



# Environmental Assessment of Some Heavy Metals Pollution in Street Dust in the Industrial Areas of Ahvaz

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Received 2018 December 08; Revised 2019 May 28; Accepted 2019 June 03.

## Abstract

**Background:** High concentrations of heavy metals in street dust are considered to be a serious risk to human health and the environment. Therefore, investigating the concentration of heavy metals to monitor pollution and preserve the quality of the environment is essential.

**Objectives:** This study aimed to examine the concentration, enrichment factor (EF), pollution index (PI), and Nemrow integrated pollution index (NIPI) of potentially heavy metals including Cr, Cu, Cd, Pb, Zn, Ni, V, As, and Co in street dust in the industrial areas of Ahvaz.

**Methods:** A total of 29 dust samples were collected from sidewalks of main streets of industrial areas of Ahvaz and were analyzed by the inductively coupled spectroscopy (ICP-OES) method.

**Results:** The average concentration of heavy metals in Pb, Zn, Cu, Cr, Cd, Ni, V, As, and Co was respectively: 86, 999, 50, 57, 0.3, 58, 184, 6, and 13 (mg/kg), respectively. The mean concentration of all heavy metals in the samples of dust in the industrial areas of Ahvaz was several times higher than that of baseline values. Based on the average EF in the study area, Zn and Pb have extremely high enrichment. In addition, Zn, V, and Pb, with the highest PI average, displayed high pollution. In addition, the evaluation of NIPI showed that 100% of samples have high pollution.

**Conclusions:** The source of pollution of studied metals was anthropogenic, such as urban industrial facilities, transport, vehicle traffic, and burning of fossil fuels in the studied area. Generally, some protective protocol are proposed to reduce the level of heavy metals pollution in the city of Ahvaz, such as environmental control of gases produced by industries and factories, increase of green space, conversion of liquid fuel to gaseous, and use of public transportation.

**Keywords:** Air Pollution, Heavy Metals, Nemrow Integrated Pollution Index, Street Dust

## 1. Background

Human activities result in environmental pollution, for example, through the release of various toxic metals containing copper, lead, cadmium, and arsenic to urban environments (1). The dust of the street is composed of solid particles deposited on the surface of the ground, which acts as a reservoir for the collection of short-lived environmental materials from the surrounding areas (2, 3). The concern about the problem of metal pollution in street dust in recent decades has increased and research efforts have been correspondingly increased on the issue. Moreover, natural resources, such as soil weathering, metals in street dust mainly consist of a range of human activities counting industrial emissions (chemical plants, power plants, coal combustion, industry Metallurgy, car repair shops, etc.), traffic (car exhaust, tire, brake lining wear

and weathered street surfaces), domestic emissions, atmospheric depositions, surfaces of asphalt, and etc. (4, 5). Heavy metals are not degradable and stay in the dust/soil environment for a long time or they can be re-suspended in the atmosphere and pose as a potential hazard to human health (6). Toxic metals usually do not decompose; they can accumulate in body fatty tissues and can be toxic to the human central nervous system (7, 8). Environmental factors, including enrichment factor (EF), modified pollution indices, and potential ecological risk (PER) can be used to assess the pollution of heavy metals, the separation of different sources of heavy metals, human activity, and parent materials in dust (9). Ghanavati (10), for Abadan street dust, showed that concentrations of Cu, As, Pb, Zn, Co, Cd, Ni, Cr, with an exception of V were several times greater than that of the baseline (concentration in the earth's crust). These findings indicate that the high con-

centrations of these elements are related to anthropogenic sources such as industrial activities, traffic, burning of fossil fuels, and also construction activities. In their study on street dust of Huainan, it was shown that contamination levels of Cd and Hg were moderate to high, while content of Cu, Pb, Cr, Co, Sb, and As were generally low to moderate. Content of Hg and Cd were related with significant health hazard at 64.3% and 58.6% of sites, respectively (11). In their research on the street dust of northwest China, it was found that the geo-accumulation index ( $I_{geo}$ ) recommended that Cu, Pb, Cr, and Cd were significantly impacted by human activity, while Zn in street dust was of natural source. The comprehensive pollution index indicated that urban dust in Lanzhou has a high potential ecological risk (12). The city of Ahvaz has been qualified as a fast urbanization and industrialization in the last years. Industrial development as well as increasing population and number of vehicles in Ahvaz increased heavy metals deposition in street dust particles. Ahvaz city was one of those cities heavily polluted in the world (13). However, it is still not clear about the spatial distribution patterns and contamination levels of heavy metals in street dust in the industrial zones of Ahvaz.

