



# Evaluation of Non-Carcinogenic Risk of Pb, Cd, and As in Air Suspended Particles of Baharestan City, Isfahan

Amir Hossein Baghaie<sup>1,\*</sup> and Ardeshir Khosravi-Dehkordi<sup>2</sup>

<sup>1</sup>Department of Soil Sciences, Arak Branch, Islamic Azad University, Arak, Iran

<sup>2</sup>Department of Environmental Sciences, Faculty of Natural Resources, Isfahan University of Technology, Isfahan, Iran

\*Corresponding author: Department of Soil Sciences, Arak Branch, Islamic Azad University, Arak, Iran. Email: a-baghaie@iau-arak.ac.ir

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## Abstract

**Background:** Entrance of heavy metals into the respiratory system has adverse effects on human health. Accordingly, measuring metals concentration in places and times is necessary.

**Objectives:** This study was done to evaluate the non-carcinogenic risk of Pb, Cd, and As in air suspended particles of Baharestan city, in Isfahan, during 2016 - 2017.

**Methods:** In order to evaluate the non-carcinogenic risk of heavy metals in air suspended particles (PM<sub>10</sub>), sampling was performed using a SKC pump with a low volume (1.5 L/min) and 37 mm membrane filter. Sampling was carried out on average every three days during 24-hours in May - June, July - August, October - November, and January - February; finally, the concentration of Pb, Cd, and As was determined using atomic absorption spectrometry (AAS) and hydride generation atomic absorption spectrometry (HGAAS), respectively. The acute and chronic non-carcinogenic risk of heavy metals sorption in the air was evaluated using the EPA method.

**Results:** The highest and lowest Pb concentration belonged to May - June and October - November, with the mean concentration of 0.25 and 0.14 mg/kg, respectively. For Cd it was 0.017 and 0.009 mg/kg, respectively. Similar results were found for the air suspended particles. The highest and lowest Cd non-carcinogenic risk was observed for permanent residents of Baharestan city and the non-dormitory students of this city with the mean of  $3.1 \times 10^{-5}$  and  $1.4 \times 10^{-5}$ , respectively.

**Conclusions:** The results of this study showed that the non-carcinogenic risk of heavy metals was lower than the standard level during the study years. However, heavy metal accumulation can threaten human health, which needs more consideration.

**Keywords:** Non-Carcinogenic Risk, Pb, As, Cd, Baharestan

## 1. Background

The industrial advances and the mechanization of human life in different societies have never been without any harm or effect. Air pollution in industrial areas seriously threatens the human health and therefore, it is more and more considered by the researchers (1-3). Among the air pollutants, suspended particles, especially in large cities, has been increasingly considered (4, 5).

Suspended particles are dangerous for human health at high concentrations, for example, they cause different diseases such as upper respiratory tract infection, pulmonary inflammation, and bronchitis (6, 7). Heavy metals are one group of compounds present in the air with a high risk for human health (8, 9). The presence of heavy metals in greater concentration than the standard levels causes environmental problems and damages the inhabitant's

health of that site and the ecosystem (10, 11). Heavy metals have different effects on human health such as neurological disorders, different types of cancers, and skeletal problems. On the other hand, the ability of bio-accumulation of heavy metals in plants and animals and their entry into the food chain will increase the risk of their toxicity (12, 13). Considering the environmental problems of heavy metals on air quality, measuring the concentration of these elements in the air and assessing their potential health risk is necessary (14).

Risk assessment is a process in which the potential health risk is estimated (15). Environmental management decisions are based on the risk assessment and risk management. Generally, risk assessment provides scientific principles for environmental legislation. The general objectives of risk assessment are the attention to the state of soil, air, water, or sediment contamination, the study of all

possible ways, which cause the organisms exposure to contamination sources, estimate the amount of pollutants entering the body of living organisms (16-18), and determining the negative effects of contaminant on organisms.

The risk assessment of heavy metals was investigated in four stages: Hazard identification, assessment of the baseline value, considering the contact pathway, and finally determining the risk index. Firstly, the harmful effects of chemical materials on human health are recognized. Then, the basic level is determined for the pathogenicity of the elements. In the third step, various ways of contacting chemicals, i.e. sorption from the oral or the skin pathway and inhalation of suspended particles are investigated. Finally, the risk factor for carcinogenic and non-carcinogenic diseases is determined (19).

