J. Hum. Environ. Health Promot. 2017; 2(3):177-185

Journal of Human, Environment and Health Promotion

Journal homepage: www.zums.ac.ir/jhehp

Assessment of the Risk of Non-Cancerous Diseases under the Exposure of Heavy Element in Urban Areas and Troubleshooting Pollutant Sources (The Case of Zanjan)

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A R T I C L E I N F O

Article history:
Received April 18, 2017
Accepted May 27, 2017

Article Type:
Original Article

Keywords:
Urban Air Quality
Heavy Metals
Non-Cancerous Diseases Risk
Zanjan

A B S T R A C T

Background: Heavy metals are the main air pollutants in cities. Therefore, assessment of the risk of exposure to these metals through inhalation, ingestion, and dermal contact on inhabitants of contaminated areas of the world is of great importance.
Methods: A weekly sampling of air particles smaller than 10 microns was performed in a residential area of Zanjan for two years. Risk assessment in the face of heavy metals from inhalation, ingestion, and dermal contact for were measured for two children and adults. After fingerprinting high-risk metals, the air pollutants of the region were analyzed according to the PMF5 model.
Results: The results showed that children at risk assessment (1.40×1000) at the highest concentration of manganese. The PMF5 model results of fingerprinting 15 heavy metals showed that predominant pollutants in the region, included lead and zinc industries with 42.3%, suspended soil with 26.4%, industrial activities with 23.5%, and combustion and fuel with 7.8% of contamination. It was also found that 55.5 percent of manganese emission was associated with lead and zinc industries and 22.4 percent were related to suspended soil.
Conclusion: Risk assessment showed that children were exposed to non-cancerous diseases due to inhalation of manganese particles.

1. Introduction

Heavy metals are the main air pollutants in cities [1] [2]. The main route of their entry into the body is through inhalation and ingestion [3]. Over the past few decades, a lot of research has been done on the concentration, fingerprinting and distribution of sources of these metals, indicating the importance of these metals in terms of health [4] [2, 5-7] [8] [9] [10, 11] [12] [13] [14] [15] [1], therefore, the risk assessment of exposure to these metals through inhalation, ingestion and dermal

To cite: Farahmandkia Z, Moattar F, Zayeri F, Sekhavatjou MS, Mansouri N. Assessment of the Risk of Non-Cancerous Diseases under the Exposure of Heavy Element in Urban Areas and Troubleshooting Pollutant Sources. *J Hum Environ Health Promot*. 2017: 2(3):177-185.

contact on the inhabitants of the contaminated areas of the world is of great importance.

Iran is the fourth largest producer of lead and zinc in Asia after China, Kazakhstan, and India [16]. The city of Zanjan is the lead and zinc production center in Iran and Anguran mine, the largest mine of lead and zinc in Iran, is located in this area. More than 100 factories are associated with the lead and zinc industry around the city.

Several studies have shown high concentrations of heavy metals in the air [17], water [18] and the soil of this area [19]. Therefore, assessment of the health risks related to heavy metals in the air is necessary for residents of this region [20]. In this context, risk assessment has been carried out in China on particulate particles collected at bus stations [21]. Risk assessment has been also conducted on children near the largest coking plant in China [22]. Among the similar investigations in this field, India [23], Oman [2][4][24], and Pakistan [6] can be mentioned.

Therefore, the purpose of this study was to investigate changes in the concentration of suspended PM10 particles and 15 heavy metals, to determine the coefficients of hazard index, and finally to assess the risk of non-cancerous pathogens caused by heavy metals of arsenic, cadmium, chromium, copper, manganese, nickel, Lead, vanadium, and zinc via respiration, ingestion and dermal contact in two age groups including children (4-12 years) and adults (20 to 50 years) in the residential area of the selected city. After fingerprinting high-risk metals, fingerprinting of all of the heavy metals measured was carried out using the PMF5 model, and main sources of air pollutants and the share of each source were identified for managing and controlling the emission of pollutants.

