Exposure and health Risk Assessment of PHEs (Pb, Cd, Cu, Fe) in Agricultural Soil in Kerman City,Southeast of Iran

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Abstract

potentially harmful elements (PHEs) are essential among environmental pollutants due to their non-degradability and physiological effects on living organisms in low concentrations, which gradually accumulate in the soil due to low mobility. These elements eventually enter the food cycle and threaten the health of humans and other organisms through their accumulation in the soil. Therefore, studying the distribution of concentration PHEs and examining soil pollution is necessary to maintain environmental quality. The contaminants in agricultural soils can, directly and indirectly, pose significant risks to human health through several paths, including ingestion, inhalation, and skin contact. In this research, the human health risk assessment of PHEs in the agricultural soils of Kerman City has been carried out. It is a descriptive-cross-sectional study in which 620 soil samples were taken from the agricultural lands and 40 samples including 20 samples of rock (lime, conglomerate) and 20 samples (wind sediments, alluvium and platy sediments) as well as 41 soil samples including 20 samples from residential areas and 20 samples from polluting areas (car repair shops, gas stations, battery productions, car painting shops and landfills) have been taken in Kerman City in 2019, The concentrations of cadmium, lead, iron, and copper have been determined by the graphic furnace atomic absorption system. The Nemrow comprehensive index method has been applied for the qualitative and quantitative assessment of soil pollution to determine the toxic source and artificial effects. The carcinogenic and non-carcinogenic risk of agricultural soil PHEs for human health has been assessed for both groups of children and adults using the recommended method proposed by the US Environmental Protection Agency (USEPA). The results have shown that the mean concentration of PHEs except for copper in the studied agricultural soils is higher than the natural background.

In addition, the obtained results, based on the Nemrow index [contamination factor (CF) and pollution loading index (PLI)], have shown that the studied agricultural soils have been heavily contaminated by lead (CF> 3), and the contamination levels of the target PHEs in all areas have been in the range of low pollution (PLI ≤1). Furthermore, the results obtained by the geo-accumulation index (Igeo) showed that the accumulation of lead in agricultural soils of Kerman City has been in the range of low pollution ($0 < Igeo < 1$) to medium ($1 < Igeo < 2$). The other metals are within the limits of non-contaminated values. The hazard index (HI) for children and adult groups is lower than one in the studied agricultural soils. The ingestion is the main pathway of carcinogenic risk for lead and cadmium in both children and adult groups. Correspondingly, the total carcinogenic risk for children and adults (*TCR)* is within the acceptable level (1×10^{-4}- 1×10^{-6}). In general, values of both carcinogenic and non-carcinogenic risks in the children group are higher than that of the adults.

Keywords: Agricultural soil; Health risk assessment; PHEs; Kerman; Soil contamination

1. Introduction

The soil is one of the compartments annually absorbing substantial contaminations from various sources. It is a place to keep chemical contaminations and acts as a natural buffer to control the transmission of chemical elements and materials to the environment (Kabata-Pendias. 2010). In many areas of the world, pollution from potentially harmful element (PHE) has become a serious environmental issue (Solgi et al.2012; Zhao et al.2014). The PHEs are one of the most dangerous environmental pollutants (Nyarko et al.2008), found in different layers of contaminated and uncontaminated soil in several environmental systems (Ernst et al. 1998). The contaminating sources of soil to PHEs include the natural or artificial sources of human activities, which adversely affect both soil and human health (Karim et al. 2014; Heberer. 2002).
The volcanic gases, metals-rich rocks erosion, and continental displacement of dust are the natural resources of PHEs (Ernst et al. 1998), transferred to the soil through the process of atmospheric deposition (Lu et al. 2010), as well as artificial sources, including the use of agricultural-enriched sewage sludge, combustion and forest fires, industrial processes, and electronic equipment (in different phases including production, use and disposal) of metal-based pesticides and agricultural activities (Inigo et al. 2013; Oves et al. 2012). However, the primary sources of soil contamination to PHEs and organic pollutants are human activities related to urbanization and industrialization (Stafilov et al.2010; Wu et al. 2011; Wu et al. 2012).

The soil can be used as a tool to detect the environmental conditions posing risk to human health (Davydova. 2005). Many researchers have investigated the toxicity of PHEs in contaminated soils (Smith et al. 1998; Homa et al. 2003; Aelion et al. 2008). One severe environmental pollution is agricultural soil contamination of PHEs (Mamut et al. 2017). The rapid process of industrialization and the excessive use of chemicals in the agricultural lands, inefficiencies and the lack of bio-management systems have caused large-scale pollution. In recent decades, the pollution originated from agricultural activities through direct consumption or storage in the food chain, and the impact on ecology has led to human health risks (Wong et al. 2002; Cheng. 2003). The soil contaminated by PHEs through various paths such as ingestion, skin and inhalation contacts can cause damage to human health. The health risks of agricultural soils contaminated by PHEs for adults and children are much higher than the risk of road dust and vehicle emissions (Pourang and Noori. 2014). The toxicity to lead at high doses can increase blood pressure, nervous system disorder and bone and ankle weakness (Flora et al. 2012). The effects of chronic exposure to cadmium include lung cancer, renal dysfunction, bone fractures, high blood pressure, and prostatic proliferative (One of the indicators used to diagnose whether the prostate gland is cancerous is the proliferative index showing the proliferation of cancer cells in the prostate gland) (Om and Shim. 2007; Kyprianou et al. 1996). Excessive copper in the body causes liver damage and severe pain in the intestine and liver (Rahman et al. 2014; Gaetke and Chow. 2003; Harmanescu et al. 2011). Despite the fact that iron, as the most abundant element in Earth's crust, is necessary for all organisms except for a few bacterial species, excessive iron in the body leads to liver and kidney damage (Gambrell. 1994). The PHEs are naturally available in the soil with a sufficient amount, but their concentration increase due to various activities such as agriculture, mining, industrialization, and urbanization (Dimitrijevic et al. 2016; Kalaivanan and Ganeshamurthy. 2016; Hanebuth et al. 2018). Among these sources, the agricultural source is the most important source of PHEs pollution (Chabukdhara and Nema. 2013). Also, high concentrations of PHEs in the blood of inhabitants consuming vegetables grown in contaminated soils have been observed (Gisbert et al. 2006; Lacatusu et al. 1996). In recent years, the scientific community has shown a growing interest in assessing the risk to human health, but few studies have considered the risk of carcinogenic and non-carcinogenicity of PHEs in soil (Chabukdhara et al. 2013; Chen et al. 2015; Qing et al. 2015). Risk assessment is a process of estimating the probability and value of damage, loss, or injury originating from a potential hazard or threat to the health factors (USEPA. 2000).
Furthermore, risk management is a process in which the results of risk assessment are considered from various economic, political, legal and ethical aspects (Yeganeh. 2012). As regards environmental management, decisions are made on the basis of risk assessment and risk management. It provides scientific principles for environmental legislation (Yeganeh. 2012). Regarding the soil, air, water or sediment pollution, the main purpose of risk assessment is to investigate all possible paths exposing the studied organisms to contamination, estimate the values of contaminants entering the body of the studied organisms and determine the potential adverse effects of the contaminants on the organisms (Yeganeh. 2012). The PHEs risk assessment can be conducted in four stages as follows (USEPA. 2002):1- risk diagnosis, 2- baseline value assessment, 3- assessment of contact paths and 4- risk description. In the first stage, harmful effects of chemicals on human health are identified. In the second stage, the base level for

the pathogenicity of the elements is determined. In the third stage, different paths of contact with chemicals, including the absorption from the path of digesting, skin, and inhalation of suspended particles, are examined.
Ultimately in the fourth stage, the carcinogenic and non-carcinogenic hazards caused by the PHEs through the three above-mentioned paths are calculated using the guidelines provided by USEPA. The risk ratio (HI) indicating the non-carcinogenic hazards to human health due to the existence of environmental contents has been applied for the first time by USEPA for hazards threatening human health as a result of the existence of toxic pollutants in the atmosphere (USEPA. 1989). Barin et al. (2017) showed that there had been no indication of non-cancerous diseases through oral consumption of wheat and rice grown in the agricultural soils around the Irankuh mine in Isfahan by calculating the risk ratio. Chen et al. (2013) conducted a study to assess the health risk of PHEs in vegetarian food sectors and the soils around the area of battery manufacturers in China, and the findings showed that approximately 3% of cadmium in plant samples exceeded the maximum concentration based on the nutritional health standards, but the levels of lead in the soil samples have been within the standard values. Therefore, the health risk assessment of PHEs in the soil, including the evaluation of carcinogenic and non-carcinogenic risks, is an important and useful tool to identify the dangers of human activities, currently considered one of the most important environmental research areas (Bempah and Ewusi. 2016). In order to manage and make wise decisions to reduce pollution and minimize the exposure and health risks of PHEs to humans, it is required to broaden the knowledge of the potential risks of contaminants in the soil (Chen et al. 2015). On the other hand, a small number of researches on the health risk assessment have been conducted regarding the PHEs pollution of soil due to agriculture. Therefore, it is required to carry out a thorough assessment of pollution in the agricultural regions of Kerman City. As a result, this research has been carried out to evaluate the levels of pollution and health risks of certain PHEs (Pb, Cd, Fe and Cu) in agricultural soils.