Barin and Chavoshi investigated the risk of Cu and Zn in wheat and rice (with the mean concentration of 8.4 and 11.4 mg/kg, respectively) cultivated around the Irankouh mine in Isfahan and concluded that the consumption of these products does not have any problem for the human body (19). Shafie-Pour et al. evaluated the air pollution risk of the Beihaqi Passenger Terminal by modeling method and reported that the non-carcinogenic risk from heavy metals sorption for drivers and terminal staff was higher than the safe level (20). Noorpoor and Sadri Jahanshahi determined the risk of heavy metals in the air of Tehran's Enghelab street, and reported that the non-carcinogenic risk index, as a result of entering heavy metals into the breathing system, is below the safety level (21). Studies on airborne diseases show that more than 2 million early deaths per year (more than 50% of deaths are attributed to the Asian continent) are due to air pollution. More than half of the deaths are attributable to industrialized and developing countries (22).

Indicators such as air quality index (AQI) are often used to indicate air pollution, which is designated by the environmental protection agency (EPA). The main purpose of these indicators is to determine the effects of air pollution on human health. The AQI indicator is usually used to determine the amount of five different pollutants, such as  $PM_{10}$ ,  $NO_2$ ,  $SO_2$ ,  $O_3$ , and  $CO$  (23). Majlesi Nasr et al. investigated air pollutant concentrations and air quality index in Shiraz during 2011 - 2013 and concluded that  $NO_2$  concentration was increased due to the fact that the number of gas fuel automobile also increased (23). Allahyari et al. with the study of air pollution condition and comparing in different areas of Mashhad in winter 2011, mentioned that AQI index can be a good factor to indicate air pollution condition (24).

Baharestan is located 20 km southeast of Isfahan, along the Isfahan-Shiraz road, with a population of about 79000, and with three universities. It is noted that in the city of Baharestan, there is not only no data regarding the state of air pollution to heavy metals, however, also no monitoring station for investigation air quality. Considering the population increasing in this city as well as the existence of universities and industrial offices, such as the Mobarakeh industrial zone in this area, it is necessary to study the status of air pollution to heavy metals in this region.

## 2. Objectives

This study was conducted to evaluate the non-carcinogenic risk of Pb, Cd, and As in air suspended particles in Baharestan city during 2016 - 2017.

## 3. Methods

In order to determine the concentration of Pb, Cd, and As, sampling of the air suspended particle ( $PM_{10}$ ) in the first phase of Baharestan (between the entrance of Baharestan until Valiasr square) was carried out during 2016 - 2017. Sampling was performed using the SKC pump with a low volume (1.5 L/min) and a 37 mm membrane filter (25). Sampling was done on average every three days during 24-hours in May - June, July - August, October - November, and January - February, and finally the concentration of heavy metals of Pb and Cd was determined using atomic absorption spectrometry (AAS) after digesting with three acids (perchloric acid, fluoroboric acid, and chloride acid); according to Hosseini et al. (25). It is mentioned that for measuring As, the hydride generation atomic absorption spectrometry (HGAAS) was used. It should be noted that sampling was also done during the days that were announced by the Meteorological Organization as dusty days (25, 26). In total, 61 samples were taken; 40 days were non-dusty days (concentrations less than  $250 \mu g/m^3$ ) and 21 days were dusty days (27) (particle concentration below  $250 \mu g/m^3$ ).

The Pb, Cd, and As non-carcinogenic hazard quotient (HQ) was calculated into two groups (acute and chronic effects base on the reference concentration (RFC)) using the Equation 1 (25, 28):

$$HQ = CDI / RFC \quad (1)$$

Where CDI is the amount of heavy metals daily sorption (mg/kg body weight per day) via inhalation pathway, which was calculated by the Equation 2:

$$CDI = (CA \times EF \times ED) / AT \quad (2)$$

Where:

CA: Heavy metal concentration ( $\mu\text{g}/\text{m}^3$ )

EF: Exposure frequency (days year<sup>-1</sup>): In this study, it was assumed to be 360 and 180 days in the year for permanent resident and students, respectively.