2. Materials and Methods

2.1. Description of the area under study

The selected region is one of the largest cities in northwestern Iran with an area of 81 square kilometers and a population of 480,000 in 2015.

The existence of lead and zinc mines and the development of this industry has been accompanied by the construction of more than 100 lead and zinc factories around the city. The activities of these industries have resulted in the production of large amounts of waste grit in two parts of the city, the geographical location of the city and the location of the factories (Fig. 1), and the location of the waste deposits of the lead and zinc factories (Fig. 2).

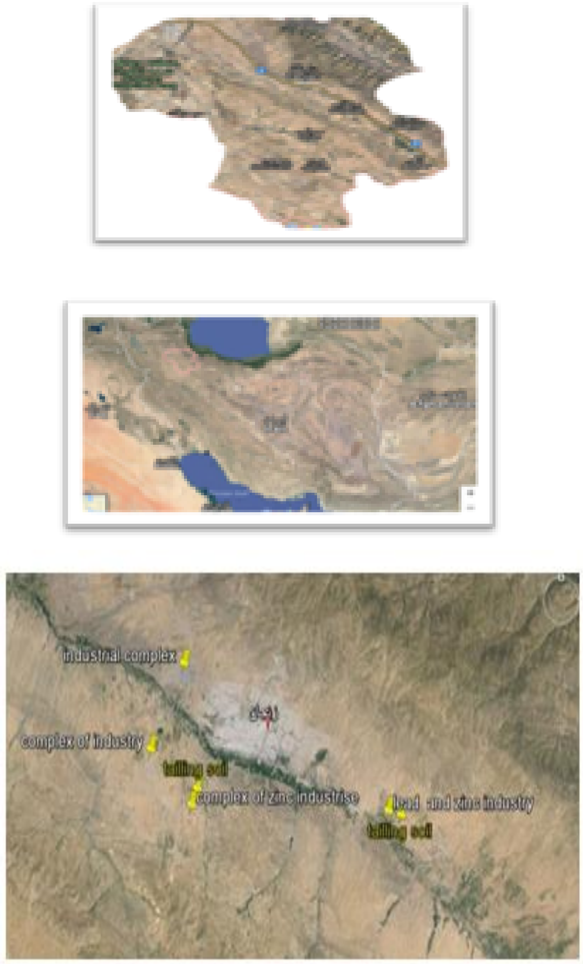

Fig. 1: Map of Zanjan and the location of the surrounding pollutants.

Fig. 2: Map of Zanjan and the location of deposits of lead and zinc waste.

2.2. Sampling

Given the location of metal factories in the region, sampling was carried out in the residential area without traffic in the east of the city. Samples were collected with a high-volume sampler, TCR-TECORA, for PM10 particles, 24 hours at a discharge rate of 16.7 liters per minute. Samples were collected randomly and weekly with a micro-quartz fiber filter. Ninety-six samples were collected during July 2013 to July 2015. The samples were digested using microwave method USEPA-IO-3.1 with the MDS-10-SINEO machine [25] and then the ICP-OES machine was used to measure aluminum, arsenic, calcium, cadmium, chromium, copper , Iron, manganese, nickel, lead, antimony, titanium, vanadium, zinc and mercury.

2.3. Health Risk Assessment

According to the US EPA, arsenic, cadmium, chromium, copper, manganese, nickel, lead, vanadium, and zinc were selected to assess the risk of non-cancerous diseases. Daily intake amounts of metals in the air through ingestion (AD_{ing}), inhalation (AD_{inh}) and dermal contact (AD_{der}) were calculated using Formulas [1], [2] and [3] in the study area. Then, the hazard quotient (HQ) from respiration, ingestion, and dermal contact of children and adults living in the area was assessed using Formula [4]. Finally, the hazard index (HI) of non-cancerous diseases was assessed by adding the risk ratios according to Formula [5] [26-28].

