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Investigating the risk assessment of heavy metal contamination of iron, zinc, lead, cadmium, chromium, arsenic and nickel in the falling dust of Tehran metropolis

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Systematic Review

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Abstract

Nowadays, the development of transportation industry and urban traffic has resulted in soil, water and air pollution. Tehran is also one of the polluted cities. In this air, heavy metals such as iron, zinc, lead, cadmium, chromium, arsenic and nickel enter the human body system through inhalation, leading to problems for citizens. The use of falling dust is known to be a suitable and effective method for monitoring and measuring air pollution. Therefore, in this study, the amount of heavy metals Fe, Cd, Cr, As, Ni, Pb, and Zn was measured in each of the 22 districts of Tehran to evaluate the amount of contamination. For this purpose, 88 sampling points were considered in the entire city. Sampling was done in three months of winter 1400s. Samples of surface dust were collected using pen brushes from the side of the main streets. Then, after preparing the samples (including drying, powdering and digesting), the concentration of the desired heavy metals was measured using an ICP-MS device. Then the indices of enrichment factor (EF), contamination factor (CF) and Geoaccumulation Index (Igeo) were calculated. Finally, the results obtained from the concentration of the studied metals were used to present the spatial pattern of the concentration of heavy metals using GIS software and inverse distance weighting (IDW) technique. The results showed that the highest concentration of all types of metals belongs to the central, south and southeast parts of Tehran. Also, among different elements, iron and then chromium have the highest average amount of pollution.

Introduction

The issue of air pollution in big cities as a result of industrialization and the increase in the population of cities in recent decades is one of the issues that has become extremely important. The increasing use of fossil fuels such as oil, coal, and gas and their combustion in the vehicle engines has caused the release of heavy metals in the air, which has subsequently led to harmful effects on the health of humans and other living beings. Heavy metals are one of the main air pollutants in the big cities (Yongming et al., 2006). Previous studies show that the accumulation and release of heavy metals in the urban dust is caused by human and natural factors (Faisal et al., 2021). The results of the study of dust particles and fine dust in the regional atmospheric environment located in the coal port indicated the accumulation of organic carbon in the atmosphere due to industrial emissions (Wang et al., 2024). Investigation of tidy stores collected in a locale in Jordan and consider of their defilement characteristics and appraisal of natural and human wellbeing chance from presentation to possibly harmful components in this tidy appeared that the foremost abundant major components within the dust were calcium, silicon, press and aluminum, whereas the most minerals were carbonate and silicate, showing a detrital sedimentary origin of the clean. The comes about of the environmental hazard potential appeared an awfully moo biological chance. For children and grown-ups, carcinogenic and non-carcinogenic wellbeing dangers related to ingestion, dermal contact and inward breath of tidy were surveyed (Batiha et al., 2024). When considering the effect of air metal contamination on vegetation, it is fundamental to evaluate the significance of the different sources of such metals. Understanding the standards of metal classification permits for a more total translation of inquire about comes about and empowers a levelheaded approach when considering the affect of gathered metals on the physiology and digestion system of

living beings (Seaward and Richardson., 2024). Meddling clean particles have risen as a major natural concern within the Center East locale. In this manner, it is imperative to examine the physical and chemical characteristics of clean particles found in a huge city. Expository methods in a consider within the Iraqi city of Sulaymaniyah uncovered primarily unpredictable shapes of tidy particles, characterized by the nearness of quartz and calcite minerals, affirming their characteristic root due to wind-induced disintegration from the bone-dry forsake scenes of Iraq and its southern and western neighboring nations. Amid this ponder, calcium, magnesium, and copper appeared critical levels of defilement in dust-fall particles from the city of Sulaymaniyah. In arrange to decrease the chances of tidy particles entering the city, planting trees and making green belt boundaries against that clean attack may be advantageous (Othman Abdulla and Souri., 2024). Within the region of metallurgical and steel exercises, it is critical to degree the critical defilement of possibly poisonous components in partitioned natural compartments (soil, biosphere, climate). Thinks about appear that soils found close mechanical zones are most influenced by mechanical clean testimony. A few variables clarifying the spatial dissemination of soil defilement levels were inspected and it appears that distance from emanation sources isn't essentially the foremost pertinent. The comes about appeared that the dissemination of vegetation or buildings may act as a obstruction that anticipates soil introduction to clean statement (Casetta et al., 2024). Farming and industrial waste, along with busy roads and highways, might cause higher levels of heavy metals in the air in each area. The results show that pollution levels go up with dust falling from the air, especially near factories. This means that human activities are a major cause of pollution (Hussein et al., 2024). We need to study the amount of heavy metals in dust storm samples and check the health risks for adults and children who may be exposed to these metals by eating, breathing, or skin contact. Heavy metals in dust are a big worry because people can get them into their bodies by eating, breathing, or touching them, which can lead to health issues. The studies show that dust storms can put our health at risk because of heavy metals, especially for kids. They stress how important it is to tackle these issues to keep everyone healthy (Hassan et al., 2024). A study of rainwater in Tehran found that heavy metals were much higher in the center and south parts of the city than in the north and west. This difference is caused by the way the city is built, more pollution from cars and homes, and wind patterns in the area. The heavy traffic in central Tehran makes the levels of heavy metals in that area worse. The strong link between the heavy metals we looked at suggests they come from the same local human activities. The levels of heavy metals in rain samples taken in spring were higher than in winter. This was likely because winter had more dilution and there were restrictions from the COVID-19 pandemic. During the quarantine, there was a big drop in traffic in Tehran. This shows that cars are the main cause of air pollution and harmful substances in the city (Malekei et al., 2024). The results showed that where and when the samples were taken had a big impact on the amount of dust and the levels of copper, nickel, and chromium in the samples. The most dust fell from the air during the fall. In winter, there was the least amount of dust fall. In Tehran, the results showed that the levels of heavy metals and dust in the air get higher from the west to the east and from winter to autumn (Samani et al., 2025). To fight pollution from dust, we need to know that plants can take in harmful metals from the air using their roots and leaves. This situation could also affect how biofiltration systems are developed. To investigate this possibility, we need to know how well plants can capture substances and where they get metals from.

For example, ferns take in materials from the air, and studies have shown they can absorb lead (Ray et al., 2024). The human factors of heavy metal contamination in the air of the Tehran metropolis include the disproportionate growth of the urban population, large number of old and dilapidated industries, more than capacity arrival of cars, and a high level of pollutant emissions into the urban transportation cycle (Sari et al., 2018).From among the natural sources of pollution, we can refer to the deposition of soil particles, resuspension, weathering and erosion, the presence of mountains around the city, the absence of continuous winds with a suitable speed, and little rain (Ali et al., 2017). The presence of heavy metals more than the defined standards in the environment causes environmental problems and complications for the inhabitants of that place and ecosystem (Absalon, 2010). As a result, inhalation of heavy metals by the citizens causes serious risks to their health. Heavy metals have different effects on humans, the most important of which is the occurrence of neurological disorders (Faisal et al., 2021). On the other hand, the toxic nature and the ability of heavy metals to bioaccumulate in plants and animals and, consequently, their entry into the food chain has doubled their dangers and has caused many ecological effects (Salman et al., 2019). Identifying the sources and composition of dust particles is vital for preparing appropriate pollution abatement plans (Ulutaş 2023a). Tehran, located in the capital of Iran, is a metropolis faced with the environmental problems of air pollution. Tehran city with a population of more than 10 million people and more than 2 million vehicles, as well as the existence of various factories, industries and production workshops, and the consumption of various types of fossil fuels per day is considered as one of the largest polluted cities in the world. In the environmental studies, there are some calculation indices based on which the type of polluting elements and the pollution intensity are evaluated. These indicators are used to compare, evaluate, monitor, and also manage the effects of polluted elements (IAEA, 2004). Some researchers have also proposed scales to convert the obtained numerical results into degrees of pollution intensity (Müller., 1969). The evaluation of heavy elements is done using various indices such as enrichment factor (EF), contamination factor (CF) and Geoaccumulation Index (Igeo). In recent years, urban development in the capital of Iran has experienced an increasing growth. Therefore, various researchers have sought to monitor the pollution in the environment. In many provinces of the country, the number of research studies that can present the state of pollution distribution in the form of functional maps have been very limited. Among the studies conducted in this field (KhodaKarami et al., 2013; Esmaeili et al., 2014; Nezhad et al., 2015). Therefore, to get a better understanding of the extent of pollution, the simultaneous use of a set of different quantitative and qualitative methods of soil pollution assessment along with zoning methods is necessary. The final achievement of this study is measuring the amount of heavy metals including arsenic, iron, zinc, lead, cadmium, chromium, and nickel in the falling dust of 22 districts of Tehran, evaluating the pollution indicators, and, finally, providing spatial maps of heavy metal pollution concentrations and measuring the degree of correlation of these elements.

Research Methodology

Area of study

Tehran province with an area of about 12,981 square kilometers is located in the north of Iran. This province is bordered by Mazandaran province from the north, Qom province from the south, Central province from the southwest, Alborz province from the west, and Semnan province from the east. According to the census report of 2015, the population of this province has reached 13,267,637 people, of which 12,452,230 live in urban areas and 814,698 live in rural areas. In terms of geographical area, Tehran is located in the limit of 17 degrees and 51 minutes to 33 degrees and 51 minutes of east longitude and 36 degrees and 35 minutes to 49 degrees and 35 minutes of north latitude in the south of Alborz mountain range. These factors have played a major role in intensifying the two phenomena of pollution and inversion in the cold region (Iran Statistics Center., 2013).