## 2. Objectives

The objectives of the present study are to: (1) determine the concentration and source of heavy metals in street dust samples collected from industrial zones of Ahvaz, and (2) assess potentially heavy metals pollution in the street dust using enrichment factor and pollution index.

## 3. Methods

### 3.1. Studied Area

Ahvaz (31°19'45" N and 48°04'28" E), the capital of Khuzestan province in Iran, with a population of approximately 1.32 million in 2016, is situated in South-West Iran bordering Iraq, Kuwait, and Saudi Arabia, whose deserts are the main source of dust events in the Middle East (14). The climate of study area, which is almost near the Persian Gulf, is arid and sultry and almost cold and rainy in the winter. Average temperature in the study area is 32°C in January, 38°C in April, and 49°C in July. The rainy season normally extends from late December to almost the end of March with an average annual rainfall of 213 mm/year. The altitude datum in industrial town is about 25 m above the sea level.

### 3.2. Soil Sampling and Analytical Methods

In July 2018, 29 street dust samples were collected from industrial areas of Ahvaz, such as the Piping Plant Company, the Steel Industry, and Karun industrial zone (Figure 1). Samples were collected in the dry season of the year to prevent rain from washing the heavy metals. The meteorological conditions were steady through the sampling with no rain had occurred during one month earlier to sample collection. About 500 g of composite street dust samples were mainly collected by sweeping an area of about  $1 \times 2$  m<sup>2</sup> from road pavement using a plastic brush. The samples were air-dried, passed through a 220 mesh (63 μm), and stored in polyethylene bags. The metals of Ni, Pb, Cu, Zn, Cd, Cr, Co, As, and V were measured by inductively coupled plasma optical emission spectroscopy (ICP-OES, Model Varian735). The preparation of samples was accomplished by dissolution using four acids, HCl, HF, HClO<sub>4</sub>, and HNO<sub>3</sub> (15). After weighing samples, 250 mg HF (8 mL) 40% and HClO<sub>4</sub> (1 mL) 70% were added; after, the prepared solution was placed in a special container (Hot Box) in water for up to 200°C until a jelly solution is obtained. Then, HCl (3.75 mL) 37% and HNO<sub>3</sub> (1.25 mL) 65% was added and the solution was transferred to a volume of 25 mL and finally analyzed by ICP-OES device. Quality assurance (QA) and quality control (QC) were measured by measuring control samples and repetitive samples (with accuracy of 4% to 6%) and reference materials NIST 2710 [with accuracy 100% ± 5% (n = 15)]. The accuracy of the repeat samples was 4% - 6% and the precision was less than 5%.

### 3.3. Pollution Assessment

#### 3.3.1. Enrichment Factor

The enrichment factor (EF) is used to distinguish between anthropogenic or natural source of pollution and also to determine the degree of heavy metal pollution in the environment (16). The EF of a particular element in a given specimen is the ratio of the concentration of that element in that sample to the baseline concentration of the same element in the environment to which the corresponding specimen belongs. Enrichment factor (EF) was estimated as follows:

$$EF = \frac{\left(\frac{C_x}{C_{ref}}\right)_{Sample}}{\left(\frac{C_x}{C_{ref}}\right)_{Background}} \quad (1)$$

The  $(C_x/C_{ref})$  is the ratio of value of heavy metal (mg/kg) to the value of target heavy metal in the selected and background sample (15).  $C_{ref}$  (concentration of reference element) is an element that has a completely geological source. In environmental research studies, Zr, Ti, Fe, Al, and Sr are commonly used as reference elements (17). In this



Figure 1. Location of street dust sample sites in the industrial zones of Ahvaz city

study, Al was considered as a reference element, because its anthropogenic sources of pollution are insignificant. This element is rich in earth's crust and is much less present in anthropogenic environmental pollution. Degree of pollution can be categorized in five classes (18): (1)  $EF < 2$  (states deficiency to minimal enrichment), (2)  $2 \leq EF \leq 5$  (moderate enrichment), (3)  $5 \leq EF \leq 20$  (significant enrichment), (4)  $20 \leq EF \leq 40$  (very high enrichment), and (5)  $EF > 40$  (extremely high enrichment).

