Qadir (Esfandiari et al., 2020). The location of the study area in Iran along with Sampling sites(A):(bus terminals and control site(number 4)) and, graphical abstract(B), are shown in Figure 1.

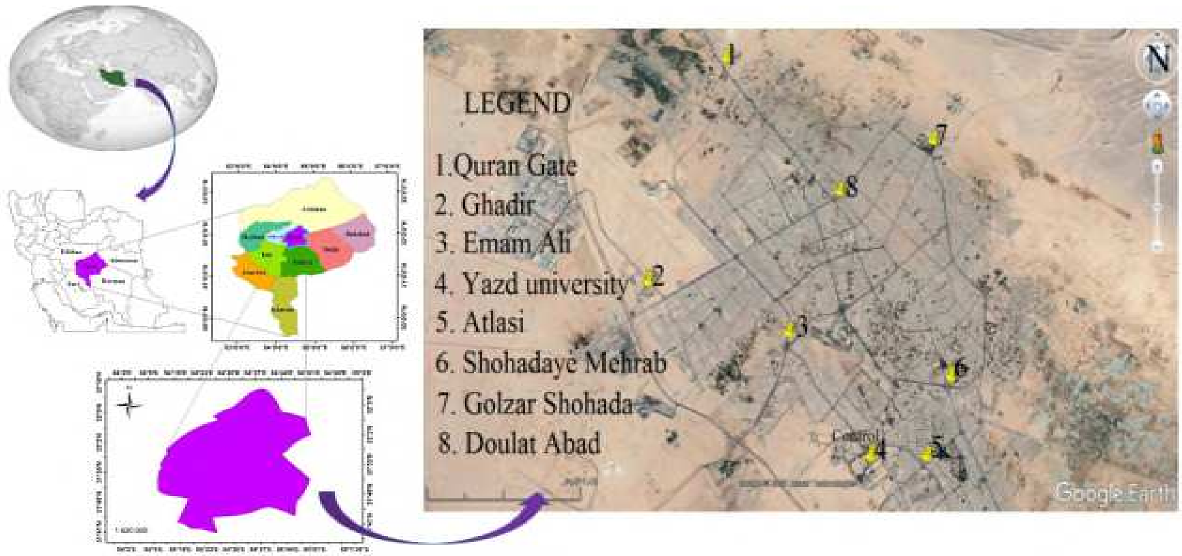
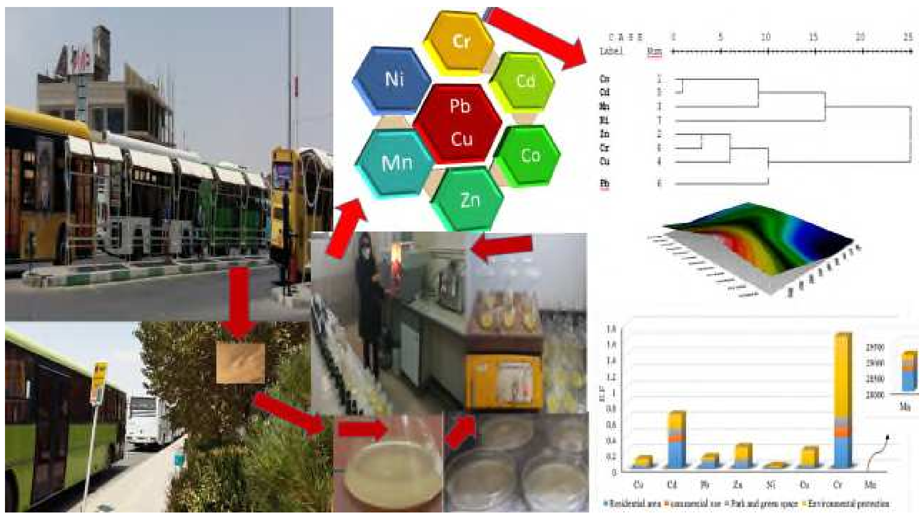


Fig. 1.(A) Location of the Study area, and sampling sites.



(**B**) Graphical abstract

2.2 Sampling and Chemical Analysis

In this study, trees in the green space in the bus terminals were used as a biological indicator and natural collector of falling dust. In this study, deposited samples of falling dust were obtained from the leaves of trees that were 1.5 - 2 meters tall. The collected leaf samples in paper bags were transported to the laboratory and rinsed with distilled water. To estimate the amount of deposited dust, the resulting solutions were centrifuged at 5000 rpm for 5 min. The water was then pipetted off the dust and the samples were placed in an oven at 55 ^{oC} for 24 hours. Finally, the dry particles were weighed with a digital scale with an accuracy of 0.001 g, and acid digestion was performed on the dust samples using the ISO method. Then, the Atomic Absorption Spectrometer (model 330) was used to determine the concentration of the given elements.

2.3 Statistical Analysis

All statistical analyses, including the correlation between variables and multivariate analysis, were performed using SPSS software. The (PCA) and (CA) methods were used to determine the relationship between HMs and their potential sources. In this study, the heavy metal concentrations were standardized through the Z method, and Euclidean intervals were used to calculate similarities in variables. Then, hierarchical clustering was employed using the Ward method of the standardized data set. Due to the lack of specific background standards to assess the degree of pollution in Iran, the average concentration of HMs in the earth's crust was used as the background concentration (Taylor 1995).

3.2 Pollution Assessment

To determine the status of contamination in the study area in terms of commercial use, residential area, green space, and environmental protection, the C_f^i, and in terms of integration, the EF, IPI, RI, and mean of mC_d were calculated.

3.2.1 Contamination index and the Mean of Contamination

C_f^i can be used to indicate the environmental contamination of a specific metal. This factor is calculated by the Eq. (1), (Hakanson, 1980).

$$C_f^i = \frac{C_{0-1}^i}{C_n^d} \qquad (1)$$

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

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

In Eq. (2), C_d 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), (Abrahim and Parker 2008).

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

Where mCd represents the mean of contamination degree and *n* is the number of examined trace elements (mg kg $^{-1}$).

3.2.2 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 -1), B_i represents the base concentration of pollutant of soil parent materials (mg kg $^{-1}$), and *n* is the number of contaminants (Dolezalova Weissmannova, 2015). Table 1 shows the categories of level of C_f^i ,mC_d and IPI.

$$PI_i=\frac{C_i}{B_i} \qquad (4)$$

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

In a recent study, the values of Iran's standard soil trace element were used for comparing rangeland and environmental protection land-use, as shown in Table 2 (Estifanos and Degefa 2012).