The effective parameters in the above calculations are presented in Tables (1) and (2).

$$AD_{inh} = (IR_{inh}\times c\times EF\times ED)/(BW\times AT) \quad (1)$$
$$AD_{ing} = (IR_{ing}\times C\times EF\times ED\times CF)/(BW\times AT) \quad (2)$$
$$AD_{der} = (SA\times AF\times ABS\times C\times EF\times ED\times CF)/(BW\times AT) \quad (3)$$
$$HQ = (AD)/(RFD) \quad (4)$$
$$HQ1+HQ2+HQ3=HI \quad (5)$$

Table 1: Daily intake formulas [28] [29] [30, 31].

ELEMENTS	ABS	EF	C	AF	AT	BW	CF	ED	SA	IR_{ing}	IR_{inh}
DEFINISTION	Absorption factor	Exposure Frequency	Concentration of metals	Adhesion	Average Time	Body Weight	Unit conversion	Exposure Duration	Area of dermal contact	Ingestion rate	Inhalation Rate
UNIT	---	day/year	mg/m^3	mg/cm^2	day	Kg	kg/mgr	Year	Cm^2	mg/day	m^3/day
Children	all metals =0.01 Arsenic =0.03	350		0.07	365× ED	20	10^{-6}	8	6.125	200	10
Adults	all metals =0.01 Arsenic =0.03	350		0.2	365× ED	65	10^{-6}	35	8.75	100	15

Table 2: Reference Absorbed Dose ($Mg.kg^{-1}.day^{-1}$) caused by inhalation, ingestion and dermal contact [30] [32, 33].

	As	Cd	Cr	Cu	Mn	Ni	Pb	V	Zn
RfD_{ing}	3.00×10^{-4}	1.00×10^{-3}	3.00×10^{-3}	4.00×10^{-2}	4.60×10^{-2}	2.00×10^{-2}	3.50×10^{-3}	5.04×10^{-3}	3.00×10^{-1}
RfD_{inh}	3.01×10^{-4}	1.00×10^{-3}	2.86×10^{-5}	4.02×10^{-2}	1.43×10^{-5}	2.06×10^{-2}	3.52×10^{-3}	7.00×10^{-3}	3.00×10^{-1}
RfD_{der}	1.23×10^{-4}	1.00×10^{-5}	6.00×10^{-5}	1.20×10^{-2}	1.84×10^{-3}	5.40×10^{-3}	5.25×10^{-4}	7.00×10^{-5}	6.00×10^{-2}

2.4. Fingerprinting pollutants with the PMF5

To determine the sources of emission of suspended PM10particles and heavy metals of USEPA-PMF5 model was used. This is a bivariate model that can predict the number of pollutant sources and contribution of each source in the study area by receiving the concentration matrix and the uncertainty matrix [34] [35, 36]. In this study, three scenarios of 4, 5 and 6 pollutant agents (major source of emissions) were considered for the model by entering the required data into the PMF5 model which included PM10 species, aluminum, arsenic, calcium, cadmium, chromium, copper, iron, manganese, nickel, lead, antimony, titanium, vanadium, zinc and mercury.

After running the model with respect to the output of the model in the field of modeling error, the 4-agent scenario was selected using tools such as displacement, bootstrap, and simultaneous implementation of these two factors.

3. Results and Discussion

3.1. Risk Ratio (HQ) and Index (HI) for groups of children and adults in the region

To measure the risk of non-cancerous diseases, the minimum, maximum and average concentrations of arsenic, cadmium, chromium, copper, manganese, nickel, lead, vanadium and zinc in particles of PM10 were used and their health effects in inhalation, ingestion and dermal contact was assessed for two groups of children aged 4 to 12 years old and adults aged 20-50 years old. The assessment showed that the overall trend belonged to HQ_{inh}, HQ_{ing}, HQ_{der} respectively.

