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Assessment of Heavy Metal Contamination in Urban Soils of selected areas in Hilla City, Babylon, Iraq

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Abstract

Modern cities suffer from heavy metal pollution to due urban expansion and population increase. Heavy metals have a great impact on human health. The objective is to determine the contamination level of heavy metals Cr, Mn, Ni, Cu, Zn, As, Zr and Pb at industrial and residential in Hilla city. The mean concentration of Cr, Mn, Ni, Cu, Zn, As, Zr and Pb enrichment factors of the investigated industrial soils are 3.43, 0.74, 6.45, 3.95, 5.60, 3.44, 1.17 and 11.44, respectively. The means of Cr, Mn, Ni, Cu, Zn, As, Zr and Pb in residential soils are 3.30, 1.09, 11.40, 0.94, 2.08, 5.39, 0.9 and 3.6, respectively. The I-geo mean values of heavy elements in the industrial area may be ordered in the following: Mn> Pb> Ni> Zn> Cu> As> Cr> Zr. While in the residential area ordered Mn> Ni> As>Cr> Pb> Zn> Cu > Zr. Integrated Pollution Load Index categories results showed high contamination in industrial and residential areas. The main sources of heavy elements pollution in the study area has been regarded as anthropogenic sources.

Keywords: Anthropogenic, contamination, Geo-accumulation index, Hilla, Heavy metals.

تقييم التلوث بالمعادن الثقيلة في التربة الحضرية لمدينة الحلة، بابل، العراق

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الخلاصة

تعاني المدن الحديثة من التلوث بالمعادن الثقيلة نتيجة التوسع العمراني وزيادة السكانية. للمعادن الثقيلة لها تأثير كبير على صحة الإنسان. الهدف هو تحديد مستوى التلوث بالمعادن الثقيلة Cr و Mn و Ni و Cu و Zn و As و Zr و Pb في المنطقتين الصناعية والسكنية في مدينة الحلة. متوسط تركيز Cr، Mn، Ni، Cu، Zn، As، Zr و Pb لتربة المنطقة الصناعية المدروسة هي 3.43، 0.74، 6.45، 3.95، 5.60، 3.44، 1.17 و 11.44 على التوالي. متوسط تركيز Cr و Mn و Ni و Cu و Zn و As و Zr و Pb في التربة السكنية هي 3.30 و 1.09 و 11.40 و 0.94 و 2.08 و 5.39 و 0.9 و 3.6 على التوالي. يمكن ترتيب متوسط القيم I-geo للعناصر الثقيلة في المنطقة الصناعية على النحو التالي: Mn> Pb> Ni> Zn> Cu> As> Cr> Zr. بينما في المنطقة السكنية رتبت As> Cr> Zr Mn> Ni> As> Cr> Pb> Zn> Cu> Zr. أظهرت نتائج

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فئات اصناف حمل التلوث المتكامل تلوثًا عاليًا في المنطقتين الصناعية والسكنية مقارنة مع المحددات العالمية.
تعتبر المصادر الرئيسية لتلوث العناصر الثقيلة في منطقة الدراسة من المصادر البشرية.

1. Introduction

The study area (Hilla city) is about 100 km south of the Iraq capital (Baghdad), and it is the center of Babylon Governorate, which rises approximately 35 meters above sea level. Arid to semi-arid climates with dry, hot summers and cold winters characterize Babylon Governorate; the mean annual rainfall is about 151.8 mm [1].

For a long time, the soil has been regarded as a reservoir for society's wastes. It is considered in the ecosystem as a complex, living, seasonally changing and dynamic component, which may be polluted from anthropogenic activities [2, 1]. Heavy metals, among these pollutants, constitute a major threat because they are unlike some other pollutants and are not biodegradable [3]. In a variety of ways such as vehicle wear (including tires, brakes and engine) as well as to leaking oil and corrosion, chemical industry, municipal solid waste, the sedimentation of dust and suspended substances in the atmosphere and other activities, heavy metals may originate and reach urban soils [4]. The main sources of pollution by trace elements in the soil are atmospheric precipitation from the combustion of wood, fuel, gasoline and diesel, sewage, animal dung, waste oils, industrial lubricants, and other organic waste. Dispose of common industrial products and waste in unhealthy environmental conditions, including burning paper, coal fly ash, incomplete combustion products, and wood ash; Fertilizers, lime and chemicals (pesticides) used in agriculture, and the widespread use of electric generators in a residential area.

In the urban ecosystem, urban soil is considered an essential component it [5]. The distribution and concentration of heavy metals in urban soils are critical for developing management strategies for improving urban environmental quality and reducing the risk of excessive heavy metals in the environment. This knowledge could be used to make reliable risk assessments for human health and long-term ecological impact [6].