2. Methodology

2.1. Study area

Kerman City is the largest city and the capital of Kerman Province. The geographical coordinates of the city is within the latitude of Eastern 50°-57 and Northern 30°-17, and the weather depends on the geometric coordinates in the northern hemisphere as well as the other factors such as the altitude, sea level, distance from the rivers, predominate winds, and the air masses. Regarding the climate, the city has warm and dry summers and cold winters (Nazarialamabadi. 2008). By Iranian Statistics Center, the population of this city has reached 537,718 people (Iran 2016). The map of the study area and sampling agricultural sites are represented in Fig.1. According to current statistics, the population density in Kerman City is 46 people per hectare. The density in this city is one-half the density of cities with average population in Iran compared to cities with average population density (100 people per hectare). Although the population density is low, it is not uniform in different parts of the city. It is so dispersed where the residential areas in the old regions of the city are almost abandoned. In contrast, the more developed areas and new residential districts around the city are located a few kilometers from the city center (such as Al-Ghadir, Elahieh, and Hava Nirooz), have a high population density.
In addition, some parts near the city such as Taherabad, Ekhtiarabad and Bagherabad have a mild density. There are similar traffic issues in the suburbs. The crowded areas of the city are mainly commercial-economic districts, the general form and shape of the streets have no specific development pattern (such as checkered, linear, radial, etc) and the type of each passage does not follow its traffic flow in most areas due to the lack of a comprehensive plan for the long-term urban development as well as the cross-cutting decisions regarding the urban expansion; for example, Shariati Street, Saadatabad street , Shahab Street, Sarasiab street , Abuzar street have a small width and mild traffic flow in daytime. The latter two streets are also known as arterial axes. Considering the conditions of the road network and the general form of their connections, a limited number of intersections and squares that have the traffic capacity issues can be considered the network traffic nodes (Sharafi, 2013).

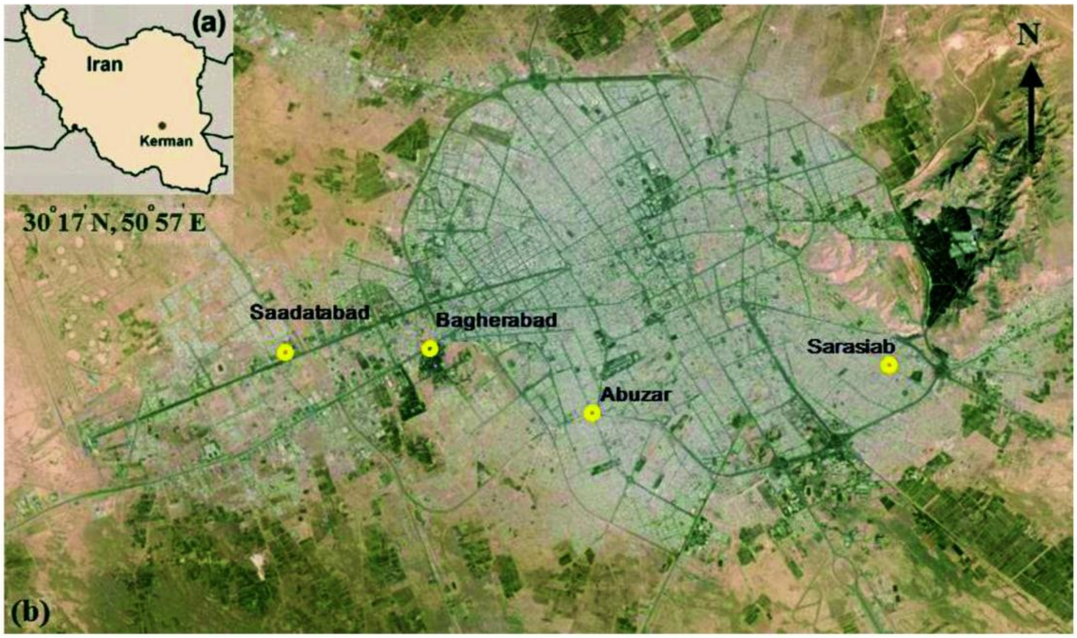

Fig 1. Map of study area (a), and sampling agricultural sites (b)

2.2. Geography and soil characteristics of Kerman City

Kerman City is located in a Grabeni plain that has been created by both direct and gravity faults on both sides (Figure 2). Around the city, various rock outcrops such as Cretaceous reef limestones (Mountains of Taq Ali, Saeedi, Kamar Siah, and Houz Dagh) Kerman conglomerate with Paleocene age (Bala Baneh Mountains) and outcrops of young conglomerate with Neogene age can be seen. Most parts of Kerman City are located on the Playaei sediments, also in the southern parts of the plain, sandy wind sediments spread, which advance towards the city. The heights of active faults border alluvial sediments between the mountain and the plain, and this city is 1740 meters above sea level (Atapour and Aftabi. 2002).

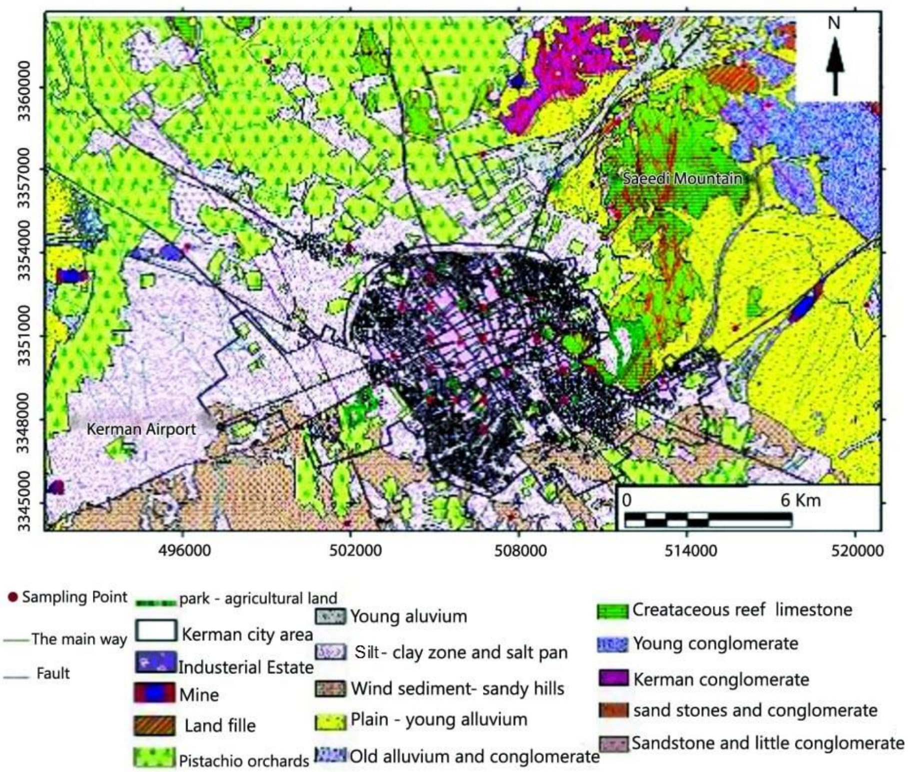

Figure 2.Geological map of Kerman City and the sampling place (rocks, sediments and the city polluting areas)

2.3. Soil Sampling

In this study, 620 agricultural soil samples from vegetable fields located in the outskirts of Kerman near highways have been taken. In addition, 40 samples including 20 samples of rock (lime, conglomerate) and 20 samples (wind sediments, alluvium and platy sediments) as well as 41 soil samples including 20 samples from residential areas and 20 samples have been taken from polluting areas (car repair shops, gas stations, battery productions, car painting shops and landfills). The preparation and preparation of soil samples have been carried out using the validated method proposed by Tuzen. (2003) has been applied. Furthermore, soil samples have been taken to investigate soil contamination with the PHEs at 0-15 cm depth. According to the systematic random sampling method, the soil sampling method based on the widelyused protocols (USEPA Category ENV 3.13, and G1740) have been applied as follows (Fergusson et al. 2007; Proce. 1997): since the samples taken from the soil need to be representative of the entire sampling area, the study area is firstly examined in terms of slope and soil type. If the soil type and slope of the region are different, the study area must be classified based on slope and type of soil and the sampling in each category is carried out based on random systemic method. As the soil type and slope of the study areas of this research are the same, there has been no need to divide the region's soil based on such factors.

Therefore, the study area has been divided into blocks of a 25 square feet. In each block, five samples have been taken using a shovel made of unbreakable plastic (copolymer) at a depth of 0-15 cm (a wooden ruler has measured the depth) in a zigzag w-shape form represented in Fig. 3, then the samples taken in each block have been mixed, and a combined sample of one kilogram has been collected in polyethylene containers (The containers were rinsed with deionized water, and then dried.); after that, the combined samples of each block have been sent to the laboratory with a label indicating depth, sampling location, date, number and name of the farm. They have been kept in the laboratory prior to putting in the oven. The additional materials, such as stones, garbage, weeds, etc., have been manually separated, and the soil samples have been ground and then dried in an oven at 110 ° C. Following that, they were passed through a sieve with 200-mesh to achieve the soil powder. They have been stored at the laboratory temperature inside the polyethylene containers until the analysis program is carried out.