According to HQ results, the non-cancerous pathogenicity index (HI) for two groups was calculated and presented in Tables (3) and (4).

The assessment provided in Table (3) for adults in the area shows that at maximum Mn concentrations, the highest respiratory HI was 6.47×10^{-01} and adults are safe within the HI range. However, according to Table 4, children in this area are at risk of exposure to respiratory HI of 1.40×10^{00} at maximum Mn concentrations and the highest HI in children is greater than 1, which means that the levels of heavy metals in terms of non-cancerous pathogens for children in this region are in the hazardous range and can contribute to disease.

3.2. Fingerprinting PM10 emission sources and heavy metals in the region

The USEPA-PMF5 model was used to determine the sources of PM10 and heavy metals emissions. The model was used for Scenarios 4, 5 and 6 pollutant agents (major source of emissions) and the 4- agent scenario was selected based on the best results of the model. The results of the implementation of the 4-agent scenario that had the best results in model implementation are shown in Table 5, indicating that 23.5% of PM10 particles are from industrial activities, 42.5% of lead and zinc industries and deposited waste, 26.4% of re-suspended soil and 7.8% of traffic and combustion. The model showed that 16.4% of manganese is from industrial activities, 55.5% of lead and zinc industries and deposited waste, 22.4%of open soil, and 5.7% of traffic and combustion.

Table 3: Results of the risk of non-cancerous diseases for adults.

METALS		con.mg/m^3	HQ $_{inh}$	HQ $_{ing}$	HQ $_{der}$	HI
As	Max	4.50×10^{-07}	3.32E-04	2.21E-09	2.83E-12	3.32E-04
	Min	1.70×10^{-07}	1.25E-04	8.36E-10	1.07E-12	1.25E-04
	MEAN	2.95×10-07	2.18E-04	1.45E-09	1.86E-12	2.18E-04
Cd	Max	9.79×10^{-06}	2.17E-03	1.44E-08	2.53E-10	2.17E-03
	Min	5.42×10^{-07}	1.20E-04	8.00E-10	1.40E-11	1.20E-04
	MEAN	3.62×10^{-06}	8.01E-04	5.34E-09	9.35E-11	8.01E-04
Cr	Max	1.13×10^{-06}	8.71E-03	5.54E-10	4.84E-12	8.71E-03
	Min	4.20×10^{-08}	3.25E-04	2.07E-11	1.81E-13	3.25E-04
	MEAN	3.92×10^{-07}	3.03E-03	1.93E-10	1.69E-12	3.03E-03
Cu	Max	3.84×10^{-05}	2.12E-04	1.42E-09	8.26E-13	2.12E-04
	Min	7.67×10^{-06}	4.24E-05	2.83E-10	1.65E-13	4.24E-05
	MEAN	1.62×10^{-05}	8.99E-05	5.99E-10	3.50E-13	8.99E-05
Mn	Max	4.18×10^{-05}	6.47E-01	1.34E-09	5.87E-12	6.47E-01
	Min	1.26×10^{-05}	1.95E-01	4.04E-10	1.77E-12	1.95E-01
	MEAN	2.39×10^{-05}	3.70E-01	7.67E-10	3.36E-12	3.70E-01
Ni	Max	5.72×10^{-06}	6.14E-05	4.22E-10	2.73E-13	6.14E-05
	Min	1.13×10^{-06}	1.21E-05	8.30E-11	5.38E-14	1.21E-05
	MEAN	2.65×10^{-06}	2.85E-05	1.96E-10	1.27E-13	2.85E-05
Pb	Max	8.09×10^{-05}	5.09E-03	3.41E-08	3.98E-11	5.09E-03
	Min	1.50×10^{-05}	9.42E-04	6.32E-09	7.37E-12	9.42E-04
	MEAN	3.87×10^{-05}	2.43E-03	1.63E-08	1.90E-11	2.43E-03
V	Max	1.54×10^{-07}	4.87E-06	4.51E-11	5.68E-13	4.87E-06
	Min	9.00×10^{-08}	2.85E-06	2.63E-11	3.32E-13	2.85E-06
	MEAN	1.16×10^{-07}	3.65E-06	3.38E-11	4.26E-13	3.65E-06
Zn	Max	3.41×10^{-04}	2.51E-04	1.68E-09	1.47E-12	2.51E-04
	Min	7.84×10^{-05}	5.78E-05	3.86E-10	3.37E-13	5.78E-05
	MEAN	1.81×10^{-04}	1.33E-04	8.90E-10	7.79E-13	1.33E-04