Selection of points, sampling method, and chemical analysis

In this part, by determining 88 stations, air falling dust samples were collected and analyzed to determine the concentration of heavy metals (including: iron, zinc, lead, cadmium, chromium, arsenic and nickel) during the winter of 1400s. The distribution map of the sampling points is shown in Fig. 1. To measure the amount of heavy metals in the metropolis of Tehran, dry dust particles were sampled from the surface of the roads and streets of the city using hair pen brushes. Street dust was collected from high traffic areas, city squares, main streets, airports, industrial areas, residential areas, sidewalks, asphalt of streets, and places where dust had been accumulated for some time. At first, preliminary measures including drying, powdering, and passing through a 2 mm sieve were performed. After extraction using the combination of nitric acid and perchloric acid in a ratio of 3:1, the total concentration of the studied elements was determined using the mass spectrometry method of ICP-MS Model 200 Analyst. All the mentioned steps were taken according to OSHA-125G 2.4 standard method (OSHA, 2002). To determine the quality of analysis methods, the evaluation of the accuracy and validity of sampling was done with 3 repetitions in each station. The amount of difference in the obtained results shows the accuracy of the analysis method. The level of accuracy varies between 3 and 15 percent, which is within the acceptable range of the American Environment Protection Agency (Table 1) (Chambers, Pardakhti, 2011). Then, to determine the degree of accuracy of the analysis method in each period of sampling, spike samples were prepared. To this aim, a certain amount of pollutants is added to the samples and are analyzed to determine the accuracy of the method by comparing the ratio of the obtained concentration to the actual concentration (Table 1). Our average recovery percentage is determined to be between 83 and 93%, which is in accordance with the instructions of the Environment Protection Agency (Chambers 2, 1983).

Table 1
The average accuracy and precision of the analysis method of heavy metals in the breathing air of Tehran metropolis (%)

Average accuracy and precision	Metal						
	Fe	Zn	Pb	Cd	Cr	As	Ni
Average accuracy percentage	15	8	4	2	4	9	12
Average recovery percentage	85	92	86	91	86	84	86

Contamination Indices

Methods have been used to determine the level of metal enrichment or pollution in soils, sediments, and dust. In this study, Ghadimi et al. (2013) used different criteria including enrichment factor (EF), contamination factor (CF), and Geoaccumulation Index (Igeo) to measure the level of dust contamination with heavy metals and the effect of external factors on the dust.

Contamination factor (CF)

The contamination factor was used to determine the contamination of falling dust with heavy metals. Based on this factor, the amount of heavy metals should be measured relative to its natural amount and the amount of falling dust contamination should also be determined. This factor is calculated by the following relationship (Facchinelli et al., 2001)

$CF_{metal} = C_{metal} / C_{background}$

In this relation, CF metal is the contamination factor, CMetal is the concentration of the metal on the soil surface, and Cbackground is the concentration of the metal in the background. In this study, Hakanson's classification for the contamination factor (Table 1) was used to evaluate heavy metal contamination (Hakanson, L. 1980). The average concentration of each metal in untouched natural lands is considered as the natural background concentration (Table 2).

Table 2
Assessment of heavy metal contamination based on contamination factor (CF)

Class	Geo-accumulation index	Contamination Level
1	CF < 1	Low Contamination
2	1 ≤ CF < 3	Moderate Contamination
3	3 ≤ CF < 6	Considerable Contamination
4	CF > 6	High Contamination

Geoaccumulation Index Igeo

In the environmental analysis, the Igeo index is used to determine the level of contamination and to distinguish the impact of anthropogenic factors from natural factors. This index can indicate the intensity of the impact of external (anthropogenic) factors (Anagnostou et al., 1997). The land accumulation index, which was first introduced by Müller (1969) can also determine the degree of dust contamination and is calculated using the following equation:

Igeo=log2 [Cn \1.5Bn]

In this equation, Cn is the element concentration in the studied sediment or soil sample and Bn is the background concentration. In this study, the concentration of heavy metals in the world's soils was used as the background concentration. To correct the effects of maternal soil materials, natural fluctuations, and very small changes caused by human activities, a factor of 1.5 is used. Müller has considered seven classes for the Igeo index (Table 3).

Table 3
Geo-accumulation index classes

Class	Geo-accumulation index	Pollution degree
0	$I_{geo} \leq 0$	Practically unpolluted
1	$0 < I_{geo} \leq 1$	Unpolluted to moderately polluted
2	$1 < I_{geo} \leq 2$	Moderately polluted
3	$2 < I_{geo} \leq 3$	Moderately to strongly polluted
4	$3 < I_{geo} \leq 4$	Strongly polluted
5	$4 < I_{geo} \leq 5$	Strongly to extremely polluted
6	$I_{geo} > 5$	Extremely polluted

Enrichment factor (EF)

In the environmental studies, especially when natural and human factors simultaneously affect the concentration of heavy metals, enrichment factor can be used to determine the effect of external factors (Qingji et al., 2008). The enrichment factor of a metal is obtained using the following relationship:

EF = [Cn (sample)/Cref (sample)]/[Bn (background)/Bref (background)]

In this formula, the ratio of the concentration of the target metal to the reference metal in the studied sample and in the background values are presented. The values of the enrichment factor are placed in five classes which are given in the Table 4. In this study, iron was used as a reference metal for the

normalization of calculations because this metal devotes to itself a greater amount in the earth's crust, the contribution of human resources in its creation in the atmosphere is insignificant, and it mainly originates from the natural resources (Hakanson, 1980).

Table 4
Enrichment factor (EF) classes

Class	Geo-accumulation index	Pollution degree
1	EF < 2	Deficiency to minimal enrichment
2	2 ≤ EF < 5	Moderate enrichment
3	5 ≤ EF < 20	Significant enrichment
4	20 ≤ EF < 40	Very high enrichment
5	EF > 40	Extremely high enrichment

Due to the lack of background standards to evaluate the degree of soil contamination in Iran, the average concentration of heavy metals in the earth's crust was used as the background concentration. Also, iron metal was used as a reference metal in this study. To perform the statistical analysis, the normality of the data was first tested by the Smirnov Kolmogorov test. Then, in order to establish a relationship between metals in soil and urban dust, Pearson's correlation coefficient was calculated. Finally, to identify polluted areas on a local scale, especially hot and cold spots, the inverse weighting method of IDW distance is more suitable. For this purpose, to prepare the concentration map of the studied metals, the inverse weighting method of IDW distance was used in the ArcGIS software version 1.10.

Results

In the current study, after determining the concentration of heavy metals in the sampling areas, different contamination indices such as enrichment factor (EF), contamination factor (CF), and Geoaccumulation Index (Igeo) were used to determine and evaluate the contamination by heavy metals such as iron, zinc, lead, Cadmium, chromium, arsenic and nickel in Tehran. Interpolation was also done in order to check the gradient of contamination and the distribution of metal concentrations. The statistical description of the heavy metals concentration in the studied area in dust samples is given in Table 5 in the form of coefficient of variation, skewness and elongation, minimum, maximum, mean, median, and standard deviation. The average total concentration of iron, zinc, lead, cadmium, chromium, arsenic and nickel in the studied area is 49320.325, 157.02, 321.94, 1.16, 161.45, 428.42 and 37.1mg/kg respectively.

The coefficient of variation CV shows the degree of variability of the concentrations of a metal in the street dust. CV ≤ 20 indicates little variability, 21 ≤ CV ≤ 50 shows moderate variability, and 50 ≤ CV < 100 represents high variability, while coefficients higher than 100 indicate infinite variability. The coefficients of variations in the concentration of metals in the street dust of the studied area have decreased in order of lead, nickel, cadmium, zinc, chromium, arsenic and iron, respectively. The high coefficient of variation

for lead metal indicates that the concentration of this metal is significantly different in different sampling locations and also represents the heterogeneous distribution of human activities. The change coefficients of cadmium, zinc, chromium, nickel and arsenic metals have shown moderate variability, reflecting the relatively heterogenious distribution of these metals in the street dust of the studied area. This variability is also estimated to be small for iron.

The standard deviation of the concentration of metals in the street dust of the studied area has faced a downward trend, which has decreased in the metals of iron, nickel, zinc, arsenic, lead, chromium and finally cadmium, respectively. The high values of the standard deviation indicate the wide range of changes in the concentrations of metals in the street dust in the study area, mainly observed for the iron metal in this study. The skewness of all metals except zinc was positive, which indicates that these metals have a positive skew towards lower concentrations. The elongation rate of cadmium, chromium and lead, arsenic and nickel metals was positive, which indicates the greater slope of the distribution diagram of these metals compared to the normal distribution curve. To calculate the statistics, Kolmogorov-Smirnov results test was used to determine the normality of the data.

Table 5. Descriptive statistics of heavy metals in Tehran Street dusts

Metal	Fe	Zn	Pb	Cd	Cr	As	Ni
Namber of sampel	88	88	88	88	88	88	88
Minimum	34919.47	201.48	38.9	0.12	61.81	3.1	0.78
Maximum	64639.78	1102.56	604.98	2.2	261.09	31.25	72.64
Mean	49779.625	157.02	321.94	1.16	161.45	18.72	36.7
Middle	46791.03	661.81	171.68	0.51	106.49	16.23	42.63
Std. deviation	9183.82	265.71	132.18	0.23	43.71	264.25	431.27
CV%	19.41	40.79	59.97	42.1	39.11	31.22	47.91
Skewness	0.55	-0.019	2.2	0.62	2.08	3.33	4.1
Kurtosis	-0.64	-0.69	4.11	0.77	5.11	2.1	0.91
Kolmogrov-Smirnove results	0	0.2	200	0	0	0	0.08
Backgroundvalues	35000	71	20	0.098	35	4.8	20

There is about 2.5 grams of zinc in the body of an average-sized person. The amount of absorption higher than 150 mg per day can cause anemia and even in high concentrations it can be fatal. Diseases related to arteries and anorexia can be symptoms of high zinc concentrations in the body. (Hambidge et al., 1986). The natural amount of zinc in the soil of the region is 71 mg/kg. The maximum observed amount of this element was equal to 1102.56 kg/mg, which was observed in areas 9, 10, 12 and 13 (Fig. 2).