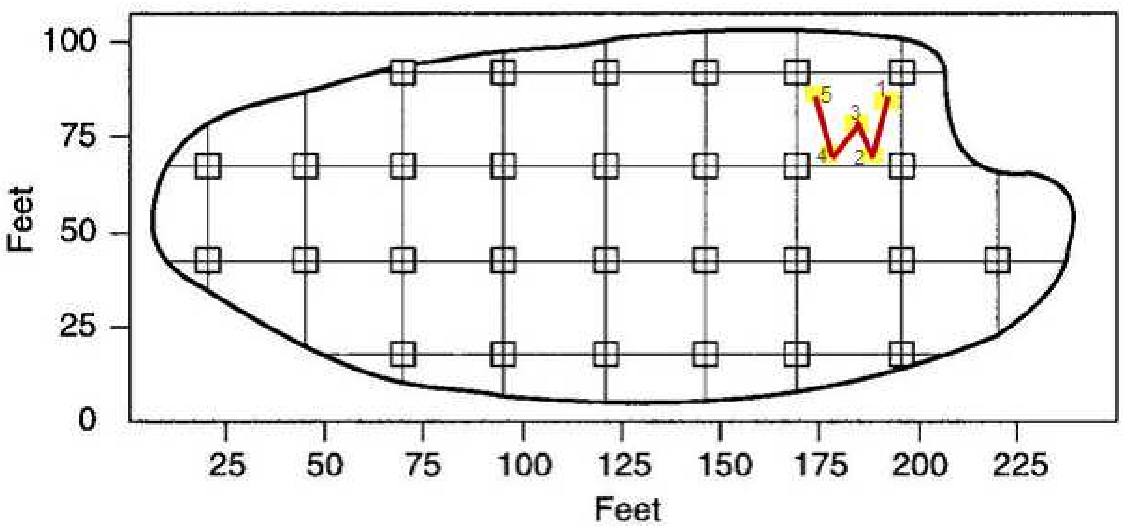

Figure 3. Systematic Grid Sampling (Proce. 1997)

2.4. Preparation and treatment of soil samples

The standard solutions of the PHEs, including Cd, Cu, Fe, and Pb (100 mg/L) and all used acids, have been ordered from Merk Company. Several concentrations of each PHE have been prepared by diluting it with deionized water. The analytical blanks have been run similar to the samples, and the PHEs have been determined using the standard solutions in the same acid matrix. The 0.5 g of soil weighed by a digital scale has been put in the Crucible and heated in the furnace at 90 ° C for 6 hours. After taking the samples from the furnace and drying them, the process of acid digestion was carried out using a 3:1 mixture of Chloride acid, concentrated Nitric acid (HCl: HNO3) to a volume of 8 ml (HCL + HNO3 = 8ml), and the concentrated Perchloric acid (HCLO4) to a volume of 3 ml. After the digestion process, the number 42-filter Watman Paper was used to filter the solution to reach a volume of 25 ml.

2.5. Determination of PHEs

The values of PHEs have been determined using a Shimadzu 6300 Atomic Absorption Spectrophotometer(Shimadzu Corportaion, Tokyo, Japan) equipped with Shimadzu 6100 Auto sampler and Shimadzu GFAEX7i Graphite Furnace Atomizer. The limit of detection (LOD) for cadmium, lead, copper, and iron are 0.05mg/kg, 0.3 mg/kg, 0.07 mg/kg, and 0.004 mg/kg, respectively. The quality control measures to assess the quality analysis and the data precision include the triplicate samples and reagent blanks. the descriptive statistical parameters including maximum, minimum, mean, standard deviation, and coefficient of variation of the target PHEs, as well as the distribution and normal test of data at 95% reliability level using Kolmogorov-Smirrov statistic (if not normal, the distribution of data has been normalized using the logarithm conversion method), and Pearson correlation coefficient between PHEs, soil and basic materials have been calculated using SPSS software version 26.

2.6. Determining soil acidity

The following steps have been applied to measure the pH of soil samples. First, the collected samples were placed in an oven at 80 ° C for 24 hours, then 20 grams of soil were weighed by a scale and transferred to an Erlenmeyer flask with 20 ml of distilled water. After that, it was mixed thoroughly using a shaker for 15 minutes at a speed of 100 rounds per minute (rpm) and then passed through Whatman No. 1 filter paper. Finally, the acidity of the samples was determined using a pH meter (Thomas. 1996).

2.7. Pollution assessment of PHEs

The PLI has also been used to assess the degree of soil contamination. This index provides a convenient way to prove the deterioration of the soil conditions due to the accumulation of PHEs (Varol. 2011). The Nemrow comprehensive index method has been used to evaluate the contamination of PHEs (Tomlinson et al. 1980). The Nemrow index includes two factors, the Contamination Factor (CF) and the Pollution Load Index (PLI), to evaluate the level of PHE pollution. The *CF* and *PLI* indices are calculated using the following formulations.

$$CF = \frac{C_i}{C_b} \tag{1}$$

$$PLI = \sqrt[n]{C_{F1} \times C_{F2} \times \ldots \times C_{Fn}} \tag{2}$$

Where *Ci* is the element concentration in the sample (mg/kg), *Cb* is the concentration of the same element in the reference material (The local background concentration of soil) (mg/kg), and n is the number of PHEs. The average concentrations of local background elements are 718, 32, 25, and 0.25 for Fe, Cu, Pb and Cd, respectively (Hamzeh et al. 2011). According to Tomlinson and Zaire's studies (Tomlinson et al. 1980; Zarei et al. 2014), the contamination levels of CF and PLI are shown in Table 1.

Table 1. Level of CF and PLI contaminations

Pollution level	*CF* Level	*PLI* level
Non pollution	$CF \le 0.07$	$PLI \le 1$
Low pollution	$0.07 < CF \le 1$	$1 < PLI \le 2$
Medium pollution	$1 < CF \le 2$	$2 < PLI \le 3$
High pollution	$2 < CF \le 3$	$PLI > 3$
Very high pollution	$CF > 3$	………

2.8. Geo-accumulation index

One of the methods to assess soil contamination is the geo-accumulation index (*Igeo)* calculated as follows:

$$Igeo = Log_2\left(\frac{cn}{1.5Bn}\right) \tag{3}$$

Based on the Moller geo-accumulation index, Cn is the total concentration of each metal in the soil, Bn is the background concentration for each metal, and the coefficient of 1.5 has been applied to reduce the potential changes in the background quantity caused by the lithologic instability of the soil sediments. According to the geo accumulation index, the level of pollution is classified into seven categories: non-polluted ($Igeo < 0$), non-polluted to moderate pollution ($0 < Igeo < 1$), moderate pollution ($1 < Igeo < 2$), moderate to severe pollution ($2 < Igeo < 3$), severe pollution ($3 < Igeo < 4$), severe to very severe pollution ($4 < Igeo < 5$), and very severe pollution ($5 < Igeo$) (Rodriguez -Seijo A, 2017, Lu and Bai, 2010).

2.9. Data analysis by GIS:

In order to better identify contaminated areas or areas exposed to PHEs contamination, the concentrations of lead, cadmium, copper and iron have been used as input data for preparing co-concentration maps of the elements and the geo-accumulation index and pollution factor distribution maps. The element contour maps have been prepared using ARC GIS 9.1 software for the Kerman City map, including geological units, urban areas, industrial districts and mines. Based on the contour maps, the surface distribution of these elements in the natural environments of the city's outskirts towards the city centre and the contaminated areas, as well as the contributions of human activities leading to an increase in the concentration of these elements in polluting areas have been determined.

2.10. Health risk assessment

The health risk is the potential hazard to human health due to environmental contaminations. As regards PHE toxicity, human exposure to PHEs in the soil occurs in three pathways: a) direct contact or ingestion, b) skin contact or skin absorption of PHEs by soil contact c) inhalation of soil particles from the mouth or nose. In order to assess the risk of carcinogenic and non-carcinogenic in children and adults living in the studied area, the health risk assessment model proposed by USPEA has been used (Xiao et al. 2017; Chary et al. 2008; Zhou et al. 2016; Liang et al. 2017). The chronic exposure is calculated using Eqs. 4-7 as follows. Furthermore, the definitions of the parameters studied, and their extent is represented in Table 2.

$$CDI_{Ingestion-soil} = \frac{CF \times IR \times CS \times EF \times ED}{BW \times AT} \quad (4)$$

$$CDI_{Inhalation-soil} = \frac{CF \times PM10 \times DIR \times PIAF \times FSPO \times CS \times EF \times ED}{BW \times AT} \quad (5)$$

$$CDI_{Dermal-soil} = \frac{CF \times AF \times SA \times ABS \times CS \times EF \times ED}{BW \times AT} \quad (6)$$

$$CDI_{total} = CDI_{Ingestion} + CDI_{Inhalation} + CDI_{Dermal} \quad (7)$$

Table 2. Definition of the parameters.

Parameters	Definition	Value parameter	Reference
CS	PHEs content in soil (mg/kg)	Observed value	----
IR	Soil ingestion rate (mg/day)	Adult = 100, child = 200	(USEPA, 2011, MEP, 2014)
CF	Convention factor	10^{-6}	(MEP, 2014, USEPA, 2002, USDOE, 2011)
EF	Exposure frequency (d/a)	365	(USEPA, 2002)
ED	Exposure duration (a)	Adult = 24, child = 6	(MEP, 2014, USDOE, 2011)
BW	Body weight (kg)	Adult = 60.7, child = 20.5	(WHO, 2014, Walpole et al., 2012)
AT	Average time (day)	Carcinogenic=365×70 Non-Carcinogenic= 365×ED	(USEPA, 2011)
PM10	Content of inhalable rate (mg/m^3)	0.15	(MEP, 2014)
DIR	Daily air inhalation rate (m^3/day)	Adult = 15, child =7.5	(MEP, 2014)
FSPO	Fraction soil born particulate in air	0.5	(MEP, 2014, NEPAC, 2014)
PIAF	Retention fraction of inhaled particulates in body	0.75	(MEP, 2014, NEPAC, 2014)
AF	Skin adherence factor (mg/cm^3)	Adult=0.07 child=0.2	(USEPA, 2011)
SA	Exposed surface area of skin (cm^3)	Adult = 4350, child = 1600	(Li Y-WaW, 2017)
ABS	Dermal absorption factor	0.001	(USEPA, 2011, USDOE, 2011)

2.10.1. Non-carcinogenic risk assessment

The non-carcinogenic risk for each metal is known as a risk factor Hazard Quotient (*HQ*) calculated by dividing the daily exposure to oral reference dose based on the following equation: the maximum daily allowable dose for human populations throughout the life cycle (Li and Zhang. 2010). The Hazard Index (*HI*) determines the risk index using the following equation (EPA, 1989).

$$HQ = \frac{CDI}{RFD} \quad (8)$$

$$HI = \sum HQ = HQ_{Ingestion} + HQ_{Inhalation} + HQ_{Dermal} \quad (9)$$

If $HI \leq 1$, it is unlikely to have adverse health effects. However, when $HI \geq 1$, the non-carcinogenic effects rise with the increase of *HI* values (USEPA. 2001).