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

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

Table 2 Standard reference value of some heavy metals of Iran for different functional areas

Element	Land-use			
	Residential area	business use	Park and greenspace	Environmental protection
Co mg kg -1	50	100	50	20
Ni mg kg -1	20	20	20	20
Cu mg kg -1	400	1100	500	63
Mn mg kg -1	950	950	950	950
Zn mg kg -1	500	5000	500	200
Pb mg kg -1	80	700	290	200
Cd mg kg -1	2	2	8	3.9
Cr mg kg -1	165	500	535	64

* The mean of earth's; crust was used as the reference standard of Mn and Ni.

3.2.3 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 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 (wan et al. 2015). Table 4 shows the classification of the index and potential environmental risk levels.

Table 3 Toxic-response factor

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

Table 4 The potential ecological risk factor

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

3.2.4 Enrichment Factor (EF)

The enrichment factor and contamination indices were used to assess the contamination, which is briefly described here.

EF is an important factor that indicates the degree of human intervention in the natural environment. The passive element is used to calculate this factor. The reference element for calculating the enrichment coefficient is an element that has a strictly geological basis. The reference element, which is necessary to calculate the enrichment factor, has a purely geological origin. In environmental research, the following components are most often used as reference: Al, Fe, Sc, Ti, Zr (Abrahim and Parker 2008). In this research the iron element has been used as a reference element. This coefficient can be calculated based on the following relation:

In this equation, $(C_i/C_{Fe})_{sample}$ is the ratio of the concentration of C_i element to a concentration of Fe element in topsoil sample; $(C_i/C_{Fe})_{background}$ is the ratio of concentrati0on of C_i element to the concentration of Fe element in the reference value (Ergin et al. 1991). Tables 5 indicate the severity of heavy metal contamination using the EF coefficient.

Table 5 Classification of heavy metal contamination intensity with an enrichment factor

Contamination level	Extremely severe enrichment	Very severe enrichment	Severe enrichment	Moderate enrichment	No enrichment	Contamination level
EF Value	EF≥40	20 ≤ EF<40	5 ≤ EF <20	2 ≤ EF<5	EF<1	EF

3.3 Distribution Map of Pollution

The maps representing spatial distribution were created through the Kriging technique using Surfer Software to identify better areas contaminated with heavy metals. Distribution maps can show the risk of contamination by dividing the site based on different levels of metal concentration and using the color separation method. Kriging is a method of estimation based on a weighted moving average. It is the best nonlinear estimator. One of the most important features of Kriging is that it can calculate the errors associated with estimation (Hakimzadeh and Esfandiari 2016).

4. Results

4. 1 Comparison of Means

The concentration of HMs in the falling dust from bus terminals using Duncan's method and comparison of means showed that the highest mean concentration of metal in dust was associated with Mn > Cr > Zn, respectively. According to the findings presented in Figure (2), the highest amount of cadmium is associated with the Qadir bus terminal. There was no statistically significant difference between Qadir and other terminals; the trend of changes in the concentrations of Co and Ni was similar in all sampling stations, and there was no significant difference between them.

The amount of Cu metal in the study area was calculated between 0.33-3.63 (mg kg^{-1}). The highest amount of Cu is associated with Emam Ali and Golzar-e Shohada bus stations. There was no significant difference between them and Darvazeh-e Quran. The lowest amount of Cu is associated with a non-polluted area (Yazd University), which there was no significant difference with Doulat Abad, Shohaday-e Mehrab and Atlasi bus stations. Chaignon et al. (2003) studied the contamination of vineyard soils with Cu, the concentration of Cu in soils was estimated 50-150 (mg kg^{-1}) which exceeded the permissible limits (5-30) (mg kg^{-1}) in soil.

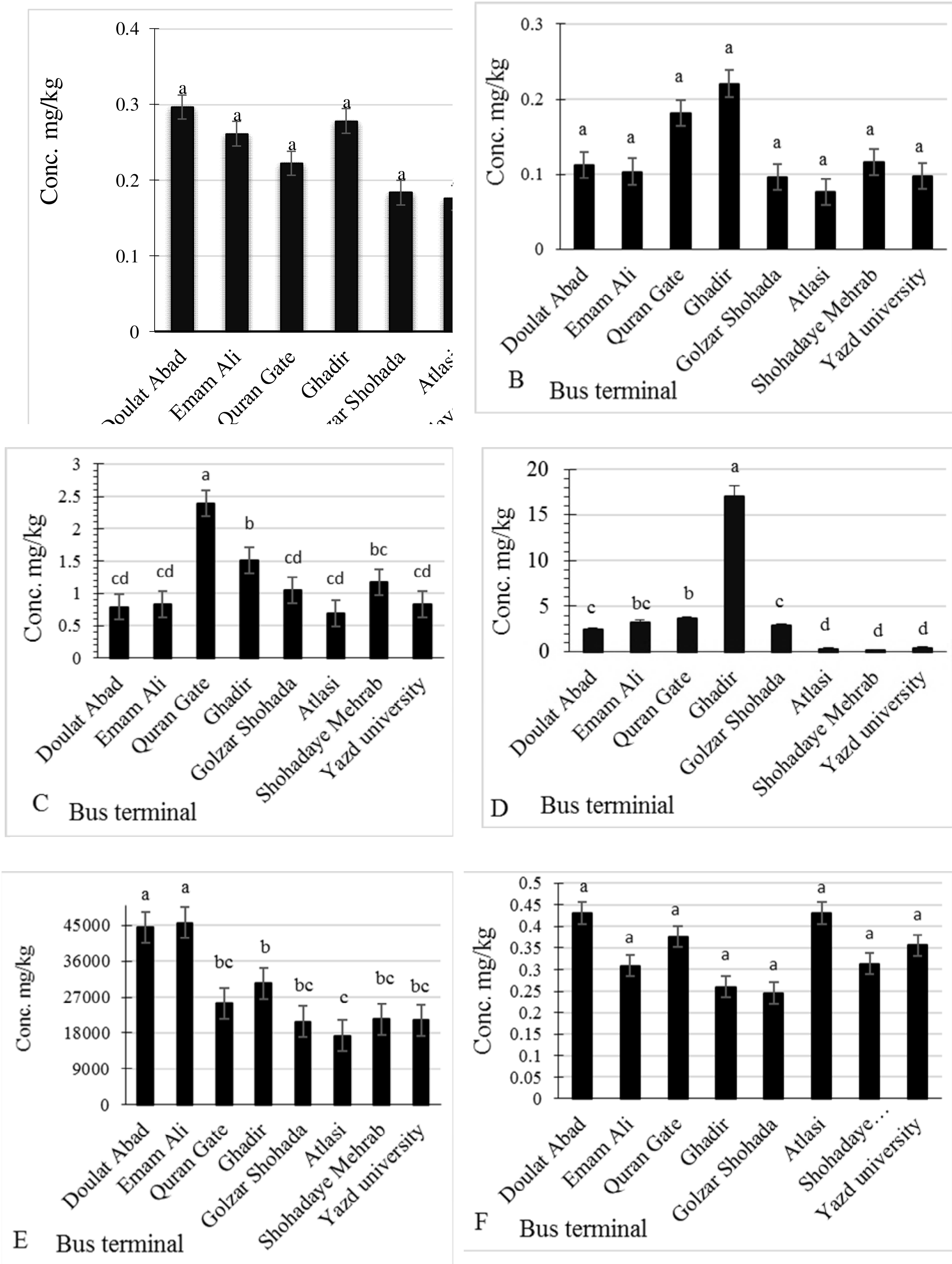
Mn concentration in the studied samples was between 13160-53600 mg kg^{-1}, the highest amount was related to Doulat Abad bus terminaland the lowest amount with Atlasi bus station, which there was no significant difference between them and the non-polluted area (Yazd University).