The daily need of the body for chromium is about 50 kg/mg. One of the ways of contamination of the human body with chromium is the inhalation of chromium-impregnated dust, which can cause complications such as the gradual destruction of the kidneys, liver, stomach, and various types of lung

cancer (Shin et al., 2023). The natural amount of chromium in the soil of the region is 35 mg/kg. The maximum observed amount of this metal was 261.09 kg/mg, observed in areas 12, 14 and 3 (Fig. 3).

Figure 4 is related to the zoning of nickel metal in 22 districts of Tehran. One of the ways through which nickel enters the body is by inhaling dusts impregnated with nickel (Linhua and Songbao., 2019). This can cause acute respiratory discomfort, severe burns in the trachea region, as well as various types of throat, nose and lung cancers (Javed., 2018). Even contact with this metal causes severe skin allergies and results in irritation and itching. The natural amount of nickel in the soil of the region is 20 mg/kg (Esmaeili et al., 2014). The highest observed amount of this metal was 72.64 mg/kg, which was observed in 10 and 12 areas.

The amount of iron in the body of an adult is 3–5 kg/mg. Too much iron in the body causes deposits that block blood vessels. In addition, poisoning with this metal can cause fatal complications such as liver failure, contraction of stomach muscles, dizziness, and vomiting (Kumar et al., 2013). The natural amount of iron in the soil of the region is 35000mg/kg. The maximum amount of this metal was 64639.78 kg/mg, which was observed in areas 14, 12, and 15, and the minimum amount was 34919.47 kg/mg, which was observed in area 3 (Fig. 5). Gholami and Staki (2009) also stated that the amount of iron in the soil of industrial and heavy traffic areas is more than the standard limit.

Figure 6 shows the zoning of arsenic metal. This metal is highly toxic and its inhalation causes respiratory cancers such as trachea and lung cancer. (Dorak and Hakan Celik, 2020). The natural amount of arsenic in the soil of the region is 4.8 mg/kg. The results showed that the lowest amount of this metal was observed in region 1 and 4 and was equal to 3.1 mg/kg and the highest amount was observed in region 11 that was equal to 31.25 g.

The heavy metal, lead, enters the environment through various sources, and its toxic effects on the human body and other organisms have been confirmed (Yang et al., 2016). Lead exists naturally in the environment, but in most cases it is the result of human activities such as its use in the production of gasoline. Lead salts enter the environment through the exhaust of cars and pollute the soil, water and air (Salih and Aziz., 2020). In recent years, removing lead from vehicle fuel has greatly helped to clean the environment and it seems that more efforts should be made in this direction. Industries are the main sources of pollution related to lead metal. Factories such as electroplating, battery making, and electronic parts production are among the most important of them (Dehghani et al., 2017). Lead enters the body of human beings and animals in two ways and causes poisoning in them. One is through entering the food chain by consuming the elements of this chain and the other is through breathing air contaminated with lead (Han and colleagues., 2016). The normal amount of lead in the soil of the region is 20 mg/kg. The lowest amount of this metal is seen in the province and is equal to 38.1 mg/kg and the highest amount is observed in the region 21.22 and is equal to 604.98 g (Fig. 7).

Cadmium is a very toxic metal that causes many deaths. A serious disease caused by it in humans is a disease called itai-itai (rheumatism disease or painful skeletal deformity) (Huang et al., 2020). The main effects of cadmium toxicity are on the lungs, kidneys, and bones. Acute effects caused by its inhalation

include bronchitis, pneumonia, and liver poisoning (Liu et al., 2019). Chronic inhalation of cadmium compounds in the form of vapors or dust causes pulmonary edema. Both chronic inhalation and oral absorption of cadmium affect kidney secretions, which is the first stage of protein excretion by the proximal tubules of the kidney (Li et al., 2019). Cadmium enters the ecosystem through soil and bedrock erosion, atmospheric polluted sediments from industrial factories, wastewater from polluted areas, and the use of sludge and fertilizer in agriculture (Tang et al., 2020). The natural amount of cadmium in the soil of the region is 0.098 mg/kg. The lowest concentration of this metal was 0.12 mg/kg that was seen in region 1 and the highest concentration was 2.2mg/kg, which was mostly observed in region 14 (Fig. 8).

In general, in this study, the highest average concentration is related to iron metal and cadmium has the lowest average concentration. In this way, the trend of the average concentration can be defined as (iron > lead > chromium > zinc > nickel > arsenic > cadmium).

The results of environmental indices

Results of contamination indices show in Table 6:

Table 6
Results of contamination indices

Metal	Fe	Zn	Pb	Cd	Cr	As	Ni
Namber of sampel	88	88	88	88	88	88	88
Minimum	34919.47	201.48	38.9	0.12	61.81	3.1	0.78
Maximum	64639.78	1102.56	604.98	2.2	261.09	31.25	72.64
Mean	49779.625	157.02	321.94	1.16	161.45	18.72	36.7
Middle	46791.03	661.81	171.68	0.51	106.49	16.23	42.63
Std. deviation	9183.82	265.71	132.18	0.23	43.71	264.25	431.27
CV%	19.41	40.79	59.97	42.1	39.11	31.22	47.91
Skewness	0.55	-0.019	2.2	0.62	2.08	3.33	4.1
Kurtosis	-0.64	-0.69	4.11	0.77	5.11	2.1	0.91
Kolmogrov-Smirnove results	0	0.2	200	0	0	0	0.08
Background values	35000	71	20	0.098	35	4.8	20

Calculation of contamination factor CF

Evaluation of contamination factor (Cf) was done for all areas. In this classification, iron with a variation range of 0.93 to 1.85 is located in the class with medium contamination. Zinc with a variation range of 2.8 to 15.5, lead with a variation range of 1.9 to 30.2 and chromium with a variation range of 1.7 to 7.4, all three are located in the class with moderate to very high contamination. Also, the cadmium metal with a variation range of 0.12 to 22.4 and arsenic with a variation range of 0.6 to 6.5 have low to very high contamination intensity. Finally, nickel with a variation range of 0.03 to 3.3 is placed in the class with low to high contamination. Also, the highest level of contamination occurs in areas 12, 13, 14 and 15 (Fig. 9).

Igeo index

The calculated values for the Igeo index of heavy metals for falling dust of the study area are presented in Fig. 10. Examining the Igeo index based on Müller's categorization shows that iron with a variation range of -0.2 to 0.9 is placed in the category with moderate contamination. Zinc with a variation range of 2.8 to 15.5, lead with a variation range of 1.9 to 30.2 and chromium with a variation range of 1.7 to 7.4, all three are located in the classes with moderate to very high contamination. Also, the cadmium metal with a variation range of 0.12 to 22.4 and arsenic with a variation range of 0.6 to 6.5 have low to very high contamination intensity. Finally, nickel with a variation range of 0.03 to 3.3 is placed in the classe with low to high contamination. Also, the highest level of contamination belongs to areas 12, 13, 14 and 15.

Enrichment factor EF

The enrichment factor was used to evaluate metal contamination in the studied area. The results show (Fig. 11) that the (EF) enrichment factor index for nickel with a variation range of 0.041 to 1.96 is in the range of low enrichment, while zinc with a variation range of 8.39 to 30.3 is in the range of high to very high enrichment. Lead with a variation range of 2.87 to 16.36 is in the range of medium to high enrichment and chromium with a variation range of 1.9 to 4.03 is in the range of medium to high enrichment. Cadmium with a variation range of 0.13 to 12.14 is also in the range of low to high enrichment. Finally, arsenic with a variation range of 0.69 to 3.52 is in the range of low to medium enrichment. Metals that have maximum EF and their enrichment value is much higher than 10 are mainly influenced by anthropogenic sources. Therefore, the enrichment factor is an indicator for distinguishing human resources from natural ones (or both), among which zinc and cadmium are in areas with an enrichment rate of more than ten.