2.10.2. Carcinogenic risk assessment:

The Carcinogenesis Risk (*CR*) indicates the development of specific cancer due to exposure to carcinogens determined by the following equation (EPA, 1989).

$$CR = SF \times CDI \quad (10)$$

Where the slope Factor (*SF*) is the indicator of carcinogenesis rate ($mg.kg^{-1}.d^{-1}$), *CR* has no specific unit. The following equation is applied to calculate the total carcinogenicity risk.

$$TCR = \sum CR = CR_{Ingestion} + CR_{Inhalation} + CR_{Dermal} \quad (11)$$

The threshold value of *TCR* is acceptable for 1 × 10-4. If the TCR exceeds 1×10^{-4}, it is considered an unacceptable value, it is negligible for the values of less than 1×10^{-6} , and it is important between 1 × 10-4 and 1 × 10-6 (Fryer et al. 2006; Hu et al. 2012).
The Reference Dose (*RFD*) and Slope Factor (*SF*) are shown in Table 3 (Ferreira-Baptista and De Miguel. 2005; Lu et al.2014; USEPA. 2004).

Table 3. Reference dose (*RFD*) for non-carcinogenic metals and SF for carcinogenic metals

Elements	*RFD*			*SF*		
	Ingestion	*Inhalation*	*Dermal*	*Ingestion*	*Inhalation*	*Dermal*
Cd	0.001	0.001	0.00001	6.1	6.3	6.1
Pb	0.0035	0.00352	0.000525	0.0085	0.042	----
Cu	0.04	0.04	0.012	----	----	----
Fe	0.7	----	0.14	----	----	----

3. Results

3.1. PHEs concentration in farmland soil in the study area

Based on the statistical tests of Shapiro-Wilk and Kolmogorov-Smirnov, and Levenz tests, it has been found that the concentration of all target metals except for copper in the regions of the study area (Abuzar, Saadatabad, Sarasiab, and Bagherabad) have not been a normal distribution. The statistical summary of concentrations of the studied metals (lead, cadmium, iron, and copper) in these four areas is represented in Table 4. The total concentration of metals measured in the Abuzar area has been higher than that of the natural background level. Accordingly, this region's lead, cadmium, copper, and iron concentrations have been 3.22, 1.58, 1.51, and 1.38 times higher than the natural background. The declining trend of the studied elements in the Saadatabad area is as follows Fe > Pb > Cu > Cd. The concentrations of iron and cadmium have been lower than those of the natural background. Regarding lead and copper, they have been 2.66 and 1.14 higher than the natural background. As shown in Table 4, all elements, including lead, cadmium, copper, and iron in Sarasiab, have been 2.96, 1.22, 2.26, and 1.66 higher than the natural background level, respectively. In Bagherabad, the concentration of cadmium, copper, and iron elements has been below that of the local natural background, but the concentration of lead has been 2.41 greater than that of the local natural background. The decreasing trend of variation coefficient of metals in the Abuzar region has been Cu > Cd > Pb > Fe. The Saadatabad region has been Cd > Fe > Cu > Pb. Furthermore, the Sarasiab region has shown a pattern of Cd > Fe > Cu > Pb, and the Bagherabad region has represented a trend of Cd>Fe>Cu>Pb. The decreasing trend of variation coefficient CV in the studied area has shown that this trend is similar in Saadatabad and Bagherabad, but it is different from that in the regions of Abuzar and Sarasiab. In the Abuzar region, the variation coefficient of lead, cadmium, and copper have been significant, which was in the range of 0.173% - 24.56%, indicating that human activities most influence the concentrations of these elements, but the very small variation coefficient of the iron in this region (7.04 × 10-3 %) indicates the effects of natural resources such as bedrock and topography of the region. Moreover, the variation coefficients of cadmium in all studied regions have been greater than the other target metals, and the decreasing trend of the variation coefficients in the two regions of the Saadatabad and Bagherabad are similar. However, this trend in the two other areas of Abuzar and Sarasiab is different with each other as well as the former two areas. The average concentrations of target metals in the four studied agricultural regions are compared with the average concentration (ppm) of metals in the natural background, global soil, and Earth's crust in Table 4 (Radajevic et al.1999; Faure. 1992; Krauskop et al. 1967; zhang. 2006; zhao. 2006).

Table 4. Descriptive statistics of the soil PHEs concentrations (ppm) in farmland soil in the study area

Area	Parameters	Range (ppm)	mean±SD (ppm)	CV%	Background value	Average shale	Global Soil	Earth crust
Abuzar	Pb	51.05-81.85	80.63±0.14	0.173	25	20	25	55
	Cd	0.331-441	0.395±0.09	22.78	0.25	0.3	0.5	0.2
	Fe	985.1029	993.0±0.07	7.04×10^{-3}	718	47200	21000	41000
	Cu	40.7-48.7	48.6±11.94	24.56	32	45	30	12.5
Saadatabad	Pb	40.03-66.7	66.60±0.07	0.105	25	20	25	55
	Cd	0.173-0.23	0.212±0.05	23.47	0.25	0.3	0.5	0.2
	Fe	699.2-727	713.27±7.69	1.078	718	47200	21000	41000
	Cu	34.11-36.49	36.00±0.05	0.137	32	45	30	12.5
Sarasiab	Pb	74.18-74.32	74.18±0.09	0.121	25	20	25	55
	Cd	0.264-0.315	0.307±0.007	2.280	0.25	0.3	0.5	0.2
	Fe	784-844	837.5±4.41	0.526	718	47200	21000	41000
	Cu	40.11-40.56	40.47±0.06	0.148	32	45	30	12.5
Bagherabad	Pb	33.8-62.35	60.35±0.09	0.149	25	20	25	55
	Cd	0.107-0.19	0.183±0.09	49.18	0.25	0.3	0.5	0.2
	Fe	424-493	482.5±6.69	1.386	718	47200	21000	41000
	Cu	29.83-31.51	31.34±0.06	0.190	32	45	30	12.5

3.2. The concentrations of lead, cadmium, copper and iron in limestone, young conglomerates and sediments in Kerman

Table 5, represents the concentration of target PHEs in the target rocks and sediments in Kerman City. Furthermore, these data have been compared with the average of Earth's crust. The alluvial and rock environments are considered natural resources of main, secondary and rare elements in the soils of Kerman City that the contaminations caused by human activities have little effects on their geo-chemical cycle. Due to almost the same origin of sediments around Kerman City, the concentrations of many elements in these sediments and rocks are similar compared to their concentrations in the earth's crust. In addition, the concentration of elements such as lead, cadmium and copper in the rock of Kerman City are lower than that in the Earth's natural crust. The iron concentration of young conglomerate rocks in Kerman City indicates its excessive concentration compared to its amount in Earth's natural crust.The concentration of iron is marginally higher than that of the average of Earth's crust. The concentrations of some elements in the playa sediments that form the city's base has changed by human activities so that the elements' grades have increased several times their natural grade in the soil shown in Table 6. For example, lead in the soils around Abuzar and the Sarasiab is approximately one and a half times higher than that of Earth's crust.
Also, the correlation of the selected elements have been calculated by comparing the concentrations of the two elements in the horizontal and vertical axes using SPSS software. The high correlation of the similar elements geochemically indicates the natural origin of elements in rocks and sediments around Kerman City; for example, the correlation of iron with copper 94 with other elements is in the range of 94-96%. The poor correlation between lead, cadmium and copper (i.e. the correlation coefficient less than 0.05) with other elements indicates that these elements are unlikely to be enriched in limestone, therefore, they are not of the natural origin. The high correlation of similar geo-chemical elements indicates the natural origin of the elements in rocks and sediments around Kerman City. For example, the correlation of iron with copper has been 94% and other elements in the range of 94-96%. The poor correlation between lead, cadmium and copper (correlation coefficient less than 0.05) with other elements represents that these elements are unlikely to be enriched in limestone; therefore, they have no natural origin. In addition, the results of correlation coefficient between elements in the soil have shown that iron has a positive and significant correlation (90-94%) with other target elements in the soil (with urban and non-urban application) indicating that the concentration of iron in the studied area is controlled by lithological factors which is less affected by human activities. While the weak correlation coefficient between other target elements (lead, copper and cadmium) indicates that these elements in the soil are affected by factors. Anthropogenic are the other physical properties of soil. The concentration of iron in the basic material and the soils formed on it has a significant correlation at the level of 99%. There is no significant correlation among the concentrations of lead, cadmium and iron in the soil and basic soil. Therefore, basic material can be considered as one of the important factors to control the iron concentration. However, the basic material does not affect the concentrations of lead, cadmium and copper in the studied area. On the other hand, the comparison of the concentrations of these elements in the soil of different areas of Kerman City with the average concentration of soil particles in major cities worldwide (global soil) shows a low concentration due to low technological development of this city, its buffering properties of soil and the reduced mobility of elements in the city. Therefore, soil pollution and these anomalies are due to various human activities in cities such as transportation, related activities, and dumping waste in the surrounding vacant lands. In addition, the abundant pistachio orchards around the city, which often spread upstream, can release large amounts of organic and chemical fertilizers and pesticides into the air and cause the spread of pollutants in the soil and air. Also, excessive use of chemical fertilizers to solve the nutrient deficiency issues in the suburbs can cause soil pollution. The geochemical maps of lead, cadmium concentrations, copper and iron are shown in Figures 4, 5, 6 and 7, respectively.

Table 5. Concentration of target PHEs in rocks and sediments of Kerman (ppm)

PHEs	Concentration in rocks in the urban area		Concentrations in alluvial sediments		Concentrations in playa sediments		Concentrations in aeolian sediments		Natural grade in the earth crust
	Limestone	Young conglomerate	Changes	Average	Changes	Average	Changes	Average	
Pb	11	25	85-11.1	43	22-34	30.5	25-16	20	55
Cd	0.16	0.19	0.37-0.19	0.23	0.36-0.22	0.28	014-0.26	0.2	0.2
Cu	1.75	10.7	54.6-24.7	41.5	41-21.5	32	38.1-30	24.5	12.5
Fe	713	40400	600-50000	31200	10000-40000	30000	900-40000	31200	41000

Table 6. Concentration of target elements in a number of polluting areas in Kerman based on ppm.