Table 4: Results of the risk of non-cancerous diseases for children.

METALS		con.mg/m^3	HQ $_{inh}$	HQ $_{ing}$	HQ $_{der}$	HI
As	Max	4.50×10^{-07}	7.19×10^{-04}	1.44×10^{-08}	2.26×10^{-12}	7.19×10^{-04}
	Min	1.70×10^{-07}	2.72×10^{-04}	5.43×10^{-09}	8.52×10^{-13}	2.72×10^{-04}
	MEAN	2.95×10^{-07}	4.72×10^{-04}	9.43×10^{-09}	1.48×10^{-12}	4.72×10^{-04}
Cd	Max	9.79×10^{-06}	4.70×10^{-03}	9.39×10^{-08}	2.01×10^{-10}	4.70×10^{-03}
	Min	5.42×10^{-07}	2.60×10^{-04}	5.20×10^{-09}	1.11×10^{-11}	2.60×10^{-04}
	MEAN	3.62×10^{-06}	1.74×10^{-03}	3.47×10^{-08}	7.44×10^{-11}	1.74×10^{-03}
Cr	Max	1.13×10^{-06}	1.89×10^{-02}	3.60×10^{-09}	3.86×10^{-12}	1.89×10^{-02}
	Min	4.20×10^{-08}	7.04×10^{-04}	1.34×10^{-10}	1.44×10^{-13}	7.04×10^{-04}
	MEAN	3.92×10^{-07}	6.57×10^{-03}	1.25×10^{-09}	1.34×10^{-12}	6.57×10^{-03}
Cu	Max	3.84×10^{-05}	4.60×10^{-04}	9.20×10^{-09}	6.58×10^{-13}	4.60×10^{-04}
	Min	7.67×10^{-06}	9.19×10^{-05}	1.84×10^{-09}	1.31×10^{-13}	9.19×10^{-05}
	MEAN	1.62×10^{-05}	1.95×10^{-04}	3.90×10^{-09}	2.78×10^{-13}	1.95×10^{-04}
Mn	Max	4.18×10^{-05}	$1.40\times10^{+00}$	8.72×10^{-09}	4.67×10^{-12}	$1.40\times10^{+00}$
	Min	1.26×10^{-05}	4.22×10^{-01}	2.62×10^{-09}	1.41×10^{-12}	4.22×10^{-01}
	MEAN	2.39×10^{-05}	8.02×10^{-01}	4.99×10^{-09}	2.67×10^{-12}	8.02×10^{-01}
Ni	Max	5.72×10^{-06}	1.33×10^{-04}	2.74×10^{-09}	2.18×10^{-13}	1.33×10^{-04}
	Min	1.13×10^{-06}	2.62×10^{-05}	5.39×10^{-10}	4.28×10^{-14}	2.62×10^{-05}
	MEAN	2.65×10^{-06}	6.17×10^{-05}	1.27×10^{-09}	1.01×10^{-13}	6.17×10^{-05}
Pb	Max	8.09×10^{-05}	1.10×10^{-02}	2.22×10^{-07}	3.17×10^{-11}	1.10×10^{-02}
	Min	1.50×10^{-05}	2.04×10^{-03}	4.10×10^{-08}	5.87×10^{-12}	2.04×10^{-03}
	MEAN	3.87×10^{-05}	5.27×10^{-03}	1.06×10^{-07}	1.51×10^{-11}	5.27×10^{-03}
V	Max	1.54×10^{-07}	1.05×10^{-05}	2.93×10^{-10}	4.52×10^{-13}	1.05×10^{-05}
	Min	9.00×10^{-08}	6.16×10^{-06}	1.71×10^{-10}	2.64×10^{-13}	6.16×10^{-06}
	MEAN	1.16×10^{-07}	7.92×10^{-06}	2.20×10^{-10}	3.39×10^{-13}	7.92×10^{-06}
Zn	Max	3.41×10^{-04}	5.45×10^{-04}	1.09×10^{-08}	1.17×10^{-12}	5.45×10^{-04}
	Min	7.84×10^{-05}	1.25×10^{-04}	2.51×10^{-09}	2.69×10^{-13}	1.25×10^{-04}
	MEAN	1.81×10^{-04}	2.89×10^{-04}	5.78×10^{-09}	6.20×10^{-13}	2.89×10^{-04}