Correlation between heavy metals concentration

The correlation between the concentrations of heavy metals in the street dust particles of Tehran using Pearson's correlation coefficient is summarized in Table 7. These correlation coefficients actually show to what extent the presence of one element can indicate the presence of other elements. Thus, a higher correlation coefficient indicates a more significant relationship between two elements. The high correlation between Pb and Zn may indicate that their sources are the same, but it is difficult to say that their sources are natural since their pollution indices are high and the average concentration of the studied metals is higher than their concentration in the earth's crust. The results showed that there is a

significant correlation at the 1% level between the elements cadmium, zinc, chromium, lead, iron, nickel, and arsenic. As shown in the table, chromium and nickel show the highest correlation value. Lead and zinc also have a relatively high correlation coefficient. The high correlation coefficient indicates the identical origin of those two elements which can be the nature. Cadmium and zinc as well as lead and chromium, zinc and arsenic also have a moderate correlation coefficient which may indicate that these two elements originate from somewhat the same sources, such as vehicles and industrial activities. The lowest correlation value belongs to lead and nickel. Their weak correlation coefficient shows that their sources of emission are numerous and independent.\

Table 7. Pearson's correlation coefficients between the investigated heavy metals

Metal	Fe	Zn	Pb	Cd	Cr	As	Ni
Fe	1						
Zn	0.604**	1					
Pb	0.468*	0.660**	1				
Cd	0.248	0.459*	0.601**	1			
Cr	0.481*	0.609**	0.481*	0.371	1		
As	0.371**	0.452*	0.299*	0.412**	0.346*	1	
Ni	0.102**	0.241*	0.420**	0.385**	0.709*	0.461*	1

** Significant correlation at the 0.01 level (two-directional)

* Significant correlation at the 0.05 level (two-directional)

Discussion

The phenomenon of dust is one of the important problems of arid and semi-arid regions of the world which has increased significantly in recent years due to the climate change, drought, and change of land use (Boroghani et al. 2019). To reduce the damages of this phenomenon in these areas, there is a need to manage, monitor, and determine the amount of contamination scattered by dust. According to the findings of this study, using ground sampling from 88 stations and investigating the concentration of metals iron, zinc, lead, cadmium, chromium, arsenic and nickel in street dust particles compared to the concentration of these metals in the earth's crust, it is revealed that the average concentration of the studied metals is higher than their concentration in the earth's crust. This issue can confirm that the role of human activities in the increase of heavy metals concentration in street dust is significant. The highest concentration of heavy metal contamination belongs to the central, south and southeast parts of Tehran, including areas such as 9, 10, 11, 12, 14, 15, 16 and 17. Region 9 is more polluted than other regions due to the high traffic of cars moving from Azadi Square to the outside of the city and the establishment of many factories and industries in its southern parts, as well as the presence of Mehrabad International Airport and several military centers. District 12 is located in the center of Tehran. This area is considered as one of the busiest areas of Tehran due to the location of Tehran's Grand Bazaar where many people from all over Iran travel to this area every day to perform their economic

activities. Also, based on the obtained results, the area of Tehran's Big Bazaar (Area 12 and Shush Square between Areas 12, 15 and 16 and the Revolution Square) have high levels of contamination. From this aspect, this is in full agreement with the results of the research (Halek and Bidhandi in 2008). Several studies have attributed the presence of cadmium, lead, zinc and chromium elements to human resources, especially road traffic. The results of this study also proved this issue. Road traffic emissions not only include vehicle exhaust emissions, but also are caused by tire dust, brake wear and dust suspension (Qing et al., 2015). High concentrations of iron metal can be caused by the soil around the street, while very small amounts of chromium, zinc and cadmium metals have been reported to originate from the soil around the street (Mummullage et al., 2016). The origin of cadmium in street dust in the study of McKenzie et al. (2009) was attributed to the dust caused by brake wear, which is also in accordance with the findings of the present study. In another study, Saeedi et al. (32), during a research on the heavy metals contamination in the street dust of Tehran, reported that the concentration of zinc and chromium metals is significantly higher than the average concentration of these metals in the earth's crust, indicating the probable human origin of these metals. The evaluation of

The evaluation of the falling dust contamination situation in different stations of the region based on the metal contamination factor (CF) indicates that the amount of iron metal contamination puts it in the middle class, and zinc, lead and iron are placed in the medium to very high class. Cadmium and arsenic are also located in the low to very high contamination class, and finally nickel metal is also in the low to high contamination class. This shows the effect of human resources, because these metals mostly come from urban and agricultural transportation sources. The Igeo index examined the amount of heavy elements in the dust samples of all stations in relation to seven metals and according to Mueller's categorization, iron is located in the class with medium contamination. Zinc, lead, and chromium are all placed in the class with moderate to very high contamination. Also, cadmium and arsenic have low to very high contamination intensity. Finally, nickel is located in the class with low to high pollution. To evaluate metal contamination in the studied area, the enrichment factor was used and the results showed that the enrichment factor (EF) index for nickel is in the low enrichment range. Zinc is in the range of high to very high enrichment. Lead is in the range of medium to high enrichment. Chromium is in the range of medium to high enrichment. Cadmium is also in the range of low to high enrichment. Finally, arsenic is in the range of low to medium enrichment. Metals such as zinc and lead are effective factors in certain human diseases such as kidney and liver problems, cancer, etc. These metals can affect the ecological function of the region with a high concentration of these metals. Therefore, reducing the amount of heavy metals in the environment and evaluating their concentration in the breathing air used by humans should be taken into consideration to prevent the potential danger of these pollutants in the environment. It is also worth mentioning that due to the time and financial limitations, as well as the lack of previous studies in the region to compare the results and evaluate the changes in the amount of heavy metals over time, and lack of study on other parts of ecosystems such as soil texture, it is recommended that a comprehensive study should be done regarding the origin of heavy metals in the region, as well as the assessment of the health risk caused by them for humans and agricultural products of the region. The geochemical structure of the soil, the social and economic status

of the region, climate and meteorological conditions, traffic conditions and local pollutant factors affect the street dust characterization. Therefore, these results can be used as a data to improve the quality of environmental and health management in the study areas (Ulutaş 2023b).

Conclusion

In this study, the concentration of 7 heavy metals was measured in 88 samples of street dust in Tehran. The average concentration of the measured elements, in order from high to low includes the elements of iron, lead, chromium, zinc, nickel, arsenic and cadmium, indicating the presence of particles originating from the earth's crust in precipitations. As seen in the results, the highest concentration of heavy metal contamination is observed in the central, south and southeast parts of Tehran which includes areas such as 9, 10, 11, 12, 14, 15, 16 and 17. Factors such as the topography of the city of Tehran, climatic factors such as wind, the increase in population and the number of cars used, and the concentration of most industries of the country in Tehran all aggravate the pollution situation in this city. Also, as observed, most of the mentioned elements are in a state of severe pollution, and the measured concentrations are higher than the standard in most cases, which can be a serious threat to the health of the city's residents. The results of this study are effective for formulating management approaches to reduce pollution. Similar papers found that the main cause of metal pollution in an area comes from vehicles and traffic, as well as from industries and their waste. Metal pollution from homes and natural resources was not very high, but there was another source of pollution (Ulutaş., 2022).

Declarations

Conflict of Interest Statement

There is no conflict of interest.

Ethical Approval

The present Study and ethical aspect was approved by Water Engineering Department, College of Agriculture.

Consent to Publish

All authors agree to publish this manuscript. There is no conflict of interest.

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Competing of Interest

The authors declare that they have no competing of interest.

Author Contribution

A.K., K.O-A-A. and P.K. wrote the main manuscript text and prepared figures and tables. All authors reviewed the manuscript.

Data Availability

Data Availability Statement:All the data, including the experimental measurements, the data used for formulating empirical relations, and the code processing the data that support the findings of this study, are available from the corresponding author upon reasonable request.