ED: The exposure duration (y): A 30 and 4 years duration was considered for permanent residents and dormitory or non-dormitory students of Baharestan University, respectively.

ET: The daily exposure hours: This was assumed 24 hours per day for permanent residents (group 1), dormitory students (group 2), and 8 hours per day for non-dormitory students (group 3).

AT: The averaging time (day) for non-carcinogenic effects ( $\text{ED} \times 365$ )

In this study, the evaluation of non-carcinogenic chronic risk was calculated based on the reference concentration (RFC) for Pb, Cd, and As, which was  $1.5 \times 10^{-1}$ ,  $1.0 \times 10^{-2}$ , and  $1.5 \times 10^{-2} \mu\text{g}/\text{m}^3$ , respectively. The reference concentration (RFC) for non-carcinogenic acute risk of Cd and As was  $3.0 \times 10^{-2}$  and  $2.0 \times 10^{-1} \mu\text{g}/\text{m}^3$ , respectively (25).

Air quality index (AQI), according to the suspended particle ( $\text{PM}_{10}$ ), was calculated as it was mentioned by Heidarnejad et al. (29).

#### 4. Results

Regardless the studied years, the highest concentration of  $\text{PM}_{10}$  particles was observed in May - June while the lowest amount of that was in July - August (Table 1). In addition, the concentration of  $\text{PM}_{10}$  particles significantly increased in 2017 as compared to 2016. The similar results were observed for AQI index (Table 1).

The heavy metals concentration was higher in dusty comparative to non-dusty days (Table 2). The highest and lowest heavy metals concentration in the air was observed in May - June and October - November, respectively. Regardless of months and years, As and Cd had the greatest and lowest concentration, respectively. Heavy metals concentration increased significantly in 2017 relative to 2016.

The highest and lowest acute or chronic non-carcinogenic risk of heavy metals belonged to As and Cd, respectively, which increased in 2017 relative to 2016. It should be noted that among the groups studied (group 1, 2 and 3), the highest and lowest chronic and acute non-carcinogenic risk was observed in group one and three, respectively (Tables 3 and 4).

#### 5. Discussion

As mentioned, the highest AQI index, based on  $\text{PM}_{10}$  suspended particles was observed in May - June, which is categorized in an unhealthy group for all individuals (31). In January - February, it was unhealthy for susceptible and general individuals, based on the AQI index (32) during 2016 and 2017, respectively. The increasing of  $\text{PM}_{10}$  suspended particle can be related to the decrease in rainfall during the studied years. Reducing rainfall by increasing soil erosion can increase the amount of suspended particles in the air, which can be dangerous for human health (25). However, the role of decreasing temperature and air inversion phenomenon on increasing suspended particles in January - February cannot be ignored (32). The similar results for the concentration of heavy metals confirm this matter clearly. The lowest  $\text{PM}_{10}$  particles in the present study were between October - November, which may be due to the humidity increasing in these months. It should be noted that in October - November, the AQI index was classified as the clean air (33) and the amount of  $\text{PM}_{10}$  was below the standard level (34).

Moattar et al. investigated the amount of heavy metals in the airborne of Atomic Energy Agency site and reported that the increasing heavy metal concentration in January - February could be related to the inversion phenomenon. However, the concentration of heavy metals studied in their research was below the standard level (32). According to their results, the highest and lowest heavy metal concentration belonged to the winter and autumn season (32), which is very similar to our results.

The concentration of heavy metals in dusty relative to non-dusty days showed a significant difference ( $P = 0.05$ ), indicating that airborne particles could be a significant factor in the transferring of pollutants, where the origin of this pollutant could be due to the soil pollution or different industrial activities in the zone (35). Hosseini et al. evaluated the health risks of airborne heavy metal particles in the Kurdistan University of Medical Sciences and reported that the highest  $\text{PM}_{10}$  particles was in May - June, which could be related to the dust events in the middle east, which also reduce the Sanandaj air quality (25). Farahmand Kia et al. studied the heavy metals in the atmospheric deposition in Zanjan, west of Iran, and concluded that the industrial sources of heavy metals play the main role in concentration of heavy metals in wet and dry atmospheric precipitation in Zanjan (36).