	Pb	Cd	Cu	Fe
Concentrations in residential areas and parks	96.5	0.32	67	31200
Concentration in soils of gas stations	443	0.33	64	
concentrations in soils of repair shops	193	0.42	87	25150
Concentrations in car painting shops	640	0.41	585	50200
Concentration in soils of battery manufacturers	4700	0.74	643	30900
Landfill sits	340	0.9	450	27900
Agriculture soil (according to table 5)				
Global soil	25	0.5	30	21000

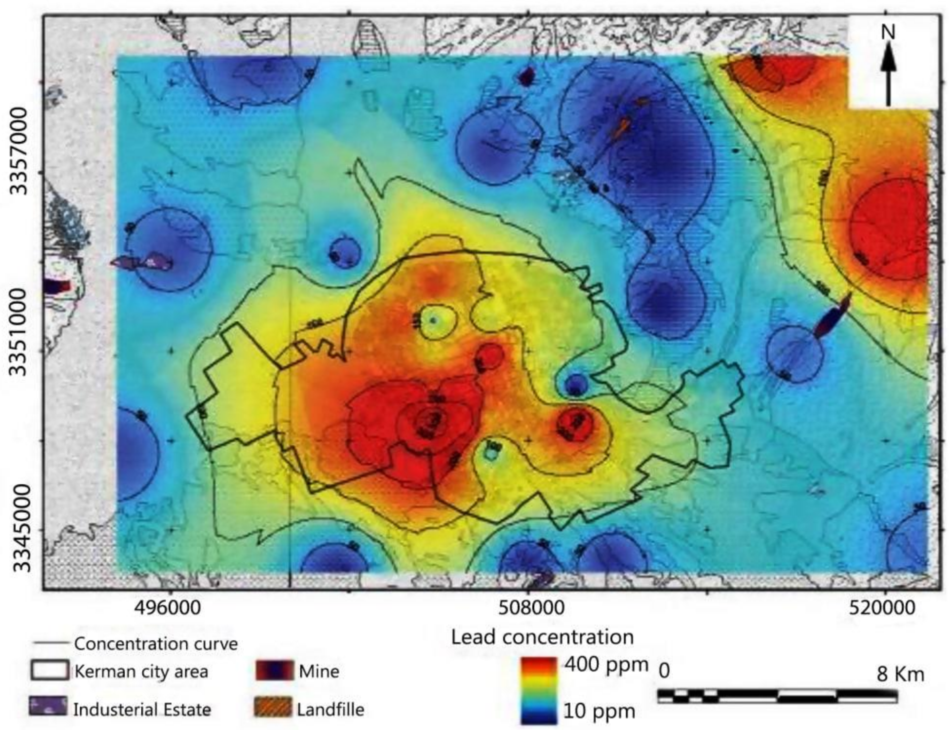

Figure 4. Geochemical map copper in sediments and soils in City of Kerman (natural grade copper in soil= 25 ppm)

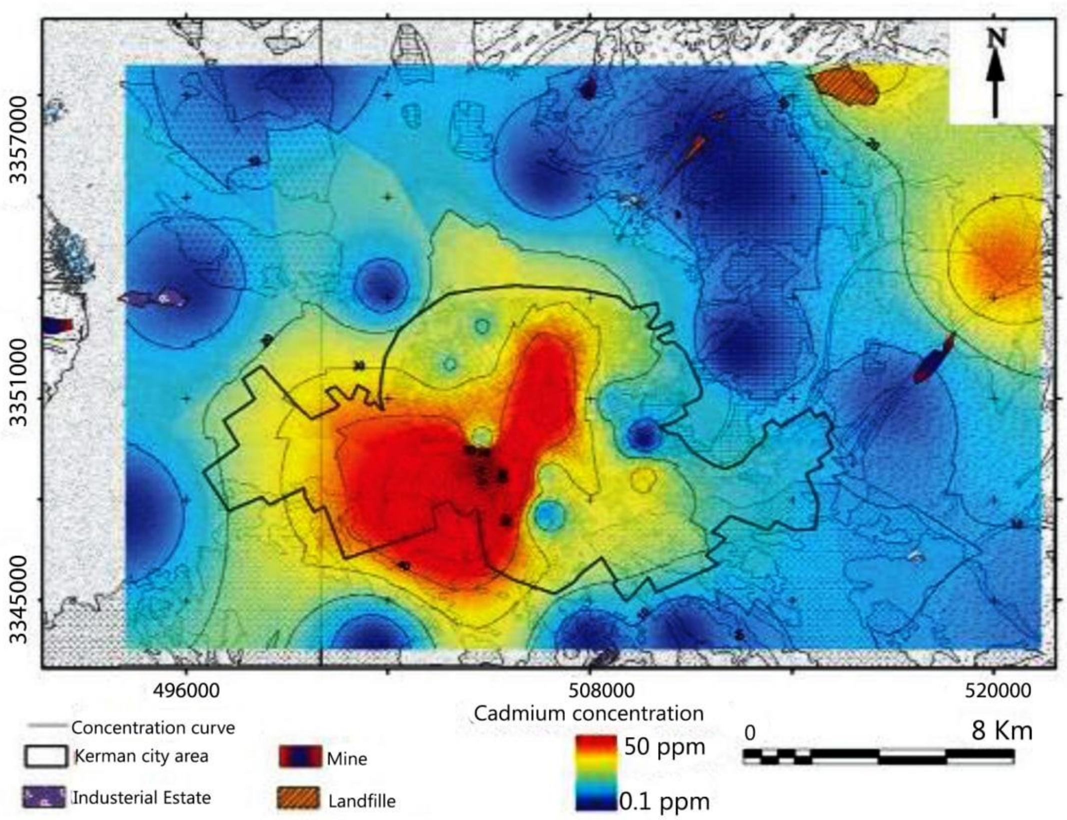

Figure 5. Geochemical map cadmium in sediments and soils in City of Kerman (natural grade cadmium in soil= 0.5 ppm)

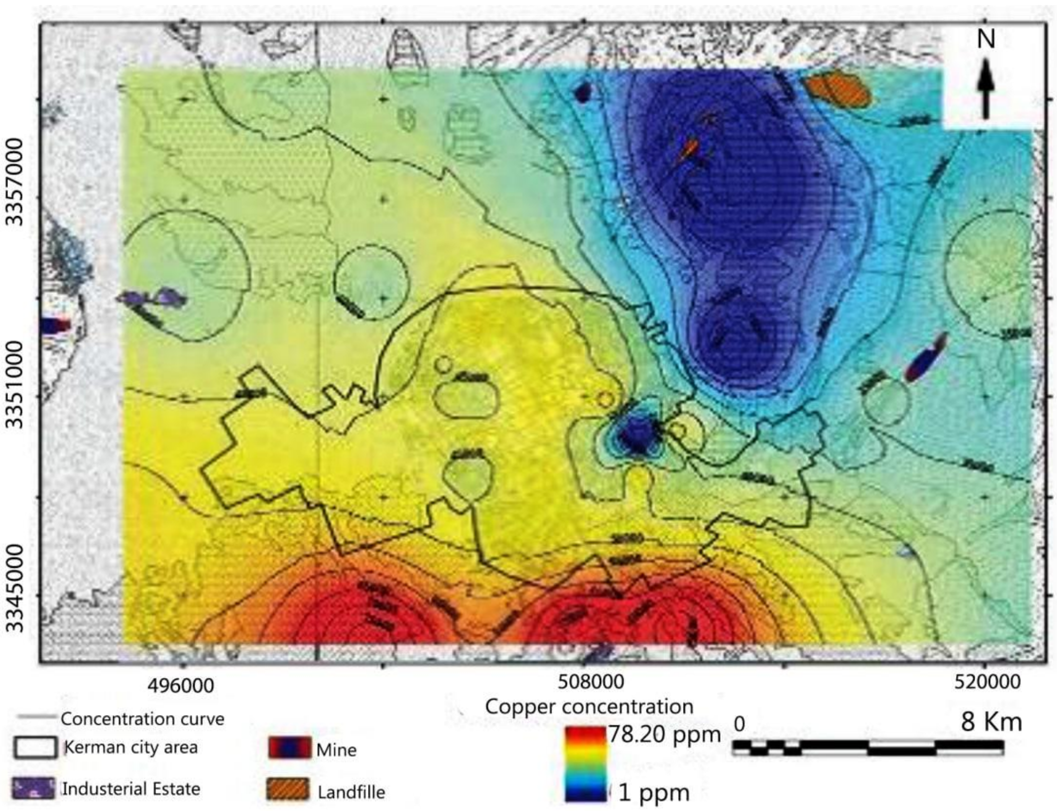

Figure 6. Geochemical map copper in sediments and soils in City of Kerman (natural grade copper in soil=30 ppm)