Lu et al. (2016) estimated that the manganese concentration is around 21.2-1286 mg kg^{-1} in the soils of Guangzhou, China. Khosravi et al. (2018) estimated that the amount of Zn metal was 684.11 in the soil around the lead and zinc metal processing plant in Zanjan. In a study, Santos-Francés, et al. (2017) examined the spatial distribution of HMs of soil in the Northern Plateau of Spain. They reported that mean Zn was 35.31 (mg kg^{-1}), in the soil, which was closely correlated with parent rock, organic matter content and pH. Anthropogenic sources of Zn included industrial activities, mining, fuel wastes, coal and steel polishing (Salminen et al. 2005).

The concentration of Pb in the studied samples was between 2.73-0.23 (mg kg^{-1}). The highest value of Pb was associated with the Quran Gate bus terminal and the lowest value with the non-polluted area (Yazd University). Ayarathne et al. (2018) evaluated the geochemical behavior of metals and their availability. They reported that a higher than average concentration of lead metal in the earth's crust was due to its anthropogenic source.

The concentration of chromium in the studied samples was between 1-22 mg kg^{-1}. The highest value of Cr was related to Emam Ali bus terminaland the lowest value to the non-polluted area (Yazd University), which there was no significant difference with the Doulat Abad bus terminal.

Jadoon et al. (2018) evaluated the highest Cr metal in the dust collected from Jalalabad city. They reported that it has geologic sources.


Conc. mg/kg
0.4
0.3
0.2
0.1
0
Doulat Abad
Emam Ali
Quran Gate
Ghadir
Atlasi
B
Bus terminal
Conc. mg/kg
0.3
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Yazd university
C
Bus terminal
Conc. mg/kg
3
2.5
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1.5
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0.5
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Bus terminal
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Shohadaye Mehrab
Yazd university
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Bus terminal
Conc. mg/kg
0.5
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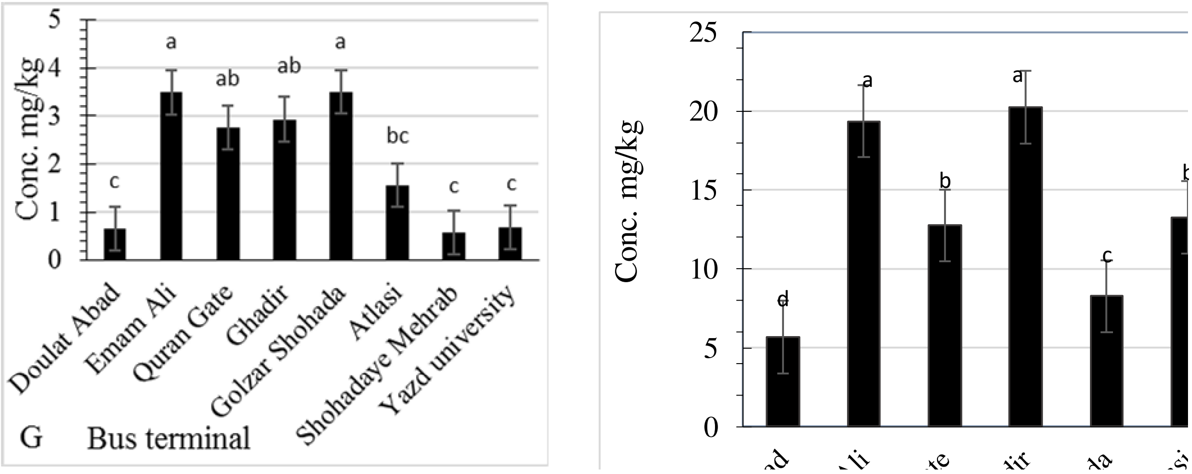


Fig 2 Mean values and ranges of heavy metal concentrations in deposited dust Co(A), Cd (B), Pb (C), Zn(D), Mn(E), Ni(F), Cu(G), and Cr(H) concentrations in the bus terminals. (The same letters in deposited dust indicates that the means were not statistically significant at 0.05%).

4. 2 Distribution Map of Pollution

Plotting a map representing the distribution of HMs to identify geographic patterns is important for understanding the distribution behavior of elements (Tang et al. 2013). To this end, this study used Sulfur Software and Kriging method to investigate the spatial distribution of pollution of different elements (Figure 3). Due to the similarity of the sources, the spatial distribution of cadmium, cobalt and nickel elements was identical. According to Figure 3, the highest amount of lead metal is observed in the Quran Gate bus terminal situated at the entrance of Yazd city. Quran Gate bus terminalis with high traffic that connects Yazd city to adjacent and industrial cities such as Ardakan and Meybod. The dust particles can be transported over long distances; they maybe have originated from the routes that lead to the large and industrial cities such as Isfahan and Tehran.

The density of spatial distribution of Zn and Cr metals is also associated with Qadir bus station. This station is located outside the city, near Yazd Industrial town. This density, compared to other stations, may be due to the high-traffic transit road from Ardakan to Shiraz and Bandar Abbas. Similarly, Ungureanu et al. (2017), concluded that the concentration of lead and zinc elements was in roads with high traffic.