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Figures

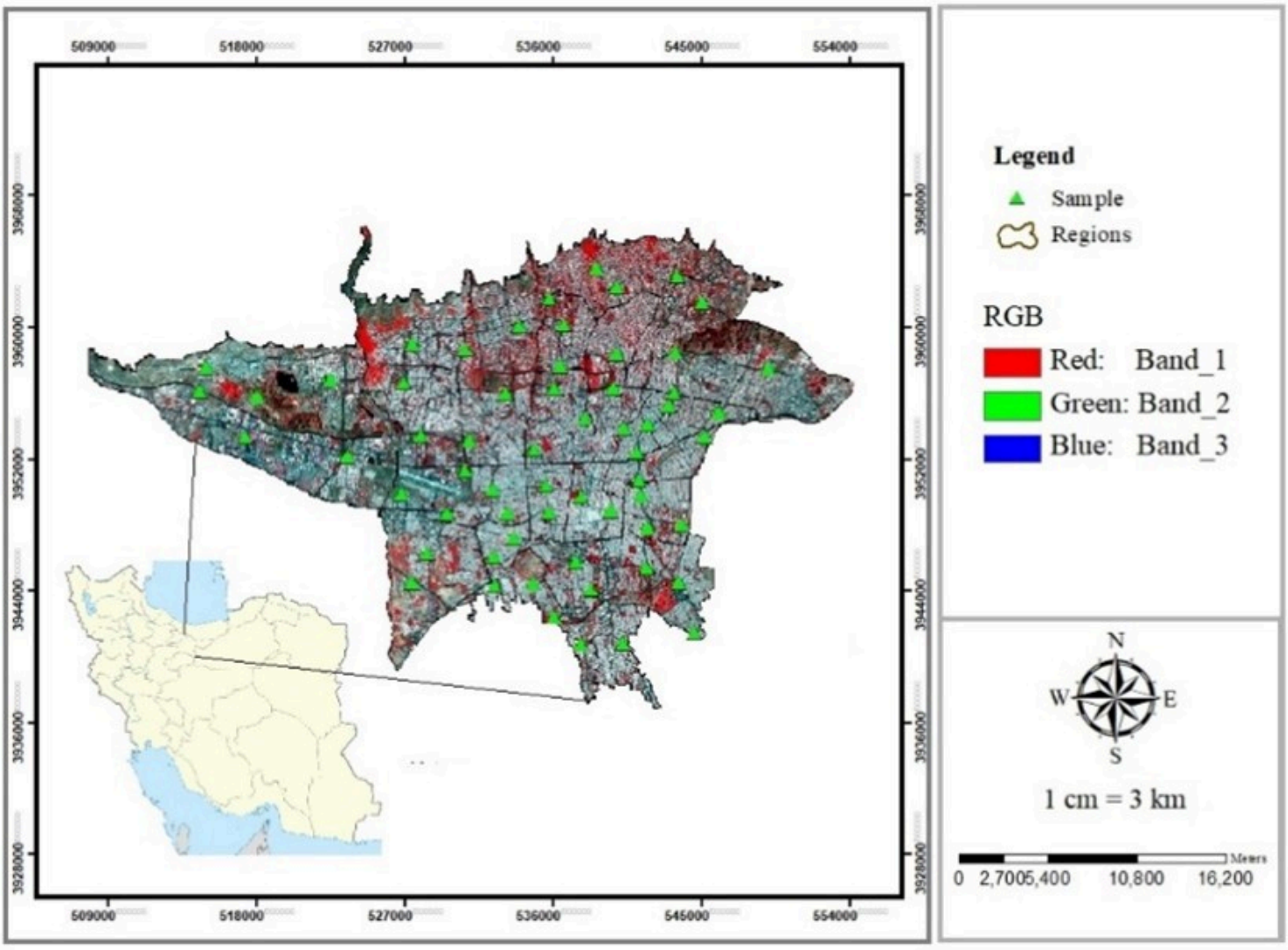


Figure 1

Sampling points in 22 districts of Tehran province

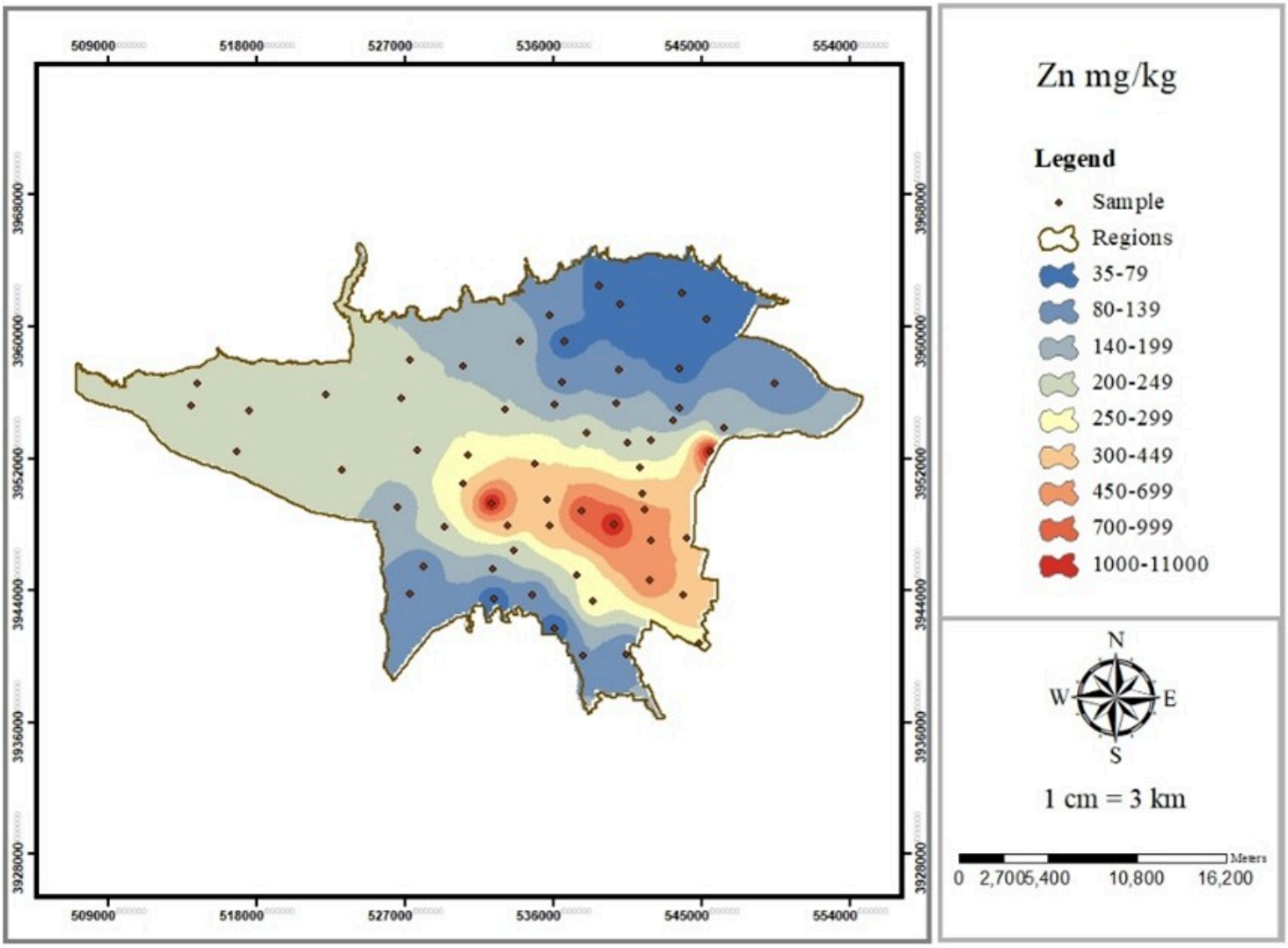


Figure 2

The map of the concentration distribution of zinc metal contamination in mg/kg

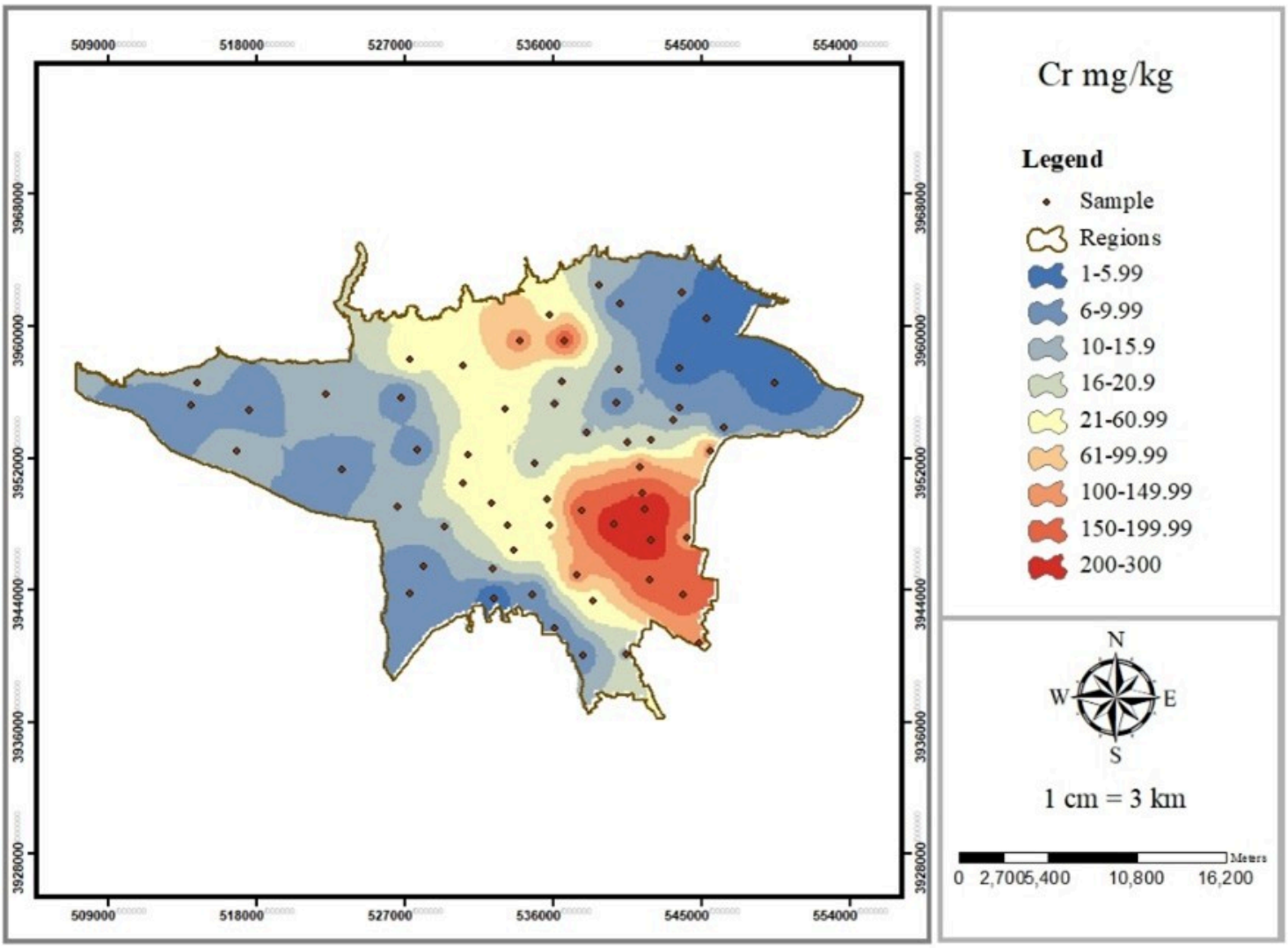


Figure 3

The map of the concentration distribution of chromium metal contamination in mg/kg