In Iraq, the knowledge of heavy metals in urban soil currently available is insignificant. Lead is among the most important elements that must disappear from the soil because of its significant impact on human health [7]. Lead must be followed continuously to threaten the environment as it enters into many industries, the most important of which is the manufacture of batteries, gasoline engines and pesticides. It affects the physiological processes in the human body for children and has a risk of emergence. As it leads to accumulation, the fetus causes mental retardation or inversion during pregnancy [8]; [9].

The mechanisms of increasing the concentration of heavy metals in the soils and sediments are atmospheric deposition, physiochemical adsorption, biological uptake and accumulation [10]. A problem with the prevailing heavy metals in the environment for a long time is present by their high ability of persistence and bioaccumulation [11]. The lead (Pb) is from leaded fuel; Cu, Ni, Cr, Fe, Mn, Co and Cd are from car components, tire abrasion, lubricants, and industrial plus incinerator emissions are heavy metals [12].

Industrial production, urbanization, lubricants, and industrial plus incinerator emission, cause their levels in the environment not stable and variable [13]. Therefore, there is an increasing interest in studies of critical soil constituents of heavy metals to examine their spatial distribution and identify the links with factors such as parent material, land use or other human activities [8]. These metals can accumulate in plants and animals, eventually making their way to humans through the food chain [14]. Soil samples are an excellent medium to monitor heavy metal pollution because heavy metals are usually deposited in topsoil. A comparative study has not been done on the effect of different land-use types-industrial, commercial and residential uses - on heavy metal contamination in urban soils, especially within Hilla City.

The study's objectives are to investigate the concentrations of heavy metals (Cr, Mn, Ni, Cu, Zn, As, Zr and Pb) in Hilla city's urban soil, their distribution, and origins, as well as to evaluate the consistency of environmental soils in terms of metal pollution.

2. Geological Setting of Study Area

It is located down the Physiographical parts in the Mesopotamian Plain [15]. In the study area, the sediments of the Quaternary Era appear, and the area is characterized by the sediments of the flood plain of the Euphrates River. There are (depression fill deposits) and wind deposits. These sediments accumulate due to floods and generally consist of thin layers of fine sediments sand, clay, and silt clay, all of which belong to the Holocene (Parsons, 1957).

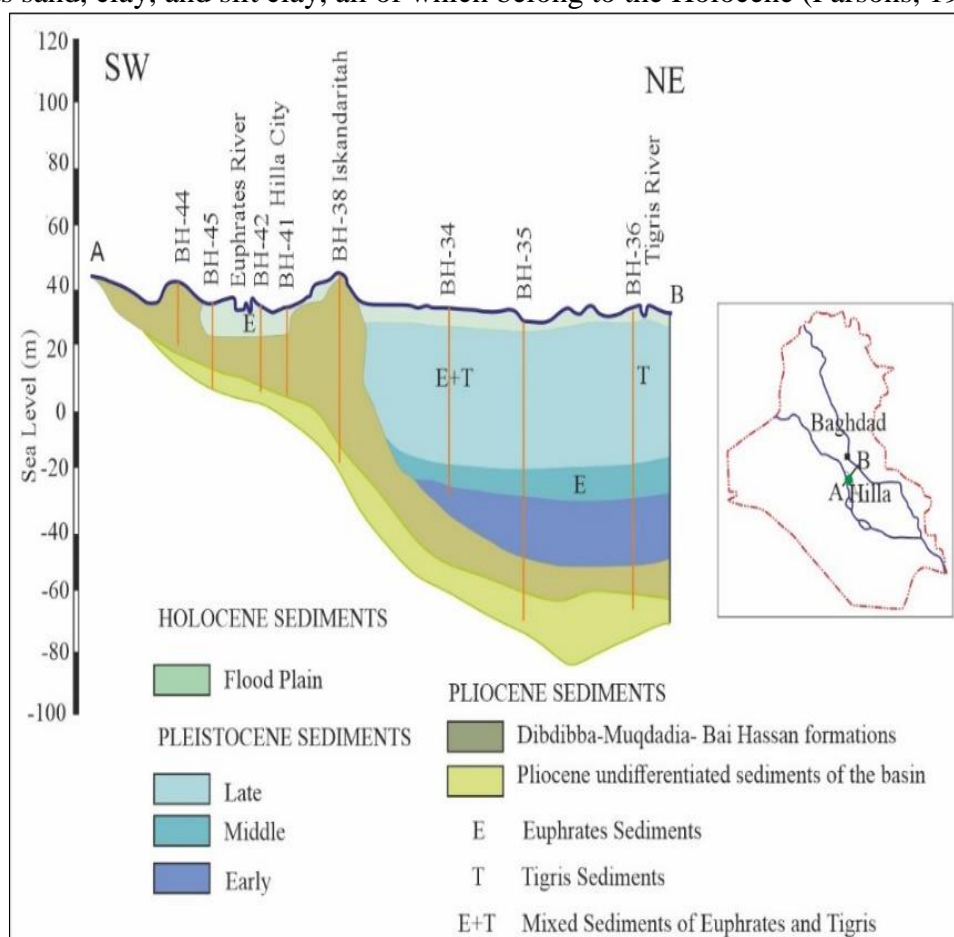


Figure 1-Stratigraphic column of the study area modified after [16]

3. Material and methods

The study can be determined more precisely by the (Longitude. 44°22'30" E - 44°27' 30" E and Latitude. 32°24'30" N - 32°31'30" N) (Figure 1).