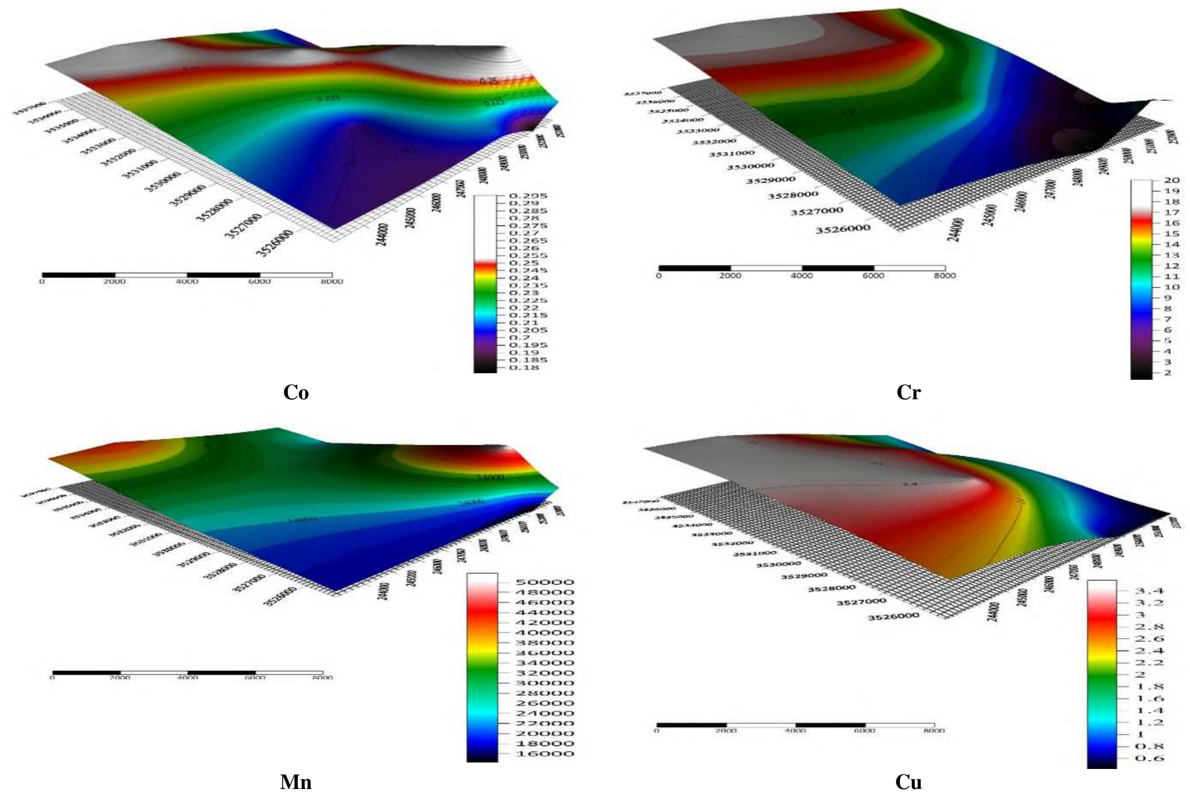
The spatial distribution of Cu metal is around the city, such as the Emam Ali bus terminal. In the southeastern part, the distribution of Mn metal is more visible in the central part of the town.

In general, compared with other bus terminal located in the city of Yazd, the two stations of Qadir and Quran Gate had the highest amount of heavy elements because the direction of the prevailing wind that enters the city of Yazd is from the west and northwest. In addition to transportation factors and urban and human activities, industrial factors have also been very effective in increasing the concentration of these elements. The location of Meybod city in Yazd-Ardakan plain, which is actually a topographic valley and surrounded by mountains, causes strong winds to be channeled from the north and northwest in the area of Meybod city to the west of Yazd city and to create winds carrying dust contaminated with hazardous materials.

Following the examination the pathway of falling dust of the 2010 hurricanes, Lyu et al. (2017), concluded that the direction of the storm is from the northwest to the eastern region of China.

Since the city of Yazd is located in the center of the Iranian plateau, it is one of the arid and desert areas with low annual precipitation, high evapotranspiration, low humidity and erosion winds, which have caused the everyday dust contaminated with heavy elements in this area.

Fengjin et al. (2008) examined the relationship between dust storms and climatic factors in northern China. They stated a negative correlation between the amount of fine dust and relative humidity in the region. They also indicated that precipitation, which is one of the factors influencing dust storm phenomena, has a significant negative correlation with the number of days of dust storms a 1% level.



Co **Cr**

Mn **Cu**

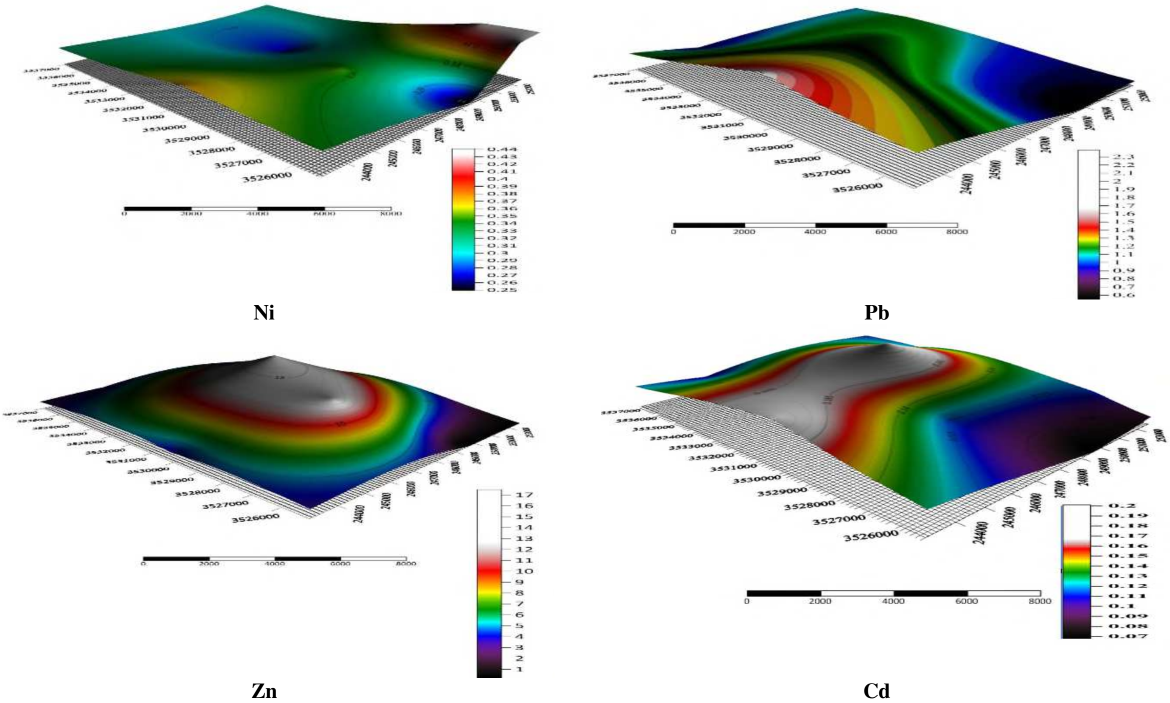


Fig. 3 3-D(three dimensions) heavy metal distribution in deposited dust by kriging method