### 3.3.2. Pollution Index (PI)

The PI is used to assess the level of contamination, the formula is as follows:

$$PI = \frac{C_n}{B_n} \quad (2)$$

Where  $C_n$  is measured concentration of element in dust, and  $B_n$  is the concentration of the same heavy metal in the earth's crust. PI is classified into four groups: non-pollution ( $PI \leq 1$ ), low pollution ( $1 < PI \leq 2$ ), moderate pollution ( $2 < PI \leq 3$ ), and high pollution ( $PI > 3$ ) (19).

### 3.3.3. Nemerow Integrated Pollution Index

A Nemerow pollution index (NIPI) was applied to assess the general quality of the soil and dust environments and was calculated as:

$$NIPI = \sqrt{\frac{PI_{imax}^2 + PI_{iave}^2}{2}} \quad (3)$$

In which,  $PI_{imax}$  is the maximum value of the pollution index for each heavy metal, and  $PI_{iave}$  is the average value of the pollution index for each heavy metal. The advantage of NIPI over other indexes is that it allows determining the pollution risk of all metals in the study area (20). The NIPI was classified as: non-pollution ( $NIPI \leq 0.7$ ), warning line of pollution ( $0.7 < NIPI \leq 1$ ), low level of pollution ( $1 < NIPI \leq 2$ ), moderate level of pollution ( $2 < NIPI \leq 3$ ), and high level of pollution ( $NIPI > 3$ ).

### 3.4. Statistical Analysis

Statistical analyses of the data were carried out using the statistical software package SPSS version 22.0 for Windows and calculations of the indicators using the Excel software.

## 4. Results

### 4.1. Heavy Metals Concentration

Summary concentration data for heavy metals in street dust from industrial zones of Ahvaz is compared to upper continental crust (UCC) values in Table 1 (21, 22). The concentration value (mg/kg) of heavy metals in street dust samples ranged as follows: Pb, 35 - 332 (average: 86), Zn, 112 - 7194 (average: 999), Cu, 25 - 111 (average: 50), Cr, 42 - 149 (average: 57), Cd, 0.3 - 0.60 (average: 0.3), Ni, 44 - 81 (average: 58), V, 60 - 654 (average: 184), As, 4 - 8 (average: 6), and Co, 8 - 19 (average: 13) mg/kg. The mean concentrations of all heavy metals were several times higher than the baseline concentration (i.e., concentration in the earth's crust) indicating possible anthropogenic sources such as Khuzestan Steel Co., Carbon Black Co., Rolling Pipe Co., Kavian Rolling Co., Sepanta and Parisaz factories, and industrial workshops in the studied region.

**Table 1.** Summary of Statistical Parameters of Heavy Metals Concentration in the Industrial Zone of Ahvaz (mg/kg)

Heavy Metal	Min - Max	Mean $\pm$ SD	Skewness	Upper Crust Content <sup>a</sup>
Pb	35 - 332	86 $\pm$ 62	2.7	15
Zn	112 - 7194	999 $\pm$ 2099	2.7	31
Cu	25 - 111	45 $\pm$ 22	1.6	29
Cr	42 - 149	57 $\pm$ 20	3.6	35
Cd	0.3 - 0.6	0.3 $\pm$ 0.1	2.1	0.09
Ni	44 - 81	58 $\pm$ 9	0.5	20
V	60 - 654	184 $\pm$ 143	1.8	60
As	4 - 8	6 $\pm$ 1	0.7	4.8
Co	8 - 19	13 $\pm$ 3	0.6	10

<sup>a</sup>Source: reference No. (22).