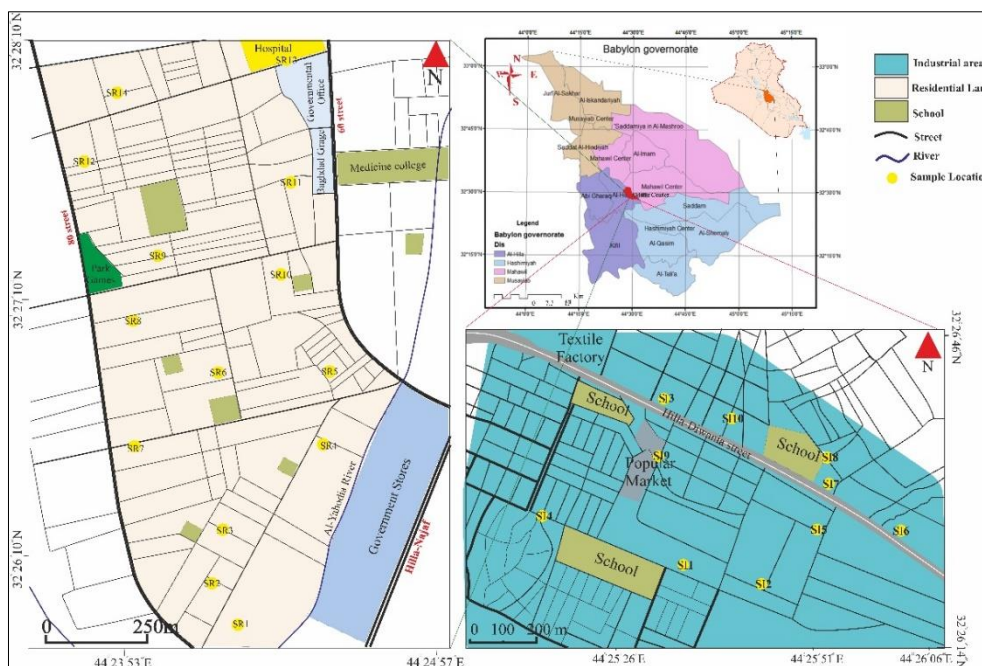


Figure 1-Location map of the study area

3.1. The data collection stage

All publications about the study area like (reports, journals, theses, papers) about assessment of heavy metal contamination were collected from various public and private organizations, maps, including geologic maps and satellite images and studied to make a better idea about the study area. For collecting soil samples, the study area was divided into two main types of land use represented residential and industrial soil areas. Soil samples were collected during the summer season during 2020.

3.2. Sample preparation stage

Twenty-four soil samples (depth for the first 30 cm of soil) were carefully obtained from each source area for various land-use types with a stainless-steel spatula. The Global Positioning System (GPS map 60C, Garmin) was used to determine the coordinates of sample sites (Table 1). Ten samples from industrial land and fourteen samples from residential land were collected from Hilla city. They air dries in the laboratory in a circulating oven at 30 °C, homogenized and sieved through a 2 mm polyethylene sieve to extract large debris, stones and pebbles after disaggregating with a porcelain pestle and mortar [17]. These samples were then placed in clean self-sealing plastic bags for further examination.

Table 1-The coordinate of sites in the study area

No.	Sam. ID	Coordinates		Locations
		Longitude	Latitude	
1	SI1	44° 25' 37.560" E	32° 26' 22.200" N	Industrial district
2	SI2	44° 25' 41.880" E	32° 26' 21.840" N	
3	SI3	44° 25' 35.040" E	32° 26' 39.840" N	
4	SI4	44° 25' 19.560" E	32° 26' 27.600" N	
5	SI5	44° 25' 54.120" E	32° 26' 25.800" N	
6	SI6	44° 26' 04.560" E	32° 26' 24.360" N	
7	SI7	44° 25' 55.560" E	32° 26' 29.040" N	
8	SI8	44° 25' 53.400" E	32° 26' 31.920" N	
9	SI9	44° 25' 33.240" E	32° 26' 32.220" N	
10	SI10	44° 25' 43.320" E	32° 26' 37.320" N	
11	SR1	44° 24' 12.240" E	32° 26' 01.320" N	Residential district
12	SR2	44° 24' 05.400" E	32° 26' 09.600" N	
13	SR3	44° 24' 08.280" E	32° 26' 21.480" N	