4. 3 Sources of HMs in Deposited Dust

Relationships between HMs in dust were investigated using the Pearson correlation matrix (Table 6). The relationships between elements could provide information on sources and pathways of heavy metals in the environment (Dragović et al. 2008). Lu and Baim (2010) stated that the correlation coefficients between metals can provide valuable information on the sources of HMs. According to (Table 6) Ni does not have a significant correlation with other metals and in some cases has a negative correlation coefficient with other pollutants. As a result, potential sources of emissions are different from other pollutants. Along with other metals, Ni occurs naturally in the earth's; crust, and human activities usually increase the concentration of this contaminant in water, soil and air. The highest correlation coefficient is associated with Co/Cd and Zn/Cu metals, with correlation coefficients (0.71 and 0.62), respectively. These significant and relatively strong correlations show that these metals came mainly from common sources, which is mostly derived from human activities. Nan (2002) also found a high correlation between Zn with Cu and Pb, metals in wheat grown in contaminated soils in China. Rodriguez Martın (2006) obtained similar results for the correlation between heavy metals.

The Cluster Analysis (CA) method is often combined with the Principal Component Analysis (PCA), method to examine the results and to group individual parameters and variables (Lu and Baim, 2010).

Figure 4, which is derived from the CA method, also confirms this. In general, emission sources can be divided into two groups: Co, Cd, Mn, and Ni in one collection, and Pb, Zn, Cr, and Cu in another, so they probably have the common emission source. Thus, Cr, Cu, Pb, and Zn raised by industrial and anthropogenic pollution resulting from traffic. Cd, Mn, Co and Ni came from lithogenic and anthropogenic sources. The results are in line with the findings obtained from (Koshravi et al. 2018; Lu et al. 2007).

Table 6 Correlation coefficients for heavy metals in deposited dust

	Metal	Cr	Cu	Zn	Mn	Ni	Co	Cd	Pb
Deposited dust (Pearson Correlation)	Cr	1							
	Cu	0.58**	1						
	Zn	0.38	0.62**	1					
	Mn	0.18	0.17	0.19	1				
	Ni	-0.08	-0.09	-0.18	0.08	1			
	Co	0.19	0.06	0.14	0.55**	0.21	1		
	Cd	0.41	0.27	0.39	0.18	0.05	0.71**	1	
	Pb	0.33	0.49*	0.28	-0.04	0.007	0.04	0.53**	1

Significance at 0.05, ** Significance at 0.01

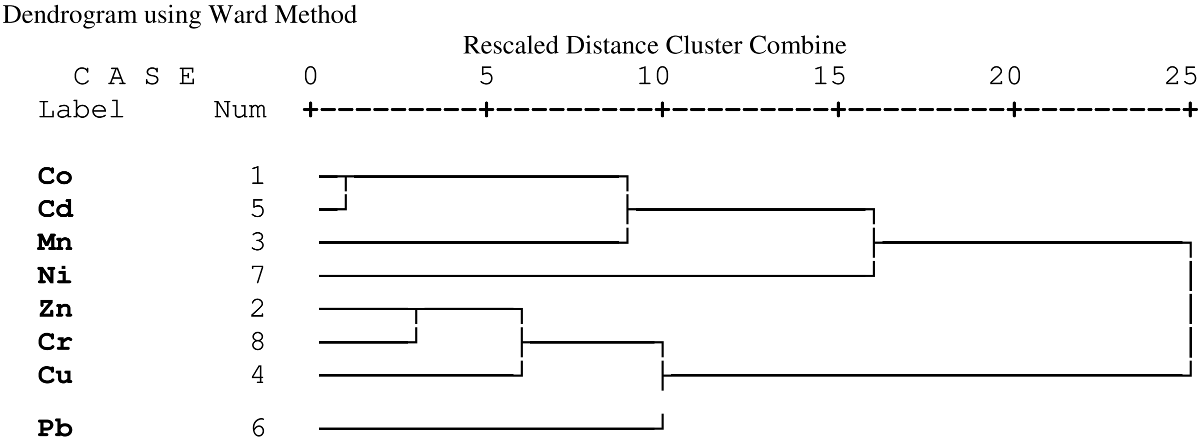


Fig. 4 Hierarchical dendrogram for heavy metals in deposited dust.

For a more accurate evaluation of metal contamination the PCA method was used. The statistical amount of KMO was 0.65, so the number of samples is sufficient for analysis and the data were generally adequate for factor analysis, and there is a significant correlation between variables (Miller 2005).

The Principle Component Analysis method by applying a varimax rotation to determine the sources of HMs in the falling dust resulting from using the factor analysis method to the data is shown in Table 7. In this Table, the results for the first to eighth main components are given. Also, the factor load of each variable before and after the rotation is presented in Table 8. The results indicate that the total variance of two of the specific amounts is more than one, and these two factors justify 57.93% of the total variance Table 7. The first factor explains 33.83% of the total variance and includes the elements of Zn, Cu, Pb, and Cr. The second factor explains 24.10% of the total variance which includes Cd, Co, Mn and Ni.

Proshad et al. (2018) used the PCA method and analyzed the soil of industrial areas in Bangladesh. They divided the measured metals into three separate clusters: 1) Ni, Pb, and Cu. 2) Ar, and cd. 3) Cr.

Ungureanu et al., 2017 stated that Cr and Cd might be affected by both lithogenic and anthropogenic sources, even if they do not exceed the alert threshold values. Xiao et al. (2019) used PAC and CA to classify the sources of heavy metals into three groups, traffic emission, natural source, and both natural and anthropogenic sources. The three different analyses used to identify the sources of pollutant emissions produced almost the same results.

The source of these pollutants is most likely human activities. According to the studies, the most prominent source of Pb emissions in street dust is fuel additives from automobiles (De Miguel et al. 1997). Cr, Cu, and Zn are originated from the erosion of alloys used in vehicles and other surfaces and metal materials (Wei et al. 2010). Industrial activities or the erosion of parts used in vehicles may also be sources for the converting of these elements into street dust (Al-Khashman 2007; Charlesworth et al. 2003). The combustion of fossil fuels and oils used in automobiles are sources of Ni (Wei and Yang et al. 2010).

The results of a study which was conducted on the pollution of HMs in China, indicated that the concentration of elements such as Pb Cu the background values and researchers concluded the anthropogenic source of these heavy metals, (Wu et al. 2015).

Other studies have confirmed the direct relationship between the amount of roadside pollution with heavy elements and the volume of traffic (Doung and Lee 2011 Wu et al. 2014;Mckenzi, 2007).