#### 4.2. Enrichment Factor (EF)

Upper crust (UCC) values were applied as background concentrations for heavy metal enrichment factors (EF) calculations, as reported in previous studies (23, 24). The enrichment factor (EF) values for each of the heavy metals are presented in Table 2. The range of EF values for Pb, Zn, Cu, Cr, Cd, Ni, V, As, and Co were 20 - 235, 26 - 1280, 6 - 33, 4 - 12, 10 - 36, 17 - 44, 7 - 106, 9 - 24, and 7 - 21, respectively. The average EF values decreased as follows: Zn (209) > Pb (55) > V (27) > Ni (25) > Cu (15) > Cd (14.6) > As (14) > Co (11) > Cr (5). Accordingly, Cu, Cd, As, Co, and Cr have high enrichment ( $5 \leq EF < 20$ ), while V and Ni have very high enrichment ( $20 \leq EF < 40$ ). In addition, Zn and Pb, due to having a mean EF higher than 40, have extremely high enrichment. These results indicate that the concentrations of heavy metals in dust samples were significantly affected by human activities.

#### 4.3. Pollution Index (PI)

The pollution index (PI) values for each of the heavy metals are presented in Table 3. According to the trend of PI in dust samples: Zn (32) > Pb (6) > V (3.1) > Ni (2.9) > Cu (1.7) > Cd (1.69) > As (1.62) > Co (1.29) > Cr (0.64). The Cr mean showed no pollution, the Cu, Cd, As, and Co showed low pollution, and Ni showed moderate pollution. In addition, Zn, Pb, and V, with the highest PI mean, showed high pollution. According to the PI of the heavy metals studied, Cr (100%) had no pollution, Cu (70%), As (76%), Co (79%), and Cd (90%) had low pollution, and Ni (59%) had moderate pollution, while Zn (100%) and Pb (79%) were found to have high pollution in the study area.

#### 4.4. Nemerow Integrated Pollution Index (NIPI)

The Nemerow integrated pollution index (NIPI) in the studied samples is presented in Table 4. The advantage of

this indicator is that the risk of pollution of all heavy metals is determined. The mean value of this indicator is 24. The results of NIPI showed that 100 % of the samples had high pollution.

## 5. Discussion

The average concentration of all heavy metals in the samples of dust in the industrial areas of Ahvaz was several times higher than that of baseline values, which indicated possible anthropogenic input of metals from large industrial plants such as Khuzestan Steel Co., Carbon Black Co., Rolling Pipe Co., Kavian Rolling Co., Sepanta and Parisaz factories, and industrial workshops in studied region. Assessment of heavy metal pollution in soils nearby the Kerman steel industry showed that the trend of EF in dust samples were: Pb > Zn > Cd > Fe > Ni > Cr. EF index also showed that 90% of the samples were moderately to significantly polluted with lead element. The average values of Cd and Cu showed low degree of pollution (25). Survey of heavy metals pollution in surface soils around the industrial town of Ahvaz showed that according to geochemical criteria such as index of geo-accumulation (Igeo), enrichment factor (EF), and pollution index (PI), the soils of the study area are considered to be moderately contaminated with respect to Cr, Ni, and Pb, and uncontaminated with respect to Co, Cu, and Zn. The calculated results of EF, Igeo, and PI of heavy metals are as follows: Ni > Pb > Cr > Zn > Cu > Co (26). Assessment of heavy metals using pollution load index in the Zanjan zinc industrial town area indicate that the measured heavy metals contents with their maximum permissible limits in the soil showed that the studied soils are polluted with Zn, Pb, and Cd; however, it was non-polluted with Ni and Cu. Classification of observations, according to the contamination factor of stud-



**Table 2.** Enrichment Factors (EFs) from Potentially Heavy Metals in Street Dust of the Industrial Zone of Ahvaz

Metals	EF			Number of Sample (%)				
	Min	Max	Mean	Low Enrichment	Moderate Enrichment	Significant Enrichment	Very High Enrichment	Extremely High Enrichment
Pb	20	235	55	0	0	0	13 (45)	16 (55)
Zn	26	1280	209	0	0	0	5 (17)	24 (83)
Cu	6	33	15	0	0	21 (72)	8 (28)	0
Cr	4	12	5	0	16 (55)	13 (45)	0	0
Cd	10	36	14.6	0	0	27 (93)	2 (7)	0
Ni	17	44	25	0	0	3 (10)	26 (90)	0
V	7	106	27	0	0	17 (59)	7 (24)	5 (17)
As	9	24	14	0	0	27 (93)	2 (7)	0
Co	7	21	11	0	0	28 (97)	1 (3)	0