No.	Sam. ID	Coordinates		Locations
		Longitude	Latitude	
14	SR4	44° 24' 33.480" E	32° 26' 39.480" N	
15	SR5	44° 24' 35.280" E	32° 26' 54.960" N	
16	SR6	44° 24' 07.200" E	32° 26' 54.600" N	
17	SR7	44° 23' 46.320" E	32° 26' 39.120" N	
18	SR8	44° 23' 45.960" E	32° 27' 05.760" N	
19	SR9	44° 23' 52.080" E	32° 27' 19.440" N	
20	SR10	44° 24' 23.040" E	32° 27' 15.480" N	
21	SR11	44° 24' 25.560" E	32° 27' 34.920" N	
22	SR12	44° 24' 24.480" E	32° 28' 00.840" N	
23	SR13	44° 23' 42.000" E	32° 27' 54.000" N	
24	SR14	44° 23' 33.720" E	32° 27' 39.960" N	

3.3. Laboratory work stage

This stage included the following tests:

a. Water content

The water content was examined according to the American Standard for Tests and Materials [18].

b. Grain size distribution

The granular size analysis was performed according to the American Society for Testing and Materials specifications [19].

c. pH test

The pH level of soil samples was calculated using pellets to determine the acidity of sediments. Five grams of the sample were mixed in 250 ml of distilled water to convert it to a suspension solution. Hundred ml of the suspended solution were taken and 50 ml of pellets are added to the pH, the color will change. The solution is calculated pH and then compared with standard pH degrees.

d. Heavy metals tests

The selected soil samples were prepared for testing by the XRF instrument. This technique deals with the chemical composition of powdered studied samples to identify the trace elements. Twenty-four soil samples were chosen, powdered and pressed to disc shape to have an XRF examination by a SPECTRO XPOS tool (manufactured in Germany) in the XRF laboratory at the Department of Geology, University of Baghdad.

4. Assessment of soil contamination stage

To evaluate the degree of contamination in the soils, four parameters were used, which are Enrichment Factor (EF), geo accumulation Index (I_{geo}), Pollution Load index (PLI) and Integrate Pollution Load Index (IPLI). The enrichment factor computed using the equation suggested [20] is as follows:

$$EF = \frac{Cx/CFe (sample)}{(Cx/CFe (reference soil))} \dots\dots\dots 1$$

Where: Cx/CFe sample of the heavy metal to the Fe ratio in the same sample and Cx/CFe reference is the natural background value of the metal ratio to Fe. Iron was chosen as a reference element because it is one of the most significant parts of soil, and iron is difficult to change by other human sources. The reference value of iron in the Earth's crust is 3.5% as the global sediment average [21].

The enrichment factor is classified into five categories according to [21]. When $EF < 2$ Deficiency- minimal enrichment (D-ME); 2- 5 moderate enrichment (Mo.E.); 5-20 significant enrichment (SE); 20-40 very high enrichment (Vh.E.) and > 40 extremely high enrichment (EE) [21].

The geo accumulation Index (I_{geo}) was computed by the equation suggested by [22]. The I_{geo} index is expressed as:

$$I_{geo} = \log_2 (C_n/B_n \cdot 1.5) \dots\dots\dots 2$$

Where: log₂ is the natural logarithm, C_n is the element concentration (n) in the soil sample, and B_n is the value of the geochemical background. Depending on [22], I_{geo} was classified into seven grades or classes. When I_{geo}> 0 practically unpolluted (Unp.); 0–1 unpolluted to moderately polluted (Unp.- MP.); 1–2 moderately polluted (MP.); 2–3 moderately to strongly polluted (MP- SP.); 3–4 strongly polluted (SP.); 4–5 strong to very strongly polluted (SP.– EP.); and > 5 very strongly polluted (EP.). Pollution Load Index calculated according to the following equation [23].

$$PLI = C_n / B_n \dots\dots\dots 3$$

Where: C_n is the calculated concentration of metal in the soil and B_n: is the concentration of background of the individual metal. PLI classified into three contamination categories when PLI ≤ 1 low contamination (LC.); 1-3 moderate contamination (MC.) and > 3 High contamination (HC.) [23]. Integrated Pollution Load Index calculated as (Wei and Yang 2010):

$$IPLI = (PLI_1 + PLI_2 + PLI_3 + \dots\dots\dots PLI_n) / n \dots\dots\dots 4$$

Where: n is the number of metals. The IPLIs were classified into three categories of contamination according to [23] when IPLI ≤ 1 low contamination (LC.); 1-2 moderate contamination (MC.) and > 2 High contamination (HC.) [24].

5. Results and discussions

5.1 Soil Properties

a. Water content

The results of the water content are shown in Table 2. The values ranged between 0.88 and 13.70. This indicates that the values were very low due to the exposure of the surface soil to sunlight.