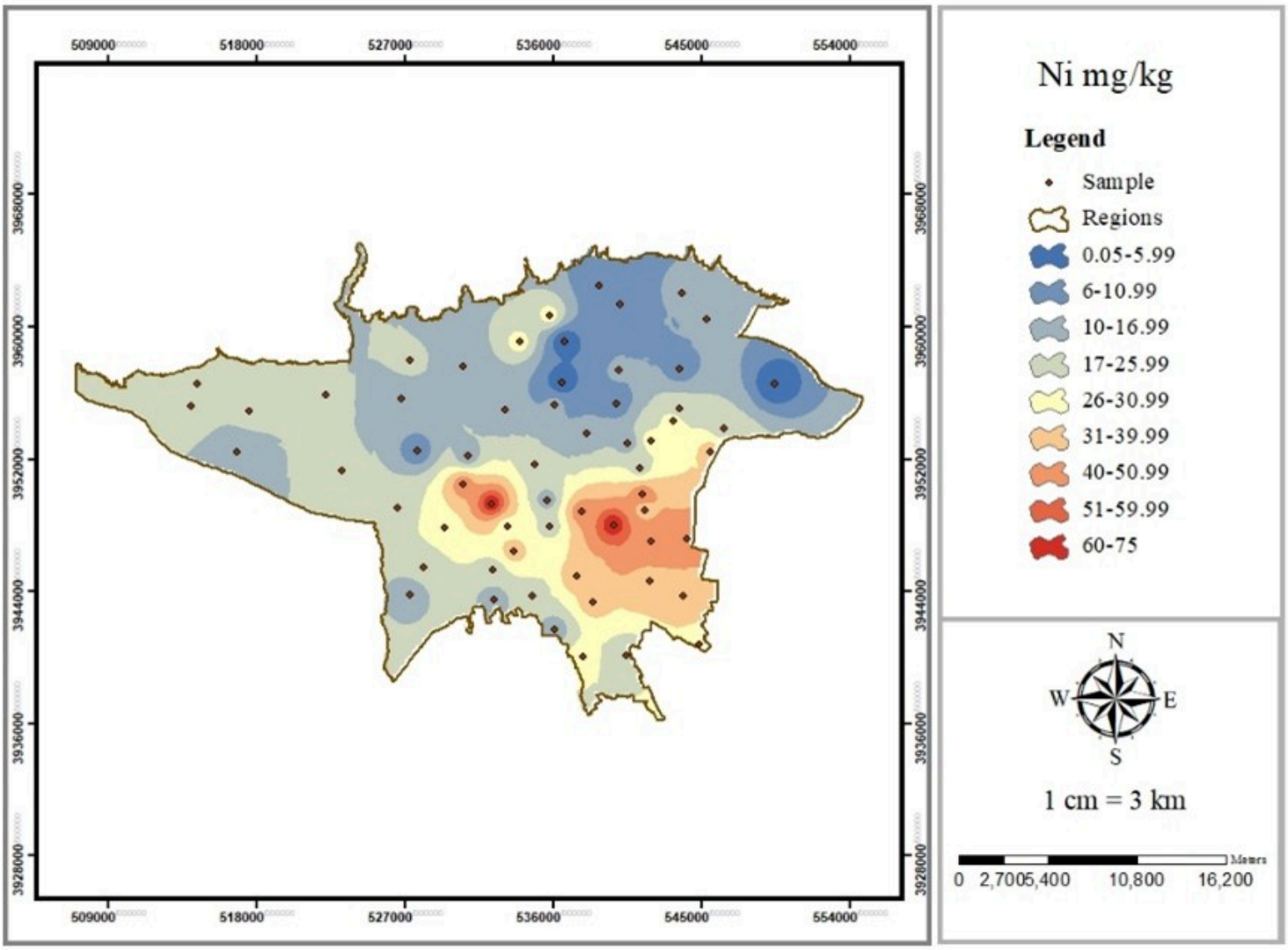


Figure 4

The map of the concentration distribution of nickel metal contamination in mg/kg

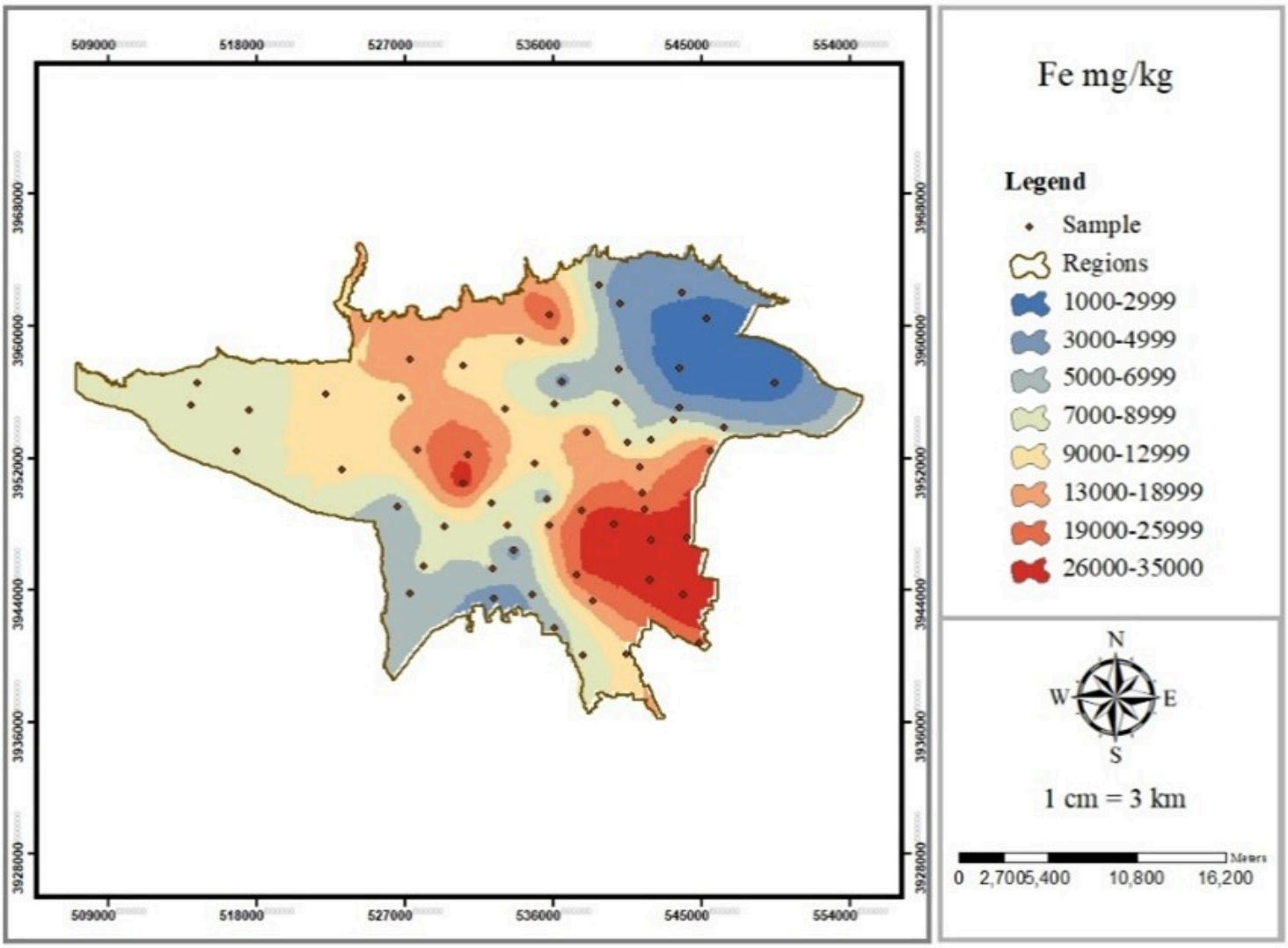


Figure 5

The map of the concentration distribution of iron metal contamination in mg/kg

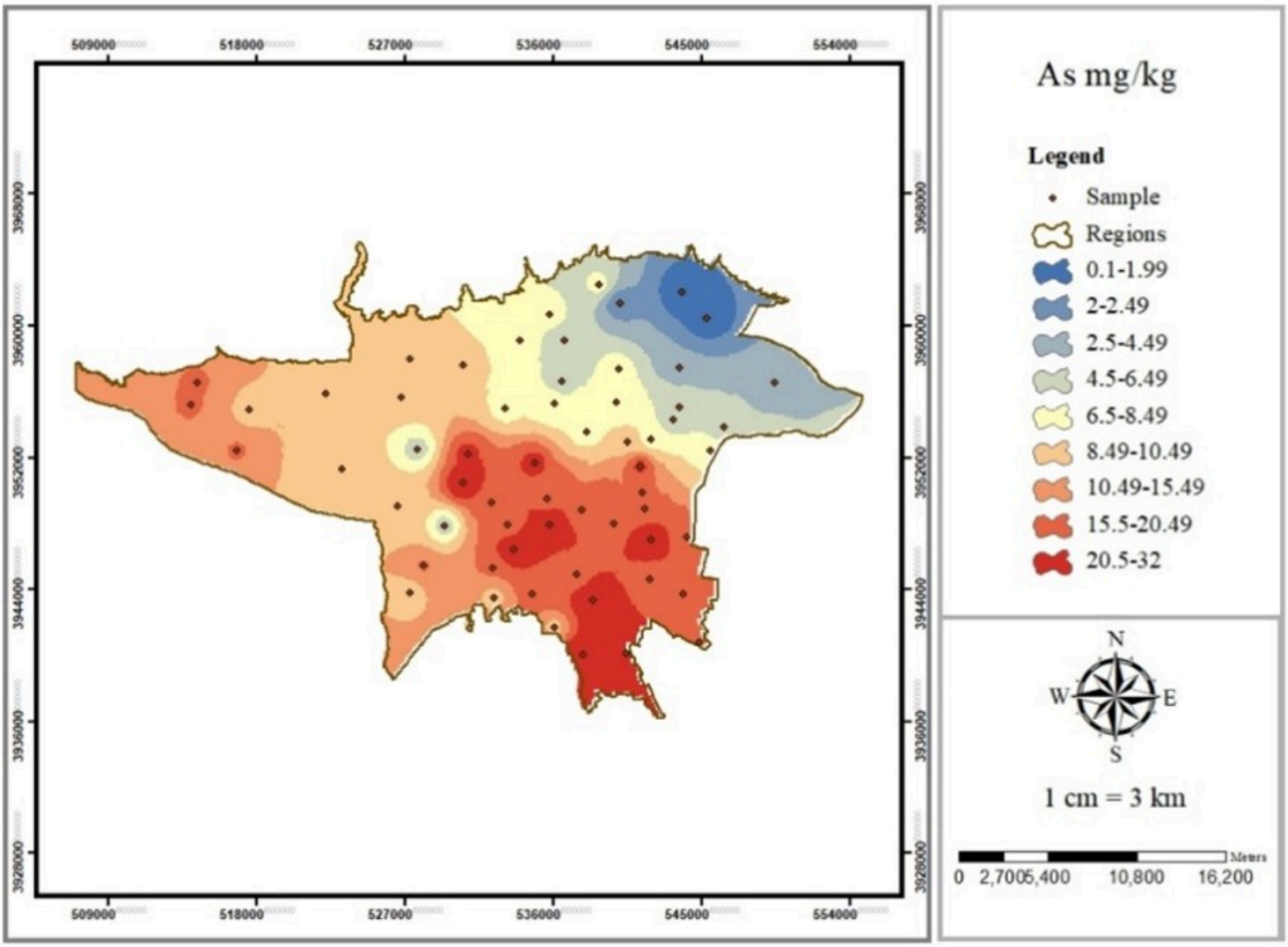


Figure 6