Table 7 PCA values for the heavy metals in deposited dust

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	2.958	36.975	36.975	2.958	36.975	36.975	2.706	33.831	33.831
2	1.677	20.959	57.934	1.677	20.959	57.934	1.928	24.103	57.934
3	1.040	13.003	70.937						
4	.849	10.613	81.550						
5	.626	7.829	89.379						
6	.554	6.923	96.301						
7	.229	2.862	99.164						
8	.067	.836	100.000						

Table 8 Factor loadings of heavy metals in deposited dust in the study area for factors with an eigenvalue > one.

Metals	Before rotation		After rotation	
	Factor 1	Factor 2	Factor 1	Factor 2
Cr	.710	-.193	-.722	-.141
Cu	.746	-.411	.851	.038
Zn	.679	-.343	.761	.007
Mn	.370	.590	.070	.693
Ni	.030	.495	- .246	.430
Co	.543	.767	.147	.928
Pb	.624	-.286	.686	.020
Cd	.784	.300	.570	.616

4.4 Pollution Assessment

In this study, geochemical indicators were used to grade the levels of dust pollution in the air. The results are shown in Figures 5–8, for residential, commercial, park and green space and environmental protection use.

According to, Figure 5 based on the EF index, the highest amount of dust enrichment with the mentioned metals is associated with Mn metal and with Cr metal. According to the classification, not including Mn metal with a very high degree of enrichment in all four uses, other metals were without enrichment. It doesn't include Cr metal, which was in the moderate degree of enrichment regarding environmental protection.

Proshad et al. (2018) used enrichment indices to calculate contamination load in Tangail ground, located in Bangladesh. The results showed that agricultural soils were heavily contaminated with hazardous elements. In terms of pollution load, the amounts of soil index in all selected sites were less than one, which indicated relative soil pollution. In terms of enrichment index, it had a potential environmental risk.

Solgi (2015) examined the Pb and Cd concentrations in the soil around the Kurdistan Cement Factory and concluded that in terms of pollution index, the soil is not contaminated with heavy metals. The findings are consistent with the results of this study.

The results of the Contamination Factor (CF) for heavy metals in the air showed that the metals Co, Ni, Cu, Zn, Cd, Cr, for all four residential, commercial, green space and environmental protection uses were in the range of low pollution. In the case of lead metal, the level of pollution for the residential area was in the range of moderate pollution. As it is shown in Figure 6, the highest contamination is associated with manganese metal in city of Yazd. Mn was classified in the very high pollution range for all four uses.

A study by Zhuang et al. (2018) showed that the concentrations of Pb, Fe, Ni and Cr in the soil of industrial towns were significantly higher than the permitted standard, which is in line with the present study in relation to lead metal in agricultural use.

Wan et al. (2018) stated that the high degree of contamination of heavy metals indicates severe metal pollution and the anthropogenic source of these metals.

The results of a study also discovered considerable contamination of Zn a high contamination of Cu in road dust samples collected from the asphalt highway in the city of Ulsan, South Korea (Doung and Lee 2011). Wong et al. (2003) stated that the high concentration of HMs in the environment indicates the anthropogenic source of these metals, resulting from the rapid growth of industrialization and urbanization.

Evaluating the general status of ecological risk of atmospheric heavy metals in the urban atmosphere of Yazd city showed that the region ranged from non-polluted to safe in different functional areas (Fig. 7).

Examining the general status of pollution in the study area using the integration of indices (IPI, mCd and RI), showed that the level of pollution in the urban atmosphere of Yazd ranges from low to extremely high (fig. 8).

Similarly, Lafta et al. (2013) concluded the contamination of their study area in Iraq with Co, Cd, and Ni. It was not contaminated with other metals. Ogunkunle and Fatoba (2013) assessed the concentrations and ecological risks of heavy metals (Pb, Cu, Zn, Cd and Cr) in soil in southwestern Nigeria. The results showed that in terms of geo-accumulative index RI, the study area is in a very high risk, which is not in line with the results of this research. Ogunkunle (2014) showed that the value of contamination of Pb and Cu metals in the study area in the mega cement factory is high to moderate. The investigations conducted by Olowoyo et al. (2015) showed that the concentrations of Pb, Ni, Zn, Cr, Cu and Cd were moderate in terms of IPI pollution index. Pollution index indicated that Anshan City's road dust were environmentally (RI index) moderate to highly polluted by heavy metals (Xiao et al. 2019).

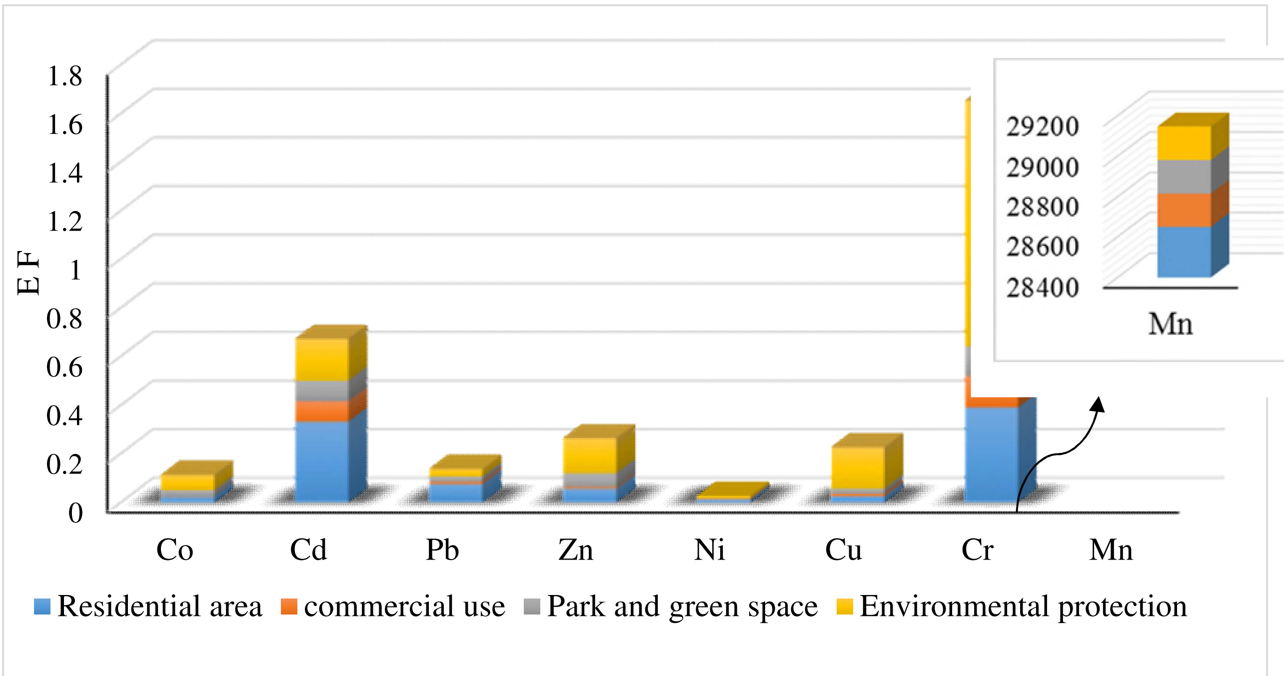


Fig. 5 Enrichment factor value of heavy metals for the assessment of different functional areas