Table 5: Sources and their contribution to PM10 and heavy metals emission in the region.

Elements	Agent 1 Industrial activities	Agent 2 lead and zinc industries	Agent 3 re-suspended soil	Agent 4 traffic and combustion
PM10	23.5	42.5	26.4	7.8
AL	32.2	20.3	42.6	5
AS	21.8	33.4	26.1	18.7
Ca	25.7	25.3	44.2	4.7
Cd	12.9	2.7	80.6	3.7
Cr	66.0	0	34	0
Cu	19.8	25.5	50.4	4.2
Fe	28.6	26.4	38.6	6.1
Mn	16.4	55.5	22.4	5.7
Ni	39.8	32.1	25.7	2.4
Pb	0	76.5	23.5	0
Sb	27.3	59.2	0	13.6
Ti	39.6	11.2	42.1	7.1
V	23.4	34.1	24.2	18.2
Zn	7.1	64.1	21.2	7.6
Hg	0	0	7.9	92.1

4. Conclusion

The risk of exposure to heavy metals affecting non-cancerous diseases was assessed on residents of an area in two age groups of children aged 4 to 12 years and adults aged 20-50 years. According to the EPA recommendation, if the HI is greater than 1, the concentration of contaminant is extremely harmful for human health [30, 31, 37].

The results showed that adults with the highest HI (6.47E-01) are not exposed to non-cancerous diseases, but children were exposed to non-cancerous diseases due to the concentration of maximum Mn with HI (1.40E + 00). Accordingly, the PMF5 model was used to detect the pollutants and the contribution of each source to PM10 airborne particles. The results showed that the share of lead-zinc industries and deposited waste in the region under study was 42.5% of PM10 particles and the share of re-suspended soil was 26.4%, and 55.5% of manganese emitted from lead and zinc industries and deposited waste, and another 22.4% was emitted from re-suspended soil. Therefore, as a conclusion of the research in this region, it can be stated that in order to reduce the risk of non-cancerous diseases in the children of this region, the share of the emission of lead-zinc industries and deposited waste near the city should be reduced. Further, the proportion of the re-suspended soil emitted in this area should decrease.

References

1. Yongming H, Peixuan D, Junji C, Posmentierc ES. Multivariate Analysis of Heavy Metal

Contamination in Urban Dusts of Xi'an, Central China. *Sci Total Environ*. 2006; 355(1): 176-186.

2. Al-Khashman OA. Determination of Metal Accumulation in Deposited Street Dusts in Amman, Jordan. *Environ Geochem Health*. 2007; 29(1): 1-10.

3. Tripathi R, Raghunath R, krishnamoorthy T. Krishnamoorthy, Dietary Intake of Heavy Metals in Bombay City, India. *Sci Total Environ*. 1997; 208(3): 149-159.