Table 2-Physical and chemical properties of soil collected from the study area.

Sam.	Area	Water content	Classification of samples				pH	
			Gravel%	Sand%	Silt%	Clay%		
SI1	Industrial Land Use	6.34	0	30	45	25	Sandy silt	8.00
SI2		2.64	0	40	45	15	Sandy silt	6.8
SI3		0.83	0	35	42	23	Sandy silt	5.5
SI4		5.39	0	40	35	24	Silty sand	6.00
SI5		0.82	0	56	24	20	Silty sand	6.4
SI6		2.17	0	42	38	20	Silty sand	7.00
SI7		6.18	0	66	14	20	Clayey sand	6.60
SI8		0.88	0	52	33	15	Silty sand	5.90
SI9		1.17	0	65	30	5	Silty sand	5.50
SI10		2.92	0	45	30	25	Silty sand	6.50
SR1	Residential Land Use	4.85	0	21	38	41	Silty clay	8.10
SR2		1.77	0	60	25	15	Silty sand	7.80
SR3		13.7	0	24	37	39	Silty clay	7.90
SR4		2.04	0	33	26	41	Sandy clay	8.50
SR5		2.47	0	33	37	30	Sandy silt	8.20
SR6		4.82	0	15	40	45	Silty clay	8.90
SR7		4.87	0	30	38	32	Clayey silt	7.60
SR8		3.66	0	58	22	20	Silty sand	9.00
SR9		2.96	0	30	31	39	Silty clay	8.60
SR10		4.11	0	75	15	10	Silty sand	8.80
SR11		2.98	0	28	35	37	Silty clay	9.50
SR12		9.01	0	20	42	38	Clayey silt	9.00
SR13		4.18	0	25	35	40	Silty clay	8.50
SR14		1.8	0	35	40	25	Sandy silt	7.80

b. Grain size analysis

It is understood that the properties of urban soils vary significantly from the agricultural soils of a specific region. Some of the properties of soils under investigation are silty sand, silty clay or clayey sand, the percentage of sand ranging between 15 and 66%. While the percentage of silt ranges from 14 to 45 %, and the percentage of clay particles ranges between 5 and 45%. These granular contents of the soils are from the flood deposits of the Tigris and Euphrates rivers in ancient times for study area.

c. Effect of pH

Several physical, chemical and biological factors control the movement of minerals in the soil [25]. Chemists have suggested that a change in the pH causes the element to move from one phase to another, thus estimating the susceptibility of heavy metals in the soil. The results of this research showed that the soil's pH in residential ranges between 7.6 and 9.5. It is indicated that residential soils are mostly neutral, semi-alkaline and alkaline state, which can be attributed to a high degree of carbonate and ash and can be explained partly of human origin [26], parts can be explained by extraneous materials such as bricks and building materials embedded in soil that can increase the pH [27]. While the results of the soil in the industrial areas may be related to the organic components available in that soil due to human and industrial activities. Most soil samples in the industrial areas can be classified as slightly acid to moderately alkaline (5.5 - 8.0) (Table 2).

6. Assessment of pollution

Several soil pollutions factors can be used to evaluate the level of contamination in the soils by heavy metals; four parameters were selected to assess the contamination degree by heavy metals, which are EF, I_{geo} , PLI and IPLI.

6.1 Enrichment Factor (EF)

The enrichment factor (EF) is an effective indicator reflecting environmental contamination. EF calculations compare each value to a specific background level, either from the local site, using ancient soils formed under similar conditions, but without human activity, or from a regional or global average composition. Although there were no background values for heavy metals in the study area, the background contents of the examined heavy elements in the present study were taken from [28] based on the crustal mean compliance from [29]. The results of the enrichment factor, range, mean, and pollution categories to the industrial and residential area for selected trace elements are set out in Table 3 and Figure 2.

Table 3-Enrichment Factors, Range, Mean and Enrichment Factors Categories values for heavy metals in the study area.