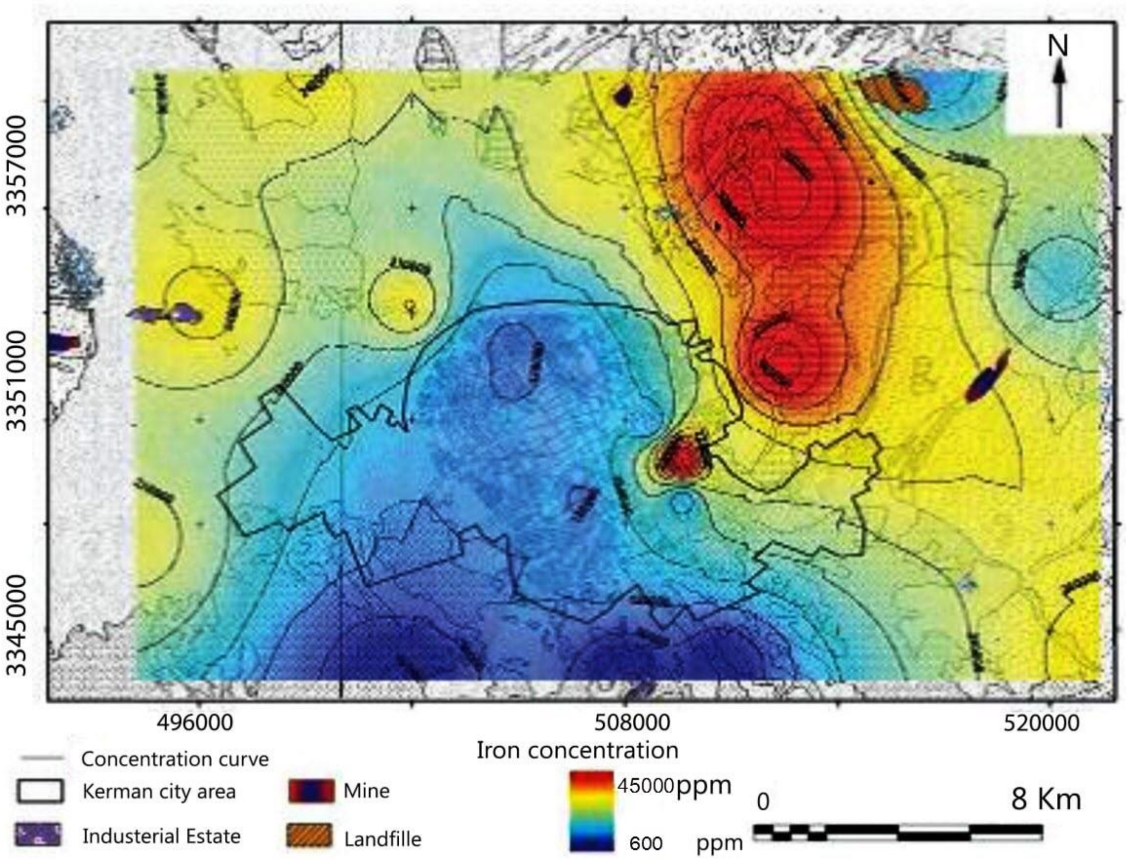

Figure 7. Geochemical map Iron in sediments and soils in City of Kerman (natural grade Iron in soil= 21000 ppm)

3.3. Pollution Assessment in farmland soil in the study area

The contamination indices of *CF, PLI*, and *Igeo* have been calculated based on the natural background level in the four studied regions. As represented in Table 7, the average *CF* value in the decreasing order in the Abuzar region is as follows: Pb > Cd > Cu > Fe. There are high levels of the PHEs contamination for the lead, while other metals are in the range of average pollution. The average amount of *PLI* for targets PHEs in this area is low contamination. The geo-accumulation index for metals in the target regions are shown in Table 8. The average geo-accumulation index (*Igeo*) for lead is in the range of medium pollution. In addition, cadmium and copper are in the range of non-pollution to medium pollution, and iron is in the range non-pollution. The investigation on the average contamination level, *CF*, in Saadatabad has shown that cadmium and iron are in the range of low pollution, copper in the medium level of pollution ($1 < CF \leq 2$), and lead with *CF*= 2.593 is in the range of heavy pollution.
Furthermore, the value of PLI in this area is within the low pollution level. It also indicates that the geo accumulation index (*Igeo*) of all metals except for lead in this region is in the non-pollution range, and lead with the index of *Igeo* lower than one is in the range of non-pollution to moderate pollution. According to the estimated contamination level (*CF*) value in the Sarasiab area, all metals except for lead are within the medium pollution range. The *CF* value for lead is in the Range of extremely heavy pollution. The average *PLI* level in this area is more than one placed within the range of low pollution ($1 < PLI \leq 2$). The *Igeo* index for iron and cadmium in this region is in the range of nonpollution, while it is in the range of nonpollution to moderate pollution for lead and copper.

The average *CF* values for cadmium, iron, and lead in the Bagherabad region are at the level of low pollution (0.7 < CF ≤ 1). According to the average CF value, lead is in the range of heavy pollution. The geoaccumulation index (*Igeo*) for cadmium, iron, and copper is below zero, which is in the range of nonpollution, whereas lead is in the nonpollution range to medium pollution (*0 < Igeo < 1*).

Table 7. Basic statistics of *CF* and *PLI* of PHEs in farmland soil in the study area

Area	Item	*CF*				*PLI*
		Pb	Cd	Fe	Cu	
Abuzar	Range	2.04±3.24	1.32±1.64	1.37±1.43	1.27±1.52	1.6067±1.84
	Mean±SD	3.15±0.30	1.56±0.07	1.40±0.01	1.50±0.06	1.79±0.06
Saadatabad	Range	1.60±2.66	0.63±0.088	0.97±1.01	1.06±1.14	1.12±1.27
	Mean±SD	2.60±0.27	0.84±0.04	0.99±0.01	1.13±0.01	1.25±0.03
Sarasiab	Range	1.77±2.97	1.06±1.26	0.59±1.18	1.25±1.27	1.29±1.53
	Mean±SD	2.88±0.30	1.21±0.05	1.12±0.14	1.26±0.003	1.48±0.07
Bagherabad	Range	1.35±2.41	0.43±0.79	0.65±0.7	0.93±0.09	0.78±1.06
	Mean±SD	2.34±0.27	0.71±0.08	0.67±0.009	0.98±0.01	1.02±0.006

Table 8. Basic statistics *Igeo* of PHEs in farmland soil in the study area

Area	Item	*Igeo*			
		Pb	Cd	Fe	Cu
Abuzar	Range	0.44±1.11	-0.18±0.01	-0.12±-0.06	-0.238±0.02
	Mean±SD	0.06±0.17	0.05±0.07	-0.09±0.01	0.001±0.06
Saadatabad	Range	0.09±0.83	-1.11±-0.07	-0.62±-0.59	-0.49±-0.39
	Mean±SD	0.77±0.18	-0.83±0.08	-0.60±0.01	-0.40±0.02
Sarasiab	Range	0.23±0.98	-0.50±-0.25	-1.34±-0.35	-0.25±-0.24
	Mean±SD	0.93±0.19	-0.30±0.06	-0.43±0.25	-0.24±0.003
Bagherabad	Range	-0.14±0.68	-1.79±-0.91	-1.19±-1.13	-0.68±-0.06
	Mean±SD	0.63±0.21	-0.08±0.20	-1.15±0.02	-0.61±0.01

3.4. Non-carcinogenic risk in farmland soil in the study area

The non-carcinogenic chronic daily intake (*CDI*) is calculated according to Eqs. 4-7. In this study, non-carcinogenic chronic daily intakes of the PHEs in both adult and children groups through the mentioned pathways have been calculated based on the average concentration of the PHEs in the studied agricultural soils, and the results are represented in Table 9.

Table 9: Daily exposure for non-carcinogenic risk of PHEs

Area	Elements	$CDI_{Ingestion}$		$CDI_{inhalation}$		CDI_{Dermal}		CDI_{total}	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
Abuzar	Pb	1.32E-04	7.86E-04	5.60E-07	3.31E-06	4.04E-07	1.25E-06	1.32E-04	7.90E-04
	Cd	6.50E-07	3.85E-06	2.74E-09	1.62E-08	1.98E-09	6.16E-09	6.54E-07	3.87E-06
	Fe	1.63E-03	9.68E-03	6.90E-06	4.08E-05	4.98E-06	1.55E-05	1.64E-03	9.73E-03
	Cu	8.00E-05	4.74E-04	3.37E-07	2.00E-06	2.43E-07	7.58E-07	8.05E-05	4.76E-04
Saadatabad	Pb	1.09E-04	6.49E-04	4.62E-07	2.74E-06	3.34E-07	1.03E-06	1.09E-04	6.52E-04
	Cd	3.49E-07	2.06E-06	1.47E-09	8.72E-09	1.06E-09	3.30E-09	3.51E-07	2.07E-06
	Fe	1.17E-03	6.95E-03	4.95E-06	2.93E-05	3.57E-06	1.11E-05	1.17E-03	6.99E-03
	Cu	5.93E-05	3.51E-04	2.50E-07	1.48E-06	1.80E-07	5.61E-07	5.97E-05	3.53E-04
Sarasiab	Pb	1.22E-04	7.23E-04	5.19E-07	3.05E-06	3.72E-07	1.15E-06	1.22E-04	7.27E-04
	Cd	5.05E-07	2.99E-06	2.13E-09	1.26E-08	1.54E-09	4.79E-09	5.08E-07	3.00E-06
	Fe	1.37E-03	8.17E-03	5.82E-06	3.44E-05	4.20E-06	1.30E-05	1.38E-03	8.21E-03
	Cu	6.66E-05	3.94E-04	2.81E-07	1.66E-06	2.03E-07	6.31E-07	6.70E-05	3.96E-04
Bagherabad	Pb	9.94E-05	5.88E-04	4.19E-07	2.48E-06	3.02E-07	9.42E-07	1.00E-04	5.91E-04
	Cd	1.48E-07	8.78E-07	6.25E-10	3.70E-09	4.51E-10	1.40E-09	1.49E-07	8.83E-07
	Fe	7.94E-04	4.70E-03	3.35E-06	1.98E-05	2.42E-06	7.53E-06	7.99E-04	4.72E-03
	Cu	5.15E-05	3.05E-04	2.17E-07	1.28E-06	1.57E-07	4.89E-07	5.18E-05	3.06E-04

The average non-carcinogenic chronic daily intakes in each of the target PHEs for both adults and children in the regions of Abuzar, Sarasiab, Saadatabad, and Bagherabad follow the declining trend of *CDI Ingestion* > *CDI Inhalation,* > *CDI Dermal*. In general, non-carcinogenic chronic intake of the PHEs in these four regions is similar with a decreasing trend of Fe > Pb > Cu > Cd.
According to the *CDI* in all studied agricultural soils, the chronic daily intake of non-carcinogenesis in children has been higher than that in adults; also ingestion has received the highest daily intake in the two groups of adults and children through all the main pathways.
HQ is used to evaluate the non-carcinogenic health risk estimated by Eq. 8. The average *HQ* value of three main pathways of human exposure (Ingestion, Inhalation, and skin contact) with the target PHEs in the agricultural soil has been calculated as represented in Table 10 (It should be considered that only the ingestion and skin contact for this metal has been calculated due to the lack of inhalation *RFD* coefficient for iron).