Nazarpur et al. investigated the Pb and Cd accumulation on the surface leaves of pine trees in the cold and hot seasons and reported that the greater heavy metal concen-

**Table 1.** Descriptive Analysis of PM<sub>10</sub> Particles ( $\mu\text{g}/\text{m}^3$ ) and Air Quality Index in the Study Area

Month Sampling	Number of Sample	Max	Min	Range	Mean	AQI	USEPA Standard (30)
<b>2016</b>							
May - June	19	840.3	85	755.3	284.1	165	100
July - August	14	145.0	37.3	107.7	78.2	62	100
October - November	12	58.0	28.0	30.0	44.9	41	100
January - February	16	720	72	648	248.3	147	100
<b>2017</b>							
May - June	22	894.0	100	794.0	321.0	183	100
July - August	12	233.6	32.1	201.5	96.7	71	100
October - November	16	77.4	33.0	44.4	51.5	47	100
January - February	19	810.2	86.9	723.3	262.4	154	100

**Table 2.** Air Heavy Metal Concentration in This Study During 2016 - 2017 ( $\text{ng}/\text{m}^3$ )

Year/Month	Dust Day			Non-Dust Day		
	Pb	Cd	As	Pb	As	Cd
<b>2016</b>						
May - June	0.25 ± 0.01	0.017 ± 0.03	0.39 ± 0.03	0.19 ± 0.02	0.27 ± 0.04	0.014 ± 0.02
July - August	0.21 ± 0.02	0.013 ± 0.01	0.28 ± 0.04	0.14 ± 0.01	0.19 ± 0.02	0.009 ± 0.03
October - November	0.14 ± 0.02	0.009 ± 0.02	0.20 ± 0.01	0.10 ± 0.02	0.13 ± 0.02	0.003 ± 0.01
January - February	0.22 ± 0.01	0.015 ± 0.04	0.29 ± 0.01	0.17 ± 0.01	0.23 ± 0.03	0.011 ± 0.03
<b>2017</b>						
May - June	0.29 ± 0.01	0.020 ± 0.01	0.46 ± 0.05	0.24 ± 0.03	0.34 ± 0.02	0.018 ± 0.01
July - August	0.25 ± 0.03	0.015 ± 0.01	0.32 ± 0.04	0.16 ± 0.01	0.24 ± 0.03	0.012 ± 0.01
October - November	0.18 ± 0.02	0.011 ± 0.02	0.26 ± 0.02	0.14 ± 0.02	0.18 ± 0.03	0.008 ± 0.03
January - February	0.27 ± 0.03	0.019 ± 0.01	0.39 ± 0.01	0.21 ± 0.02	0.29 ± 0.01	0.014 ± 0.02

**Table 3.** Non-Carcinogenic Acute Risk of Heavy Metals in Baharestan City

Year/Group No.	Dust Day			Non-Dust Day		
	Pb <sup>a</sup>	Cd	As	Pb	Cd	As
<b>2016</b>						
Group 1	-	$3.1 \times 10^{-5}$	$4.8 \times 10^{-4}$	-	$2.4 \times 10^{-5}$	$4.1 \times 10^{-4}$
Group 2	-	$2.3 \times 10^{-5}$	$4.4 \times 10^{-4}$	-	$1.9 \times 10^{-5}$	$3.8 \times 10^{-4}$
Group 3	-	$1.4 \times 10^{-5}$	$3.5 \times 10^{-4}$	-	$1.0 \times 10^{-5}$	$2.9 \times 10^{-4}$
<b>2017</b>						
Group 1	-	$4.4 \times 10^{-5}$	$6.5 \times 10^{-4}$	-	$3.6 \times 10^{-5}$	$5.9 \times 10^{-4}$
Group 2	-	$3.7 \times 10^{-5}$	$5.6 \times 10^{-4}$	-	$2.3 \times 10^{-5}$	$5.1 \times 10^{-4}$
Group 3	-	$2.6 \times 10^{-5}$	$5.1 \times 10^{-4}$	-	$1.7 \times 10^{-5}$	$3.8 \times 10^{-4}$

<sup>a</sup>It is not calculated as the reference concentration (RFC) value for lead is not available.

trations on the surface of pine leaves was observed in the cold season, which may be due to the air inversion (37).