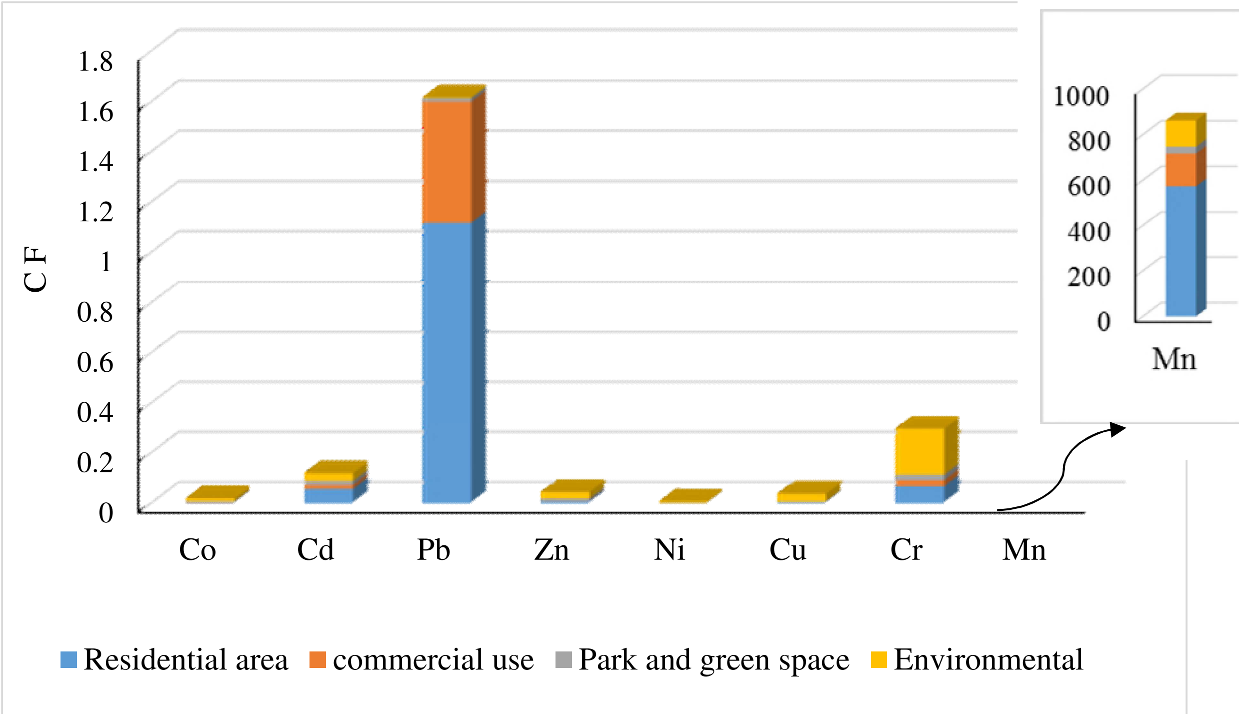


Fig. 6 Contamination factor value of heavy metals for assessment of different functional areas.

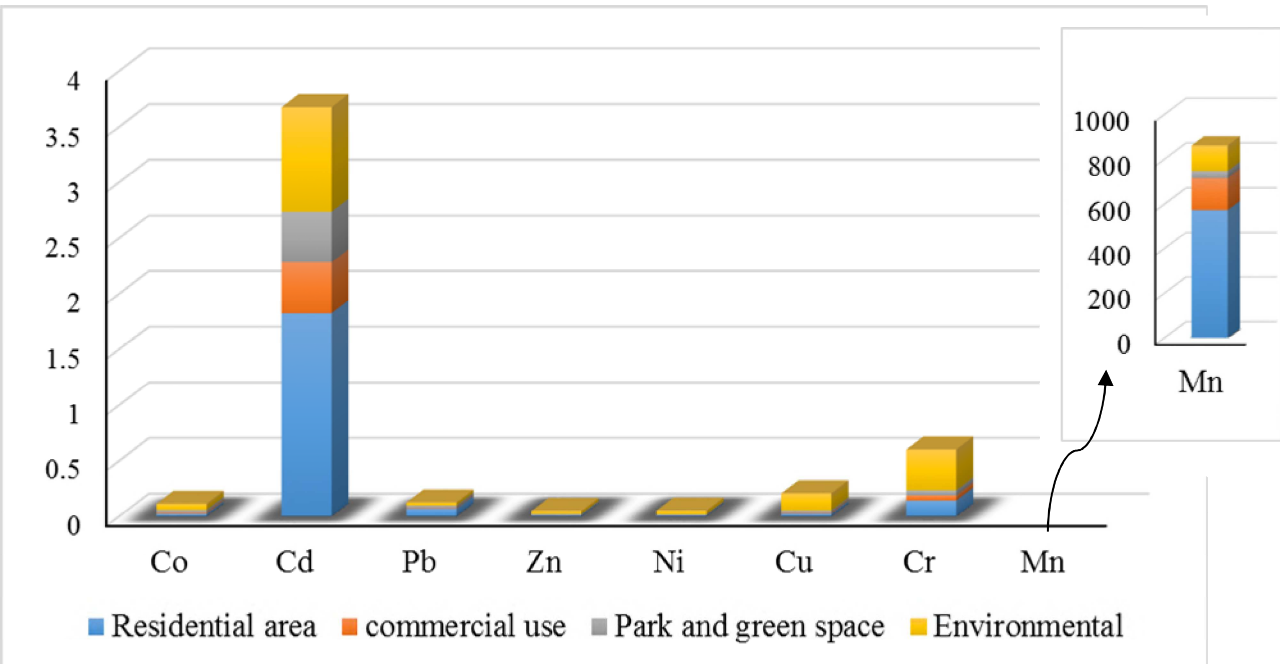


Fig.7 Risk factor value of heavy metals for assessment of different functional areas