The map of the concentration distribution of Arsenic metal contamination in mg/kg

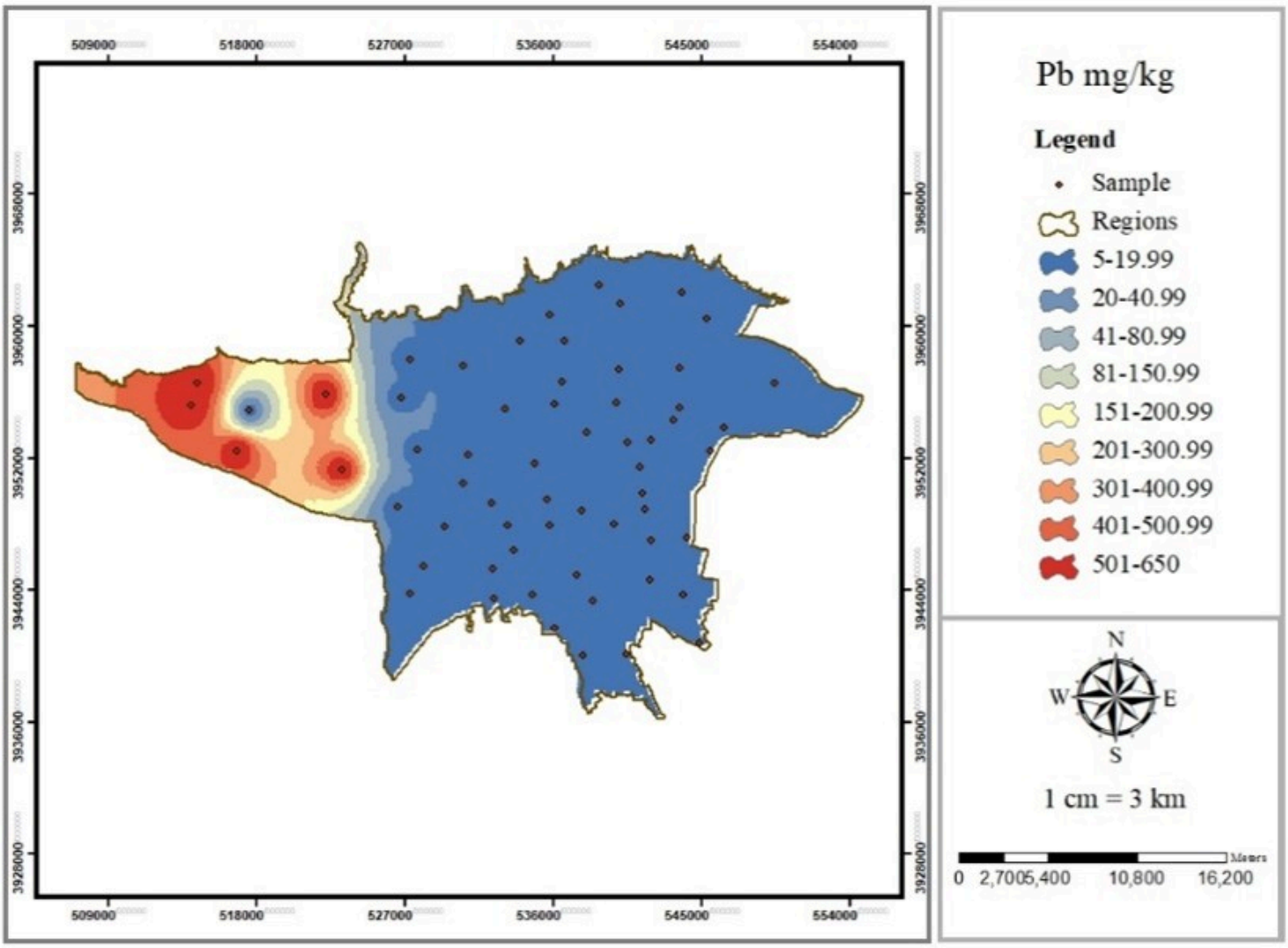


Figure 7

The map of the concentration distribution of lead metal contamination in mg/kg

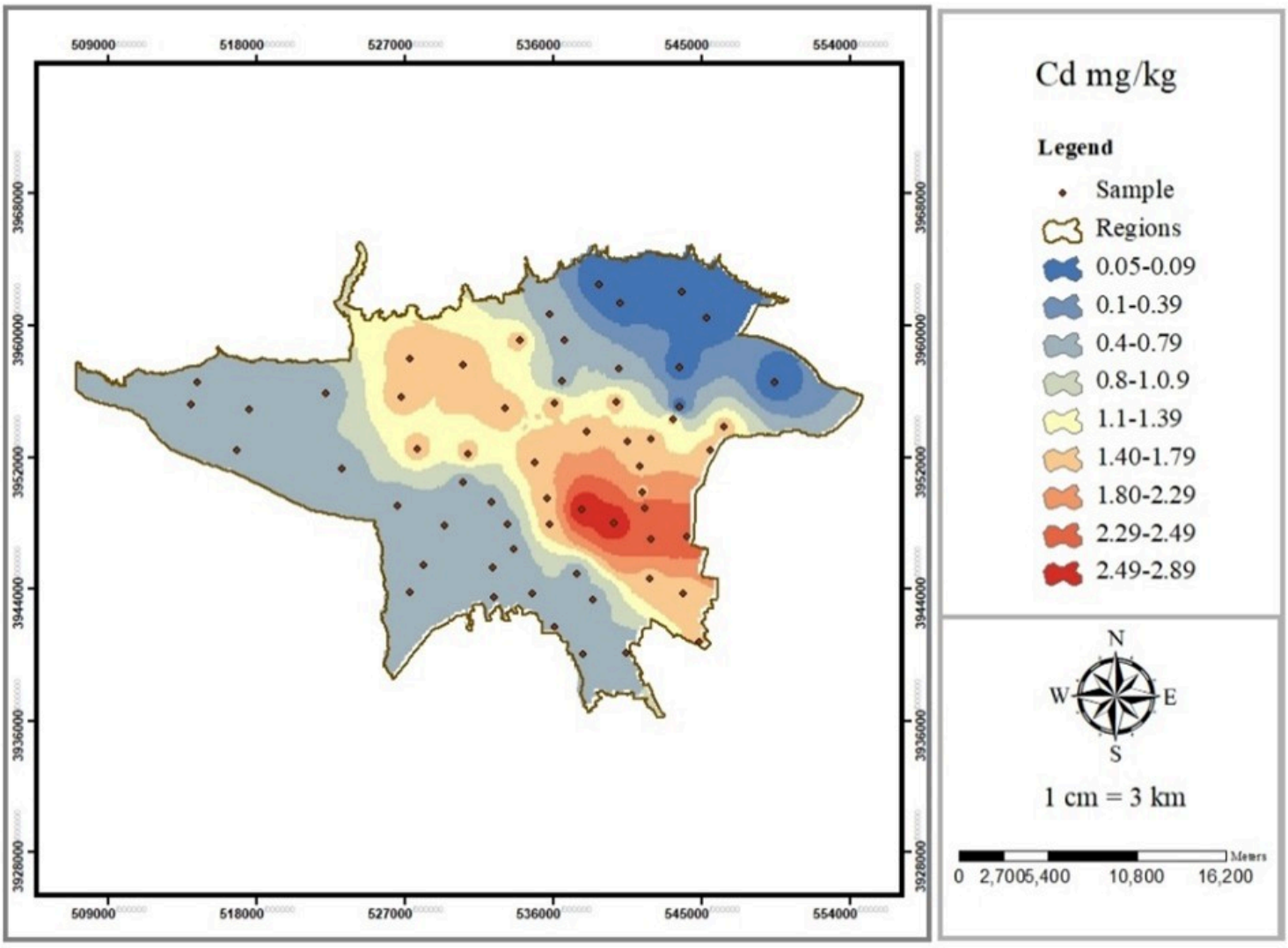


Figure 8

The map of the concentration distribution of cadmium metal contamination in mg/kg