Based on the results, the non-carcinogenic risk of As is higher than that for Cd, although these are below the standard level (25), indicating that As and Cd concentration in the air studied does not pose a high risk of non-carcinogenic diseases.

Regardless of the element type, the highest and low-

est risk of acute non-cancerous diseases was in permanent residents and non-dormitory students with the most and the least hours of contact with the region air, respectively. However, the non-carcinogenic risk was below the standard level (25). The non-carcinogenic risk in non-dusty days has been decreased relative to dusty days, which is consistent with reducing the heavy metals concentration in non-dusty days.

**Table 4.** Non-Carcinogenic Chronic Risk of Heavy Metals in Baharestan City

Year/Group No.	Dust Day			Non-Dust Day		
	Pb	Cd	As	Pb	Cd	As
<b>2016</b>						
Group 1	$4.9 \times 10^{-5}$	$4.2 \times 10^{-5}$	$5.8 \times 10^{-4}$	$4.1 \times 10^{-5}$	$3.3 \times 10^{-5}$	$4.7 \times 10^{-4}$
Group 2	$3.7 \times 10^{-5}$	$3.1 \times 10^{-5}$	$5.1 \times 10^{-4}$	$2.8 \times 10^{-5}$	$2.4 \times 10^{-5}$	$4.2 \times 10^{-4}$
Group 3	$3.3 \times 10^{-5}$	$2.5 \times 10^{-5}$	$4.6 \times 10^{-4}$	$2.4 \times 10^{-5}$	$2.1 \times 10^{-5}$	$3.5 \times 10^{-4}$
<b>2017</b>						
Group 1	$5.7 \times 10^{-5}$	$4.7 \times 10^{-5}$	$6.4 \times 10^{-4}$	$4.6 \times 10^{-5}$	$4.1 \times 10^{-5}$	$5.4 \times 10^{-4}$
Group 2	$4.5 \times 10^{-5}$	$3.9 \times 10^{-5}$	$5.7 \times 10^{-4}$	$3.4 \times 10^{-5}$	$3.3 \times 10^{-5}$	$4.9 \times 10^{-4}$
Group 3	$3.9 \times 10^{-5}$	$3.1 \times 10^{-5}$	$5.1 \times 10^{-4}$	$3.1 \times 10^{-5}$	$2.8 \times 10^{-5}$	$4.4 \times 10^{-4}$

Ghanavati investigated the risk of heavy metals on human health in the street dust of Abadan and concluded that human activities play an important role in decreasing air quality. In addition, the risk of heavy metals in that area was higher than the standard level, in which this risk was higher in children than in adults (38). Shomali and Khodavardilo investigated the risk of heavy metals in Kerman and concluded that the non-carcinogenic risk of heavy metals is more related to the pollution of motor vehicles (39).

The chronic non-carcinogenic risk of Pb and Cd in 2016 was observed in order of permanent residents (Pb =  $4.9 \times 10^{-5}$ , Cd =  $4.2 \times 10^{-5}$ ), dormitory students (Pb =  $3.7 \times 10^{-5}$ , Cd =  $3.1 \times 10^{-5}$ ), and non-dormitory students (Pb =  $3.3 \times 10^{-5}$ , Cd =  $2.5 \times 10^{-5}$ ). It should be noted that due to the higher concentrations of As comparative to Pb and Cd in respiratory air, the highest non-carcinogenic risk was related to AS, although it was below the standard level.

It should be mentioned that the chronic non-carcinogenic index is greater than the acute non-carcinogenic index, however, they are lower than the standard level. The results of Hosseini et al. confirm this matter clearly (25). Noorpoor and Sadri Jahanshahi et al. mentioned the similar results for heavy metal non-carcinogenic effects of Tehran air (21).

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### Footnotes

**Authors' Contribution:** Amir Hossein Baghaie: Concept and design, writing the manuscript and revision, Ardeshir Khosravi-Dehkordi: Collection and analysis of data.

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