Sam.	Area	Heavy metals							
		Cr	Mn	Ni	Cu	Zn	As	Zr	Pb
SI1	Industrial Land Use	2	0.55	4.12	1.44	4.1	0.44	0.77	6.22
SI2		3.79	0.94	8.75	2.87	4.16	5.4	1.01	13.98
SI3		3	0.66	5.22	3.11	5.22	2.33	1	6.99
SI4		2.01	0.51	4.11	5.82	8.82	0.43	1.04	29
SI5		3.22	0.76	4.55	3.66	3.44	3.11	0.89	7
SI6		3.83	1.09	10.32	1.46	2.62	4.48	1.13	6.33
SI7		3.77	0.33	6.54	4.13	4.18	4.22	0.99	9
SI8		3.01	0.87	8.01	8.08	13.02	5.74	0.79	16.99
SI9		4.44	0.77	6.88	5.44	6.44	3.44	1.55	12.55
SI10		5.21	0.88	5.97	3.51	3.97	4.83	2.49	6.36
Range		2.00-5.21	0.33-1.09	4.12-10.32	1.46-8.08	2.62-13.02	0.43-5.74	0.77-1.55	6.22-29
Mean		3.43	0.74	6.45	3.95	5.6	3.44	1.17	11.44
EF Category		Mo.E	D- ME	SE	Mo. E	SE	Mo.E	D- ME	SE
SR1	Residential Land Use	1.96	1.06	12.5	0.92	1.59	6.94	0.9	1.21
SR2		1.99	1.07	12.2	0.99	1.65	6.55	0.88	1.44
SR3		3.39	1.1	11.72	0.97	2.14	5.74	0.84	2.7

Sam.	Area	Heavy metals							
		Cr	Mn	Ni	Cu	Zn	As	Zr	Pb
SR4		3.55	1.09	11.88	0.88	2.15	5.66	0.96	2
SR5		3.13	1.1	11.51	0.9	1.74	5.11	0.79	1.69
SR6		3.66	1.11	10.99	1	2.01	4.88	0.8	4.77
SR7		4.09	1.11	11.45	0.88	2.04	4.62	0.88	9.72
SR8		4	1.13	11.32	0.77	2.11	4.89	0.98	2.35
SR9		3.19	1.15	10.86	0.98	2.51	6.03	0.97	5.27
SR10		2.99	1	10.73	0.87	2.06	5	0.66	4.44
SR11		4.3	1.14	10.5	1.04	2.46	5.55	1.37	2.14
SR12		3.76	1.08	11	1.01	2.09	5.33	1.03	3.99
SR13		2.58	1.05	11.33	1.03	2.54	4.62	0.87	2.61
SR14		3.55	1.06	11.55	0.87	2.07	4.54	1.08	5.44
Range		1.96-4.09	1.05-1.15	10.50-12.5	0.77-1.04	1.59-2.54	4.54-6.94	0.79-1.37	1.21-9.72
Mean		3.3	1.09	11.4	0.94	2.08	5.39	0.9	3.6
EF Category		Mo.E	D.-ME.	SE.	D.-ME	Mo.-E	SE.	D.-ME	Mo.E

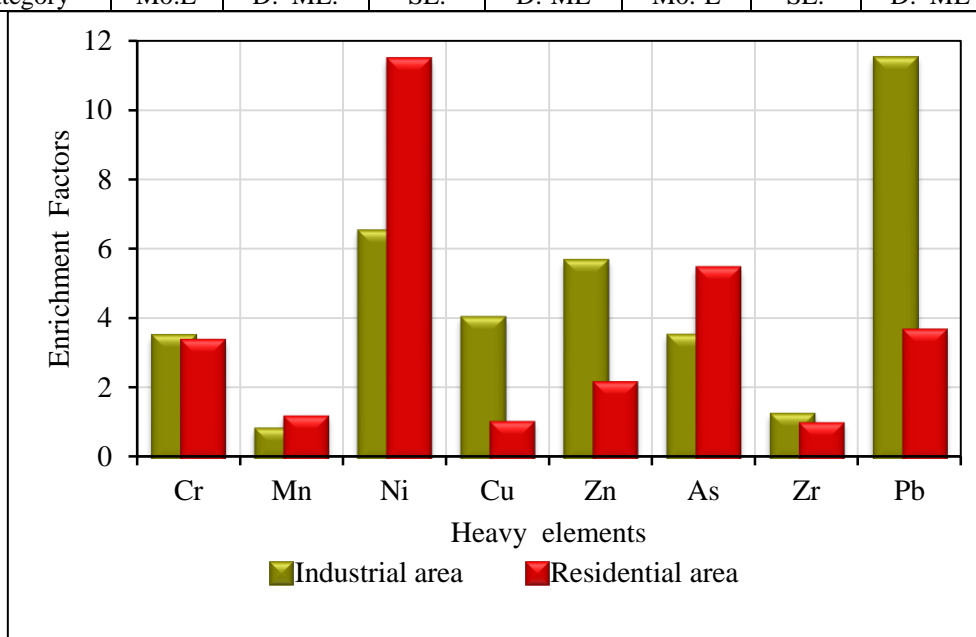


Figure 2-Enrichment factors mean values in Industrial area and Residential area.

The enrichment factor values for the trace elements such as Lead, Nickel and Zinc were significant enrichment, and this reflects the high pollution. In contrast, the elements like Manganese, Zirconium were deficiency to minimal enrichment, which indicates low pollution, but the other metals such as Chromium, Copper, and Arsenic were moderate pollution, in the industrial area of the study area. Whereas the heavy elements in the residential area such as Nickel and Arsenic were highly polluted, while the moderate pollution is Lead, Chromium and Zinc, the low pollution is Zircon, Manganese and copper according to the enrichment factor values of soil samples.