**Table 3.** Pollution Index (PI) from Potentially Heavy Metals in Street Dust of the Industrial Zone of Ahvaz

Metals	PI			Number of Sample (%)			
	Min	Max	Mean	No Pollution	Low Pollution	Moderate Pollution	High Pollution
Pb	2.50	24	6	0	0	6 (21)	23 (79)
Zn	3.61	232	32	0	0	0	29 (100)
Cu	0.86	3.83	1.71	3 (10)	20 (70)	3 (10)	3 (10)
Cr	0.47	1.66	0.64	28 (97)	1 (3)	0	0
Cd	1.30	3	1.69	0	26 (90)	3 (10)	0
Ni	2.20	4.05	2.90	0	0	17 (59)	12 (41)
V	1	11	3.06	1 (3)	11 (38)	8 (28)	9 (31)
As	1	2.40	1.62	1 (3)	22 (76)	6 (21)	0
Co	0.80	1.90	1.29	6 (21)	23 (79)	0	0

**Table 4.** Nemerow Integrated Pollution Index (NIPI) for Heavy Metals in the Study Area

NIPI			Samples Pollution Level, No. (%)				
Min	Max	Mean	No Pollution	Warning Line Pollution	Low Pollution	Moderate Pollution	High Pollution
3	165	24	0	0	0	0	29 (100)

ied heavy metals, showed that most of sampling points occurred in very high contamination class regarding Zn and Pb (65.9% and 68.2%, respectively) and in the medium contamination class regarding Cd, Cu, and Ni (57.7, 51.8 and 68.2%, respectively). The mean EF values for Zn, Pb, V, Ni, Cu, Cd, As, and Co in industrial zones of Ahvaz street dust samples were greater than 10, which indicate that their source is mainly anthropogenic. However, the mean EF for heavy metal of Cr indicated that their source of pollution could be related to both natural sources, such as weathering. These results prove that the heavy metals can be related to industrial plants, vehicles tires, corrosion of met-

als, and fossil fuel combustion (27). The highest enrichment factor (EF) and pollutant index (PI) in the study area are related to heavy metals of Zn and Pb. Zinc is used as an activator in the rubber manufacturing process (28), widely utilized for corrosion protection of steel (29), and extensively used for soldering in the automotive industry (30). Whilst many studies show that the main source of Pb in street dust is from fuel additives for automobiles (31), the banned usage of leaded petrol in Ahvaz suggests alternative sources of Pb in street dust (29), such as in lubricating oils in motor vehicles or wear of brake linings from road vehicles (32). According to NIPI, 100% of the samples had

high pollution. This result proposes that the dusts in this study area are significantly affected by human activities. Therefore, reducing the levels of heavy metals in order to prevent the potential hazard of these metals in industrial areas should be considered.

### 5.1. Conclusions

The concentration values, enrichment factors, pollution index, and ecological risk of the potentially heavy metals (Pb, Zn, Cu, Cd, Cr, As, Ni, Co, and V) in the industrial areas of Ahvaz street dust were determined and concentration of all heavy metals in street dust was greater than their corresponding UCC, demonstrating potential anthropogenic sources (industrial plants, vehicular traffic, abrasion of tires, and asphalt pavement). The average EF values decreased as follows: Zn > Pb > V > Ni > Cu > Cd > As > Co > Cr. The evaluation of NIPI showed that 100% of samples have high pollution. Therefore, some protective measures have been proposed to reduce the amount of heavy metals pollution in the city, such as environmental control of gases produced by industries and factories, increasing green space, converting liquid fuel into natural gas, and using public transport.

### Acknowledgments

The authors thank all faculty members and other participants who took part in the study.

### Footnotes

**Authors' Contribution:** All authors are equally involved.

**Conflict of Interests:** Authors declared no conflict of interest.

**Ethical Approval:** This article comes from a Master's thesis of soil science. It has been registered with code 10650202952002 at Research Committee of the Islamic Azad University.

**Funding/Support:** No grants were received from any funding agencies in the public, commercial, or profit sectors.

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