4. Al-Khashman OA. Heavy Metal Distribution in Dust, Street Dust and Soils from the Work Place in Karak Industrial Estate, Jordan. *Atmos Environ*. 2004; 38(39): 6803-9.

5. Banerjee AD. Heavy Metal Levels and Solid Phase Speciation in Street Dusts of Delhi, India. *Environ Pollut*. 2003; 123(1): 95-105.

6. Faiz Y, Tufail M, Tayyeb Javed M, Chaudhry MM, Siddique N. Road Dust Pollution of Cd, Cu, Ni, Pb and Zn along Islamabad Expressway, Pakistan. *Microchem J*. 2009; 92(2): 186-192.

7. Lu X, Li LY, Wang L, Lei K, Huang J, Zhai Y. Contamination assessment of mercury and arsenic in roadway dust from Baoji, China. *Atmos Environ*. 2009; 43(15): 2489-7.

8. Lu X, Wang L, Li LY, Lei K, Huang L, Kang D. Multivariate Statistical Analysis of Heavy Metals in Street Dust of Baoji, NW China. *J Hazard Mater*. 2010; 173(1): 744-749.

9. Zhu Z, Li Z, Bi X, Han Z, Yu G. Response of Magnetic Properties to Heavy Metal Pollution in Dust from three Industrial Cities in China. *J Hazard Mater*. 2013; 246: 189-198.

10. Ajmone-Marsan F, Biasioli M, Kralj T, Grčman H, Davidson CM, Hursthouse AS, et al. Metals in Particle-Size Fractions of the Soils of Five European Cities. *Environ Pollut.* 2008; 152(1): 73-81.

11. Chen X, X Lu, Yang G. Sources Identification of Heavy Metals in Urban Topsoil from Inside the Xi'an Second Ring Road, NW China Using Multivariate Statistical Methods. *Catena.* 2012; 98: 73-78.

12. Laidlaw MA, Taylor MP. Potential for Childhood Lead Poisoning in the Inner Cities of Australia Due to Exposure to Lead in Soil Dust. *Environ Pollut.* 2011; 159(1): 1-9.

13. Li X, Lee S, Wong S, Shi W, Thornton I. The Study of Metal Contamination in Urban Soils of Hong Kong Using a Gis-Based Approach. *Environ Pollut*. 2004; 129(1): 113-124.

14. Xiao-Yan L, Tong-Bin C, Mei L, Yun-Feng X, Bo S. Concentrations and Risk of Heavy Metals in Surface Soil and Dust in Urban Squares and School Campus in Beijing. *Environ Ecol.* 2010; 29(6): 989-7.

15. Shi G, Chen Z, Xu S, Zhang J, Wang L, Bi C, et al. Potentially Toxic Metal Contamination of Urban Soils and Roadside Dust in Shanghai, China. *Environ Pollut*. 2008; 156 (2): 251-260.

16. Farahmandkia Z, Moattar F, Zayeri F, Sekhavatjou MS, Mansouri N. Cancer Risk Assessment and Sourse Identification of Heavy Metals in a Low Traffic Urban Region. *Appl Ecol Environ Res.* 2017*;* 15(3): 687-696.

17. Farahmandkia Z, Mehrasbi,MR, Sekhavatjou MS. Relationship Between Concentrations Of Heavy Metals In Wet Precipitation And Atmospheric Pm^ Sub 10^ Particles In Zanjan, Iran. *Iranian J Environ Health Sci Eng*. 2011; 8(1): 49.

18. Mohammadian M, Nouri J, Afshari N. Nassiri J, Nourani M. Investigation of Heavy Metals Concentrations in the Water Wells Close to Zanjan Zinc and Lead Smelting Plant. *Iranian J Health Environ*. 2008; 1(1): 51-56.

19. Parizanganeh A, P Hajisoltani, Zamani A. Assessment of Heavy Metal Pollution in Surficial Soils Surrounding Zinc Industrial Complex in Zanjan-Iran. *Procedia Environ Sci*. 2010; 2: 162-166.