The enrichment factor values for some heavy elements such as Lead and Zinc in the industrial area were relatively higher than in the residential area. In contrast, some elements such as Nickel and Arsenic were somewhat higher in the residential area than in the industrial area. In general, the reasons for that due to industrial waste, sewage sludge and other human activities in both regions. Enrichment factor mean values of heavy metals in the soil of industrial area are ordered in the following: Pb> Ni> Zn> Cu> As> Cr> Zr> Mn. While Enrichment factor mean values of heavy metals in the soil of residential area are ordered in the following: Ni> As> Pb> Cr> Zn> Mn> Cu> Zr.

6.2. Geo- Accumulation index (I_{geo})

The I_{geo} index means the pollution assessment enriches heavy metals' concentration above the baseline concentrations [30]. The constant 1.5 is introduced to minimize possible variations of the background values attributed to lithogenic variations in the soil. The results of the Geo accumulation index, range, mean, and pollution categories to the industrial and residential area for selected trace elements are listed in Table 4 and Figure 3.

Geo accumulation index mean values for heavy elements for Chromium, Copper, Zinc, Arsenic in the industrial area fall into class 1 (unpolluted to moderately polluted), while the elements Cr, As, Pb, in the residential area occupied class 1 (unpolluted to moderately polluted). The heavy elements Mn, Ni, Pb record moderately polluted grade (class 2) in the industrial area, while Nickle element falls into a moderately polluted grade (class 2) in a residential area only. The I-geo has a mean negative value of Zircon element records unpolluted grade (class 0) in industrial area only. At the same time, the elements Cu, Zn, Zr records unpolluted grades (class 0) in the residential area.

Table 4-Geo accumulation index, Range, Mean and Geo accumulation index Categories values for heavy metals in the study area.

Sam.	Area	Heavy metals							
		Cr	Mn	Ni	Cu	Zn	As	Zr	Pb
SI1	Industrial Land Use	0.12	0.90	0.88	0.06	0.55	0.23	-0.33	0.97
SI2		0.59	1.50	1.43	0.32	0.69	0.95	-0.72	1.90
SI3		0.14	0.99	0.55	0.05	1.00	0.44	-0.70	1.98
SI4		-0.09	0.85	0.62	0.97	1.38	-1.62	-0.74	2.44
SI5		0.18	1.33	1.14	0.88	0.33	0.53	-0.45	1.66
SI6		0.46	1.51	1.45	-0.50	0.08	0.61	-0.75	0.96
SI7		0.39	1.40	1.33	1.00	0.23	0.34	-0.62	1.23
SI8		0.15	1.19	1.13	1.13	1.61	0.79	-1.18	1.88
SI9		0.41	1.09	1.05	0.09	1.01	0.84	-0.78	0.87
SI10		0.47	0.99	0.60	0.07	0.19	0.39	-0.26	0.66
Range		-0.09-0.59	0.85-1.51	0.55-1.45	-0.50-1.13	0.08-1.61	-1.62-0.95	-0.26-(-1.18)	0.66-2.44
Mean		0.28	1.17	1.01	0.40	0.70	0.35	-0.65	1.45
Igeo Category		UP- MP	MP	MP	UP- MP	UP- MP	UP-MP	UP	MP
SR1	Residential Land Use	0.14	1.83	1.99	-0.60	-0.06	1.40	-0.63	-0.33
SR2		0.23	1.60	1.00	-0.67	-0.11	0.40	-0.66	0.86
SR3		0.27	1.45	1.51	-0.97	-0.18	0.79	-1.11	0.04
SR4		0.32	1.44	1.23	-0.84	-0.14	0.55	-0.76	0.45
SR5		0.46	1.76	1.76	-0.77	-0.12	0.95	-0.90	-0.15
SR6		0.45	1.66	1.38	-0.74	0.01	0.64	-1.11	-0.44
SR7		0.67	1.67	1.70	-0.85	-0.01	0.79	-0.85	1.54
SR8		0.08	1.45	1.47	-1.13	-0.32	0.71	-0.84	-0.50
SR9		-0.02	1.25	1.20	-1.19	-0.25	0.61	-1.20	0.48
SR10		0.25	1.32	1.29	-0.99	0.01	0.43	-1.18	0.98
SR11		0.15	1.11	1.02	-1.27	-0.41	0.39	-1.00	-0.55
SR12		0.10	1.18	1.06	-1.21	-0.22	0.81	-1.01	-0.38
SR13		0.03	1.44	1.51	-0.88	0.018	0.61	-1.04	0.04
SR14		0.40	1.59	1.69	-0.67	-0.40	0.76	-0.93	0.75
Range		-0.02 – 0.67	1.11–1.83	1.02-1.99	-0.60–(-1.19)	-0.41–0.01	0.39–1.40	-1.20-(-0.6)	-0.55–1.54
Mean		0.25	1.48	1.41	-0.91	-0.15	0.70	-0.94	0.19
Igeo Category		Up- MP	MP	MP	UP	UP	UP- MP	UP	UP- MP