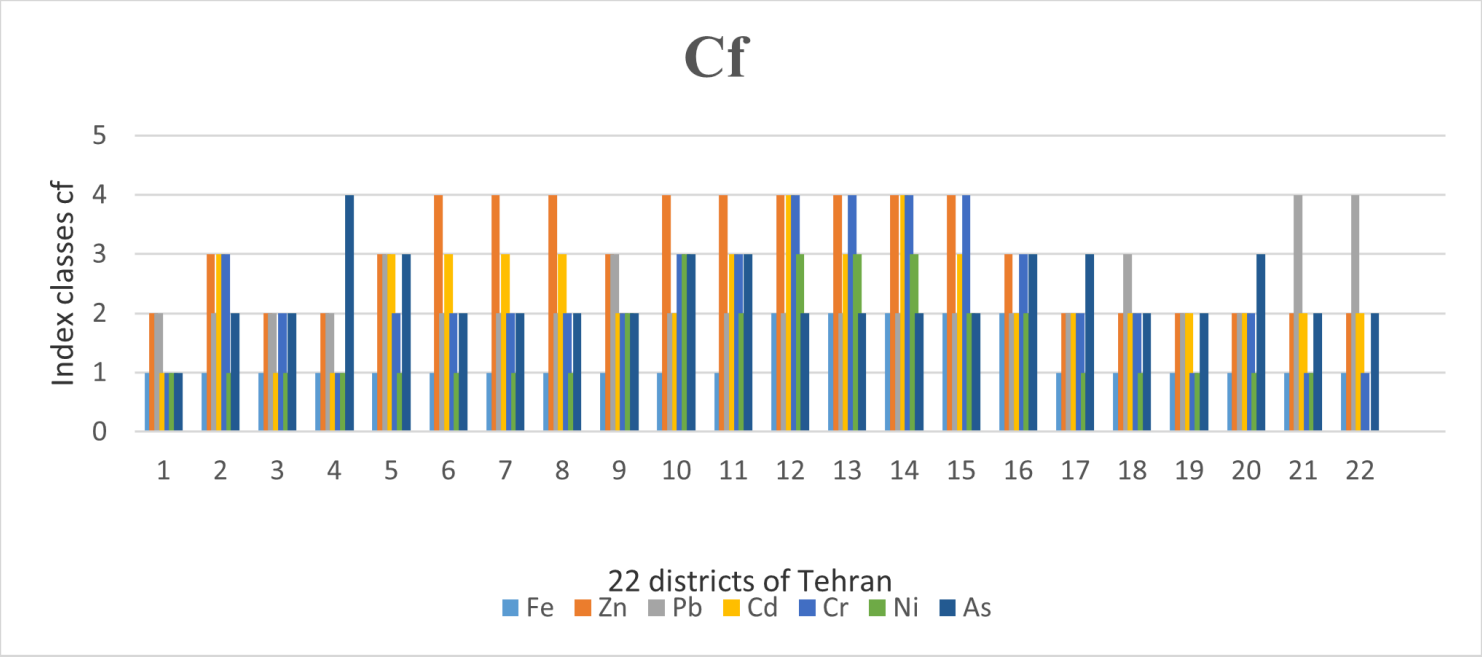


Figure 9

The pollution factor estimation diagram of the study area

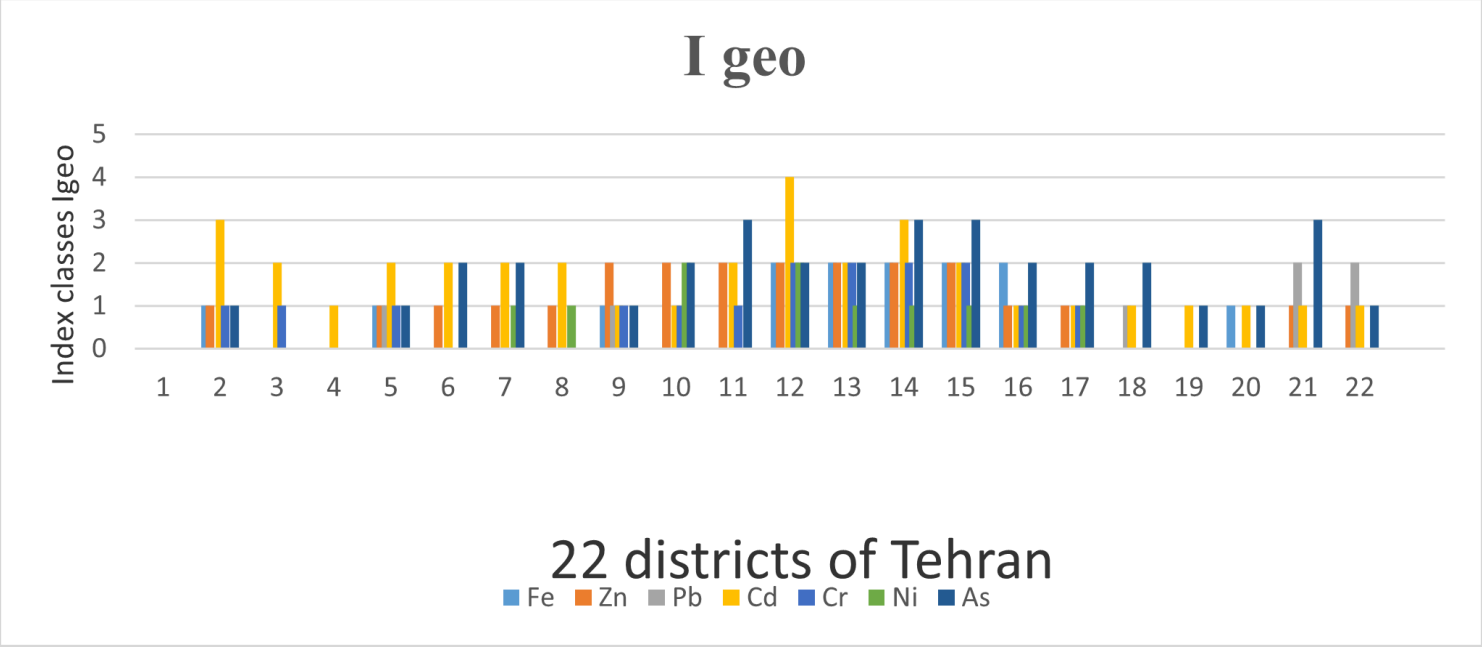


Figure 10

Igeo index estimation diagram of the studied area

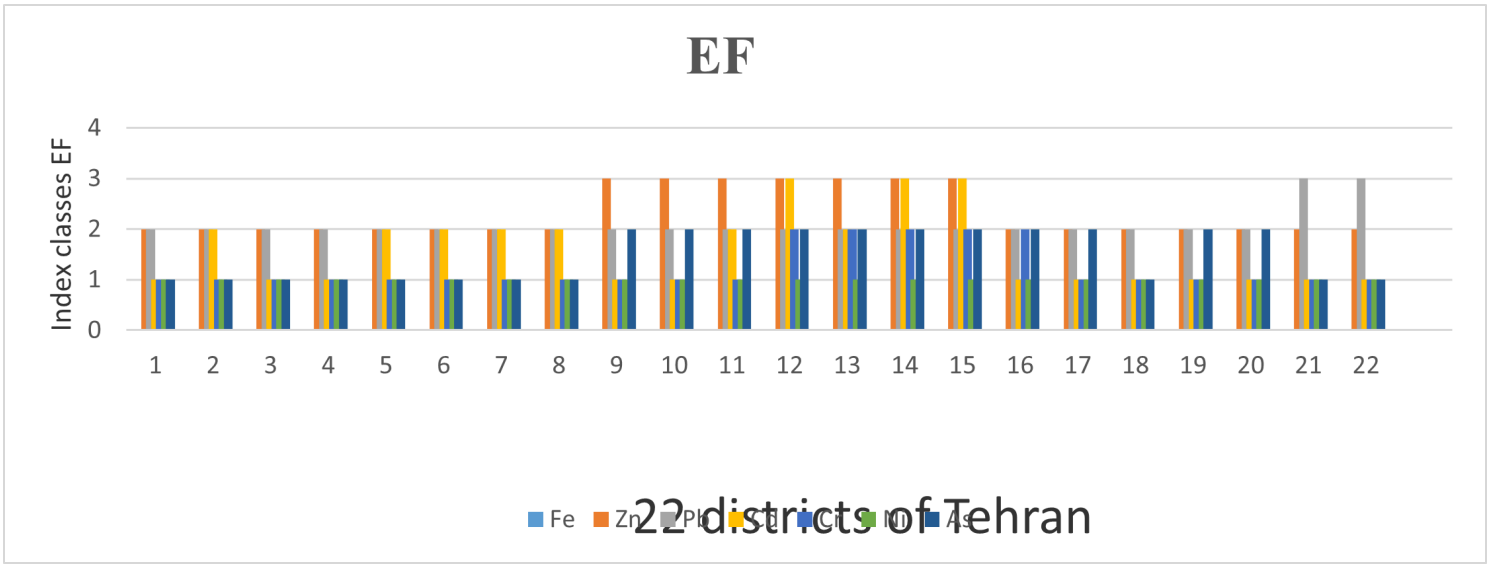


Figure 11

EF index estimation diagram of the studied area