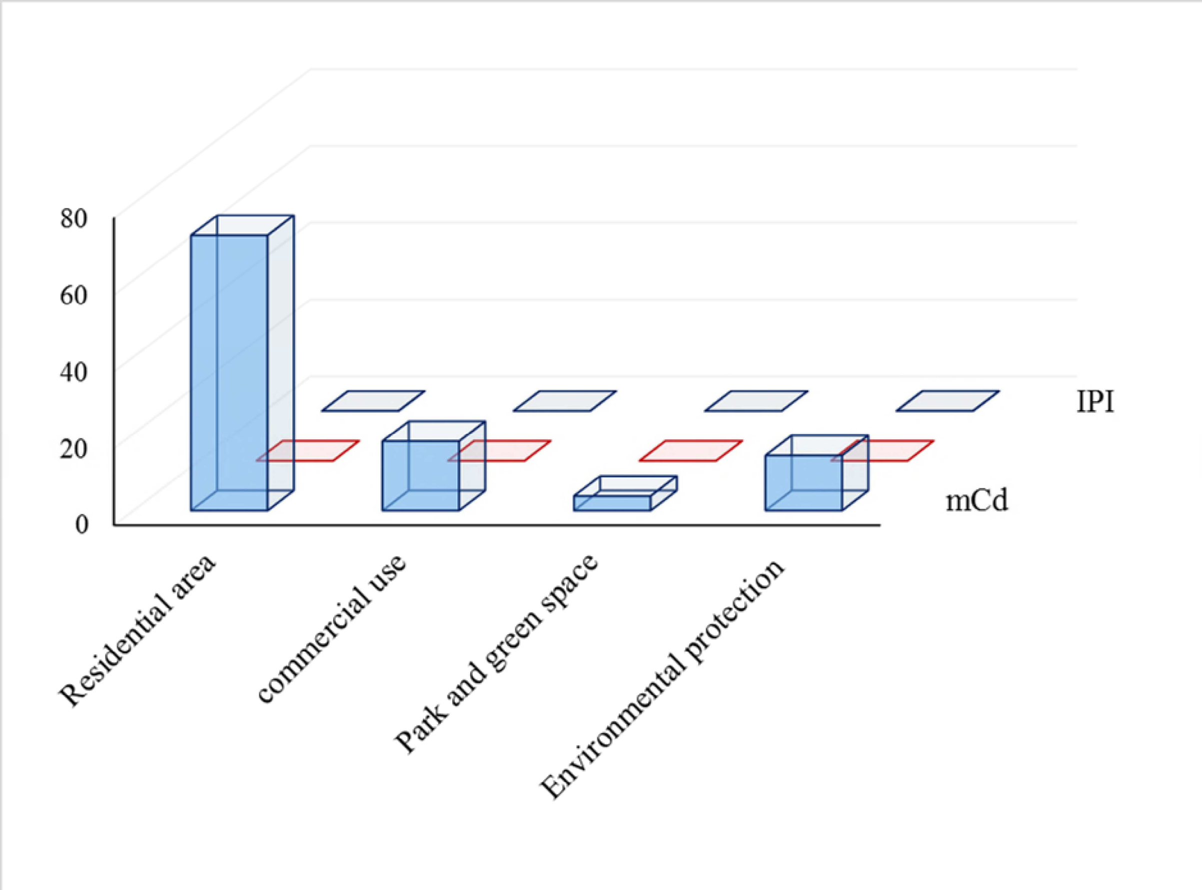


Fig. 8 classification of mC_d RI, IPI indexes, in deposited dust from bus terminals for different functional areas.

5. Conclusion

This study aims to evaluate the role of transportation in the production of some heavy metals cadmium (Cd), cobalt (Co), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), chromium (Cr) and manganese (Mn) in the falling dust. The results suggest that the mean concentration of HMs in the deposited dust in natural sediment traps (leaves of trees in the bus terminal) has increased in the following order from low to high: Cd <Co <Ni <Pb <Cu <Zn <Cr <Mn.

The highest concentration of heavy metals is associated with Qadir bus terminal and Quran Gate bus terminal because these two stations are more exposed to winds that enter Yazd city from the west. In addition to the traffic-related pollution, other pollutants came from brick-making furnaces, mines, industrial centers and industrial towns adjacent to or located along the winds entering Yazd, power plants and glass, steel, pelletizing, ceramic, and tile and other plants built in Ardakan and Meybod, which multi-directional winds are blowing their pollutants towards the city of Yazd.

In this study in addition to office and residential buildings located in the city the canopies constructed in stations that are made of metal can produce heavy metals. The main sources of heavy metals are the wear and tear of the tire and various vehicle parts, car battery and building materials. Human activities determined the severity of these contaminants. The results showed that the emission sources of Cr, Zn, Pb and Cu metals in addition to the combustion of fossil fuels, also originated from other emission sources in the second major cluster of Cd, Ni, Mn, and Co. Ni metal is emitted from heavy fossil fuels and gas oil. There is also the possibility that some elements of this cluster may have originated from the combustion of heavier fuels and other heavy hydrocarbon sources such as bitumen used to cover roadsides. However, since the average concentration of Mn metal is higher than that of the amount existing in the earth's; crust it may have human sources in addition to natural source and local soils. The elements of Mn, and Co have a positive and significant correlation with each other at 1% level. Due to the relatively high level of Mn in the dust, it may have natural and anthropogenic a sources, **to** are not identical with the sources of other metals.

Studying the indices, separately and integrated, on metals in the dust fall collected in the bus stations of Yazd are categorized in the range of low or non-polluted to extremely high pollution. most concerns are related to manganese and chromium metals. These changes can be considered as the result of the lack of urban spaces, open space areas, and the difference of urban surface roughness in terms of buildings' height and urban operations.

According to the obtained results, though currently the average concentration of Ni, Co, Cd, Cu, in the samples of dry atmospheric deposition in Yazd is lower than the permitted limit, the lack of continuous monitoring of heavy metal concentrations in dust and particles suspended in the air can lead to the emission of harmful pollutants such as heavy metals into the atmosphere. Public health is affected by heavy metals through inhalation, ingestion, skin contact and absorption of toxic metals. To this end and to support general health, it is suggested to study the radioactive substances, bacteria fungi in the dust and particles suspended in the air.

Therefore, policymakers and regulators involved in the urban traffic systems and health professionals in Iran, should pay much more attention to the impacts of traffic plans on public health. Moreover, comprehensive investigations are needed to evaluate the effects of traffic and urban transport on health and its determinants this means a community health promotion team should assess the impacts of traffic and urban transport on general health to support, and strengthen health principles and practices from different aspects with the enactment of any law and plan. The team must work in partner with the relevant organizations to implement health promotion strategies by carrying out community-based measures.

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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.

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