20. Farahmandkia Z, Moattar F, Zayeri F, Sekhavatjou MS, Mansouri N. Evaluation of Cancer Risk of Heavy Metals in the Air of a High Traffic Urban Region and Its Source Identification *J Hum Environ Health Promot*. 2017; 2(2): 79- 88.

21. Zheng X, et al. Pollution Characteristics and Health Risk Assessment of Airborne Heavy Metals Collected from Beijing Bus Stations. *International J Environ Res Public Health*. 2015; 12(8): 9658-13.

22. Cao S, Duan X, Zhao X, Ma J, Dong T, Huang N. Health Risks from the Exposure of Children to As, Se, Pb and other Heavy Metals Near the Largest Coking Plant in China. *Sci Total Environ*. 2014; 472: 1001-9.

23. Khanna I, Khare M, Gargava P. Health Risks Associated with Heavy Metals in Fine Particulate Matter: A Case Study in Delhi City, India. *J Geosci Environ Prot*. 2015; 3(02): 72.

24. Al-Khashman OA. The Investigation of Metal Concentrations in Street Dust Samples in Aqaba City, Jordan. *Environ Geochem Health*. 2007; 29(3): 197-207.

25. Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, in Selection, Preparation and Extraction of Filter Material. *USEPA*. 1999; C.m. IO-3.1: Cincinnati, OH.

26. Guidelines for the Health Risk Assessment of Chemical Mixtures. *USEPA Fed Regist*. 1986; 51(185): 34014-11.

27. Risk Assessment Guidance for Superfund: Process for Conducting Probabilistic Risk Assessment, in Chapter l, part A. *USEPA Washington, IX*. 2001; U. 540-R-02002.

28. Standard Operating Procedures (SOPs) for Residential Exposure Assessments. *USEPA, Washington, DC: Office of Pesticide Programs*. 1997.

29. Guidance on Cumulative Risk Assessment. Planning and Scoping. *USEPA, Washington, DC: Sci Policy Council*. 1997.

30. Asian American & Pacific Islander Initiative Outreach Strategy. *USEPA, Washington, DC: Office of Administration and Resource Manag*. 2001; EPA/202/K-01/003.

31. Draft Protocol for Measuring Children's Non-Occupational Exposure to Pesticides by all Relevant Pathways, in National Exposure Research Laboratory. *USEPA, Office Res Dev: Res Triangle Park, NC*. 2001; EPA/600/R-03/026.

32. Ferreira-Baptista L, De Miguel E. Geochemistry and Risk Assessment of Street Dust in Luanda, Angola: A Tropical Urban Environment. *Atmos Environ*. 2005; 39(25): 4501-11.

33. Wei X, Gao B, Wang P, Zhou H, Lu J. Pollution Characteristics and Health Risk Assessment of Heavy Metals in Street Dusts from Different Functional Areas in Beijing, China. *Ecotoxicol Environ Saf*. 2015; 112: 186-192.

34. Norris GA, Duvall R, Brown SG, Bai S. Positive Matrix Factorization (PMF) 5.0 Fundamentals and User Guide Prepared for the US Environmental Protection Agency. *USEPA, Office Res Dev, Washington. DC*. 2014; *EPA/600/R-14/108*.

35. Paatero P, Eberly S, Brown SG. Methods for Estimating Uncertainty in Factor Analytic Solutions. *Atmos Meas Tech*. 2014; 7(3): 781.

36. Paatero P. Least Squares Formulation of Robust Non-Negative Factor Analysis. *Chemometr Intell Lab Syst*. 1997; 37(1): 23-35.

37. Risk-assessment Guidance for Superfund, in, H.H.E. Manual. *USEPA, Office of Solid Waste and Emerg Response: Washington, DC*. 1989; EPA/540/1-89/002.