Table 10. The non-carcinogenic risk index of PHEs in farmland soil in the study areas

Area	Elements	$HQ_{Ingestion}$		$HQ_{Inhalation}$		HQ_{Dermal}		HQ		HI_{Total}	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Abuzar	Pb	3.77E-02	2.24E-01	1.59E-04	7.69E-04	2.38E-03	3.86E-03	2.27E-02	2.27E-01	4.38E-02	2.57E-01
	Cd	6.50E-04	3.85E-03	2.74E-06	1.62E-05	1.98E-04	6.16E-04	8.50E-04	4.48E-03		
	Fe	2.32E-03	1.38E-02	----	----	3.55E-05	1.10E-04	2.35E-03	1.39E-02		
	Cu	2.00E-03	1.18E-02	9.32E-06	5.00E-05	2.02E-05	6.31E-05	2.02E-03	1.19E-02		
Saadatabad	Pb	3.11E-02	1.85E-01	1.31E-04	7.78E-04	6.36E-04	1.96E-03	3.18E-02	1.87E-01	3.81E-02	2.06E-01
	Cd	3.49E-04	2.06E-04	1.47E-06	8.72E-06	1.06E-04	3.30E-04	4.56E-04	5.44E-04		
	Fe	2.42E-03	9.92E-03	----	----	2.55E-05	7.92E-05	2.44E-03	9.99E-03		
	Cu	1.34E-03	8.77E-03	6.25E-06	3.70E-05	1.50E-05	4.67E-05	1.36E-03	8.85E-03		
Sarasiab	Pb	3.48E-02	2.06E-01	1.47E-04	8.66E-04	7.08E-04	2.19E-03	3.56E-02	2.09E-01	3.99E-02	2.34E-01
	Cd	5.05E-04	2.99E-03	2.13E-06	1.26E-05	1.54E-04	4.79E-04	6.61E-04	3.48E-03		
	Fe	1.95E-03	1.16E-02	----	----	3.00E-05	9.28E-05	1.98E-03	1.16E-02		
	Cu	1.66E-03	9.85E-03	7.02E-06	4.15E-05	1.69E-05	5.25E-05	1.68E-03	9.94E-03		
Bagherabad	Pb	2.84E-02	1.68E-01	1.19E-04	7.04E-04	5.75E-04	1.79E-03	2.90E-02	1.70E-01	3.16E-02	1.85E-01
	Cd	1.48E-04	8.78E-04	6.25E-07	3.70E-07	4.51E-05	1.40E-05	1.93E-04	8.92E-04		
	Fe	1.13E-03	6.71E-03	----	----	1.72E-05	5.37E-05	1.14E-03	6.73E-03		
	Cu	1.28E-03	7.62E-03	5.42E-06	3.20E-05	1.30E-05	4.07E-05	1.29E-03	7.69E-03		

The comparison of average *HQ* for the PHEs in the studied area regions has shown that this factor's decreasing trend in all regions is similar for both adults and children (*HQ Pb* > *HQ Fe* > *HQ Cu* > *HQ Cd*). The main pathways of *HQ* for lead, cadmium, and copper for adults and children in all regions of Kerman City have been ingestion, skin contact, and inhalation, respectively (*HQ Ingestion* > *HQ Dermal* > *HQ Inhalation*).

For iron in the regions mentioned above, the main pathways for *HQ* have been largely ingestion and skin contact. The total hazard equations of the target PHEs have represented that the share of the lead for two groups of adults and children, respectively, have been 88% and 88% in the Abuzar region, 90% and 85% in Saadatabad, 87% and 89% in Sarasiab, and 91% and 91% in Bagherabad region, which has the highest share of *HI* value among target metals, indicating that lead has the highest potential non-carcinogenic potential among the target PHEs. The values of *HI* in adults and children in all regions (Abuzar, Saadatabad, Saraasiab, and Bagherabad) have been less than one, which indicates that, based on USEPA Standard, the target PHEs in these regions have no destructive effects on human health.

3-5. Carcinogenic risk in farmland soil in the study area

Based on the Eqs. 4-7, the chronic carcinogenic daily intakes of lead and cadmium through ingestion, inhalation, and skin contact have been calculated in adults and children in the four studied regions, as shown in Table 11.

Table 11. Daily exposure to the carcinogenic risk of PHEs in farmland soil in the study area

Area	Elements	$CDI_{Ingestion}$		$CDI_{Inhalation}$		CDI_{Dermal}		CDI_{total}	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
Abuzar	Pb	4.55E-05	2.69E-04	1.92E-07	2.84E-07	1.38E-07	1.07E-07	4.58E-05	2.69E-04
	Cd	2.23E-07	3.30E-07	9.41E-10	1.39E-09	6.79E-10	5.28E-10	2.24E-07	3.31E-07
Saadatabad	Pb	3.76E-05	5.56E-05	1.58E-07	2.34E-07	1.14E-07	8.91E-08	3.78E-05	5.59E-05
	Cd	1.19E-07	1.77E-07	5.05E-10	7.47E-10	3.64E-10	2.83E-10	1.19E-07	1.78E-07
Sarasiab	Pb	4.18E-05	6.20E-05	1.76E-07	2.61E-07	1.27E-07	3.35E-08	4.21E-05	6.22E-05
	Cd	1.73E-07	2.56E-07	7.31E-10	1.08E-09	5.28E-10	4.10E-10	1.74E-07	2.57E-07
Bagherabad	Pb	3.40E-05	5.04E-05	1.43E-07	2.12E-07	1.03E-07	8.07E-08	3.42E-05	5.06E-05
	Cd	5.08E-08	7.25E-08	2.14E-10	3.17E-10	1.54E-10	1.20E-10	5.11E-08	7.56E-08

Comparing the values of carcinogenic *CDI* for lead and cadmium in all regions has represented that ingestion is the main pathway to receiving these metals in adults and children. The decreasing pattern of carcinogenic *CDI* for lead and cadmium in adults and children is *CDI Ingestion > CDI Inhalation, > CDI Dermal*.

The comparison of total CDI values in four regions has shown that the chronic daily intake of carcinogens in children is more than that of adults. In addition, this decreasing trend in the adult and children groups has a similar declining trend for lead and cadmium as follows: Abuzar > Sarasiab> Saadatabad > Bagherabad. The carcinogenic risk (*CR*) of lead and cadmium from the three main pathways and the total carcinogenic risk (*TCR*) are shown in Table 12.

Table 12. Carcinogenic risk index of PHEs in farmland soil in the study area

Area	Elements	$CR_{Ingestion}$		$CR_{Inhalation}$		CR_{Dermal}		CR		TCR_{total}	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Abuzar	Pb	3.86E-07	2.26E-06	8.06E-09	1.19E-08	----	----	3.94E-07	2.29E-06	1.76E-06	4.35E-06
	Cd	1.36E-06	2.01E-06	5.92E-09	8.75E-09	4.14E-09	3.22E-09	1.37E-06	2.06E-06		
Saadatabad	Pb	3.19E-07	4.72E-07	6.63E-09	9.82E-09	----	----	3.25E-07	4.81E-07	1.05E-06	1.55E-06
	Cd	7.25E-07	1.08E-06	3.18E-09	4.70E-09	2.22E-09	1.72E-09	7.30E-07	1.07E-06		

Sarasiab	Pb	3.55E-07	5.27E-07	7.39E-09	1.09E-08	----	----	3.62E-07	5.37E-07	1.41E-06	2.09E-06
	Cd	1.05E-06	1.55E-06	4.60E-09	6.80E-09	3.22E-09	2.50E-09	1.05E-06	1.56E-06		
Bagherabad	Pb	2.89E-07	4.28E-07	6.00E-09	8.90E-09	----	----	2.95E-07	4.36E-07	6.05E-07	8.96E-07
	Cd	3.09E-07	4.58E-07	1.34E-09	1.99E-09	9.39E-10	7.32E-10	3.10E-07	4.60E-07		

Due to the lack of *SF* coefficient for lead, the carcinogenic risk has been only calculated for the ingestion and inhalation pathways. The values of carcinogenic risk *CR* in the four regions have shown that the *CR* levels of lead and cadmium in children have been higher than in adults. It is also concluded that ingestion has been the main carcinogenic pathway for lead and cadmium in adults and children in all regions.

The carcinogens risk *CR* of lead in adults and children in all regions is negligible, less than 1×10^{-6} (a possible cancer of one in every million people). Regarding cadmium for the adult group, the CRingestion in Sadatabad and Bagherabad is less than 1×10^{-6}, whereas it is within the range of 1×10^{-4} - 1×10^{-6} in Abuzar and Sraasiab, indicating the acceptable carcinogenic risk under controlled conditions. Regarding children, the *CR ingestion* in all regions except for Bagherabad has been within the range of 1×10^{-4} - 1×10^{-6}, considered acceptable carcinogen risk under control and monitoring conditions. Regarding children in Bagherabad, it has been below the value of 1×10^{-7} and is considered negligible. *CR inhalation* of cadmium and lead for adults and children in all regions has been lower than 1×10^{-6}, which is a negligible value. The CR dermal level for cadmium in adults and children has also been lower than that of 1×10^{-6}, considered a negligible value.

In comparison with *TCR* in all studied areas, it is concluded that the carcinogens risk in children is higher than that of adults. Also, the carcinogen risk in adults and children in all regions has been within the range of 1×10^{-4} and 1×10^{-6}, considered acceptable carcinogen risk under control and monitoring conditions. The comparison of total carcinogenic risk *TCR* for adults and children in four regions follows the decreasing trend of Abuzar > Sareasiab > Saadatabad, > Bagherabad.

4. Discussion

Most toxic elements absorbed by humans and animals are rapidly excreted, and only a tiny proportion of them remain in the body tissues. Depending on the amount and digestion time, absorption of rare and secondary elements can bring about several serious health risks (Kahrom. 1997). The children with 10 kg absorb approximately 0.5 g of soil per day (Walker et al. 1998), depending on the climatic conditions of their area of residence. This amount reaches its maximum value in arid areas such as Kerman City, where there is a large amount of dust in the air. The soil can directly enter the body through playing on dusty playgrounds, working on agricultural lands, agricultural products partially washed, and grazing animals. Since cretaceous limestone is the most common rock unit in Kerman City and the previous studies show that the concentrations of particle elements in limestone and its sediments in the regions of the study area are lower than the world average in limestone (Atapour and Aftabi. 2002), the probability of the natural origin of the target metals except for iron is low in the studied area. According to the map of Kerman city (Figure 2), the mines of this city are mainly stone, gypsum, and sand mines without a significant role in the concentrations of these elements. The mobility of rare elements with toxic potential by human activities is a crucial process in the geochemical cycle of these elements. Various fixed and moving agents enter large amounts of the PHEs into the air and soil beyond their natural levels (Schwedt. 2001). One of the main paths of direct transfer of PHEs and quasi-metals from paints, gasoline, vehicles, and local industries to the human body, especially in hot and dry climates such as Kerman City, is swallowing soil and dust. The coefficient of CV is used to study the indicators (Mamut et al., 2017). The range of metal concentrations, along with their wide variation coefficient, indicates the effect of human activities on the increase of the metal concentration in the agricultural soils of the studied area, confirmed by a comparison of the average concentrations with the local background concentration. Although soil pollution is not solely the conclusive factor based on the background concentration, the local background concentration has been used in this study which is the best concentration to estimate the pollution (Wu et al. 2014). Dust is another important source of soil pollutants in Kerman City due to the Kerman Cement Factory in the west of the city located upstream of the wind direction. The process of heating clay minerals to produce cement up to about 1000 ° C causes the release of a proportion of lead, zinc, tellurium, cadmium, and bismuth, of which lower than 20% enter the atmosphere that is carried away long distances by the airflow. Many toxic elements are in small particles, and industrial filters are highly efficient at absorbing small gaseous particles.

For example, large particles emitted from the coal furnaces often contain oxides of aluminum, silicon, sodium, potassium, magnesium, iron, and copper, while larger particles are rich in elements such as zinc, lead, cadmium, selenium, antimony, and arsenic (Merian et al. 2004). Therefore, the industrial districts in this study area have a minor role in increasing the concentration of the studied elements due to their small size and the absence of polluting manufacturers. Although Kerman City has a small concentration of industrial units and factories, the increasing number of streets and related occupations has led to a rise in the concentration of some toxic elements, especially in agricultural lands along the streets with high traffic flow and near vehicle-related units such as gas stations. In the study area, pollution spreads vigorously through the wind due to the dry climate and wind erosion (Eby. 2016). As a result of the lower development and limited industrial activities of Kerman City, in comparison with the major industrial cities in the world, the most anthropogenic origins of the PHEs in the urban agriculture areas include the proximity to roads and highways, heavy traffic, vehicle emissions, mechanical components of cars and wearing rubber tires, the excessive use of fertilizers, and over-irrigation. Lead in all soil samples of the studied agricultural fields is more than cadmium which is similar to the results of previous studies (Jung. 2008; Orisakwe et al., 2012). The environmental studies are required to focus on urban traffic since air is the only source expected to increase its pollutants in the future; consequently, the deposition of these pollutants in the soil causes environmental issues and adverse effects on human health in different ways (Merian et al. 2004). Despite that the use of lead in fuels was banned according to the Persian Gulf Cooperation Council in 2003, leaded petrol is still available in some regions of Iran. The high concentrations of lead in the urban soils, lands, and places near the high traffic roads indicate the high levels of lead pollution and long half-life of lead in the soil (Thomas et al. 1999).

Furthermore, the excess anti-impact blend of lead tetra ethylene (TEL) with the chemical formula of (CH3 CH2)4 to gasoline at the temperature of the internal combustion engines turns into carbon dioxide, water and lead, then it is deposited on the soil surface through the process of atmospheric deposition and sedimentation. In general, 90% of the total lead emissions in the absence of industry or other sudden lead-related production activities are related to the release of exhaust fumes from the leaded gasoline emitted from vehicles (Thomas. 1995). Furthermore, lead is the main element of the paints, greases, and vehicle components which are usually found in places near the high traffic roads and vehicle repair shops, as the waste in the soil results in the increase of lead concentrations in the soil. Some sources indicate the role of vehicles in increasing lead concentrations. The fuel, batteries, and rubber tire abrasion from the sources of cadmium production are related to the vehicles (Bottoms. 2000; Sayed et al. 2003). The replacement of steel with the copper-nickel alloy in the vehicles' brake systems and the use of Cu-Brass alloy to increase the resistance and conductivity of radiators, the mechanical deterioration of cars, and the wiring of bearings and gear over time results in the increase of the amount of copper in the surrounding areas (Alloway. 1995, Li et al., 2004). Because most vehicle repair shops are distributed in different districts of Kerman City, their distribution pattern shows they are mainly in the Sarbaz streets near Kerman Old Terminal. The mobility and bio-availability of the PHEs are reduced due to the arid weather conditions, the alkaline pH (8- 8.5), and the high amount of clay with carbonate compounds in the agricultural soils.

Since the two main natural pathways to transmit the pollutants and their propagations in the city are through the prevailing winds and soluble and suspended materials in the street water canals. The horizontal or vertical movement of rare toxic elements in the urban soils and, ultimately, agricultural soils located in the urban areas generally depends on the amount of surface runoff, such as water canals on streets. These elements are transferred from the polluting environments in the form of the ionic solution, suspended charge, and solids in which soil colloids absorb toxic elements. The movement of these elements is controlled by properties such as acidity, humic components, and minerals, the structure of the soil, composition and size of soil grains, absorption ability, an abundance of microorganisms, and most importantly, water (Eby. 2016; Chen. 2015). The important role of the colloids such as clays, iron, manganese oxides, and organic compounds in the absorption of toxic elements and natural water treatment must be considered. The clay soils in Kerman City with medium to alkaline pHs have low mobility for elements based on Beckett (1958). Several clay minerals with different ratios in different soil horizons in the Kerman plain lead to a cation exchange capacity of 35m.Eq / 100gr. The X-ray studies have indicated the existence of 25% montmorillonite,

10% chlorite, 50% mica, 15% of kaolinite, and small proportions of feldspar and calcite in some soils, and the high amount of organic elements in agricultural soils and low quantity of organic elements in urban soils.
The relatively high solutes in these soils are the soluble salts of sodium, potassium, and manganese, but they are less than the calcium carbonate (Beckett. 1958).
The relatively high solutes of these soils are the soluble salts of sodium, potassium, and magnesium, much less than calcium carbonate (Beckett. 1958). Due to the high amount of clay minerals, these soils have a high ion exchange capacity. The oxides and hydroxides of aluminum and iron, clay minerals, kaolinite, and some organic matter are highly effective in absorbing contaminating metal cations (Eby. 2016). In addition to the direct roadside emissions and vehicles near the agricultural fields, these pollutants are transported through the pathways mentioned above to all regions of the city, including agricultural fields located in the urban area, and the PHEs in the soil eventually increase due to the process of atmospheric deposition and sedimentation or absorption of ionic solutions on the soil colloids. Several factors such as pH values of various minerals, soil structure and composition, the abundance of microorganisms, and water contents control the absorption of PHEs by sediments and soil. The primary source of accumulation of atmospheric subsidence is dry sediments playing a crucial part in changing the concentration of PHEs in the soil (Graef. 1997; Rea et al. 2001).
The geochemical map of lead, cadmium, copper, and iron has been prepared using Arc GIS software to identify the changing trends in the elements' concentration from the outskirts to the city center. Although the geochemical map of copper shows the high concentration of this element in the south of Kerman plain and the city center where wind sediments dominate, It also represents the low concentration of copper near the limestone outcrops in the east of Kerman City (Figure 2) where the concentration of iron shows a significant increase that is entirely consistent with the cretaceous limestone outcrops (Figure 3). The concentrations of toxic lead and cadmium show a markedly increasing trend from the outskirts to the city center (Figures 4 and 5).
Therefore, the precipitates of dry matter have been the primary source of deposited PHEs in the studied area. Furthermore, the most critical pollution factors of the studied soils have been the direct roadside emissions of vehicles and the transfer of pollutants from polluted areas by prevailing winds (West-Northwest winds). The second important factor is chemical fertilizers in agricultural land that have been widely used in recent years to achieve more products and higher economic profit.

5. Conclusions

In summary, the method with the location-dependent parameters proposed by USEPA has been performed to assess the health risk of PHEs in the soils of the studied areas. Therefore, this method can be carried out in other regions worldwide. The selected parameters in this study, such as mean age, mean longevity, and soil swallowing rate, have been extracted from the cited references, and therefore they would not be thoroughly appropriate for the mentioned studied regions. However, using the availability of PHEs instead of total concentrations of PHEs is recommended to more accurately assess the health risk using this method. It is also recommended to modify the exposure parameters in future research to develop a new method and consider the available fraction of metals that can be applied for various applications and gender-related studies. In addition, based on the results of this study, practical tools and efficient measures should be consistently applied to control and monitor the health risks caused by the PHEs to reduce the carcinogenic and non-carcinogenic risks of agricultural activities in urban areas. Likewise, essential measures should be taken to continuously monitor the PHEs in the soil and the subsequent carcinogenic and non-carcinogenic risk in the consumers of the agricultural products.

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