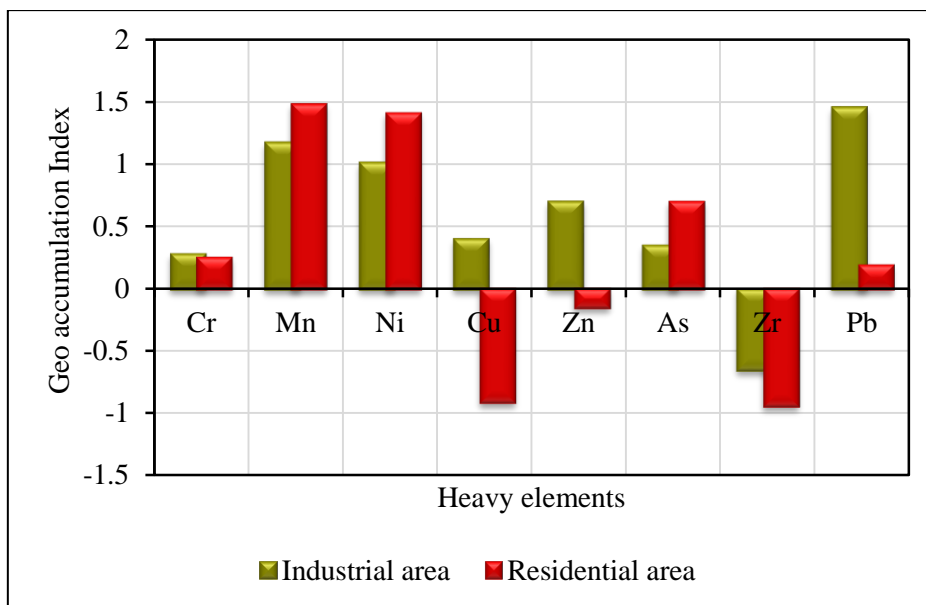


Figure 3-Geo accumulation index in Industrial area and Residential area

The difference in the classification categories for the geo- accumulation index values can result from pollution in industrial pollutants from some effects such as organic chemistry, waste machinery and cars, oils and fats, especially in the soil samples of the industrial zone. The source of these pollutants is the remnants of waste from industrial workshops and factories located in the area and the remnants of motor oils, lubricating fats, fuel, waste of tires and batteries, and remnants of parts of cars and machinery. While the impact of domestic and human activities, private generators, the accumulation of random domestic waste, and sewage sludge are evident in the residential area.

6.3. Pollution Load Index (PLI)

The PLI is defined as a ratio of heavy metal concentration in the soil and the background concentration of the metal [23]. The results of the Pollution Load Index, range, mean, and pollution categories to the industrial and residential area for selected trace elements are listed in Table 5 and Figure 4.

Table 5-Pollution Load Index, Range, Mean and Pollution Load Index Categories values for heavy metals in the study area

Sam.	Area	Heavy metals							
		Cr	Mn	Ni	Cu	Zn	As	Zr	Pb
SI1	Industrial Land Use	1.88	0.37	2.55	0.98	3.66	1.55	0.55	6.77
SI2		2.73	0.68	6.3	2.07	3	3.88	0.72	10.07
SI3		2.11	0.43	3.11	1.66	4.65	2	0.65	4.55
SI4		1.37	0.35	2.8	3.96	6	<0.29	0.7	25.5
SI5		1.77	0.55	4.13	2.07	2.22	0.99	0.54	6.66
SI6		2.38	0.68	6.4	0.9	1.62	2.77	0.7	3.92
SI7		1.4	0.39	5.43	2.66	3.46	1.03	0.58	7.88
SI8		1.75	0.5	4.65	4.65	7.55	3.33	0.46	9.85
SI9		2.04	0.45	3.66	1.43	6.43	1.87	0.49	8.33
SI10		2.4	0.4	2.75	1.61	1.82	2.22	1.14	2.92
Range		1.37-2.73	0.35-0.68	2.75-6.4	0.90-4.65	1.62-7.55	0.29-3.88	0.46-0.72	2.92-25.5
Mean		1.98	0.47	4.17	2.19	4.04	1.99	0.65	8.64
PLI Category		MC.	LC.	HC.	MC.	HC.	MC	LC.	HC.
SR1	Residential Land Use	1.73	0.93	11	0.81	1.4	6.11	0.79	1.07
SR2		1.66	0.56	5.33	0.48	1.22	3.67	0.5	1.05
SR3		1.97	0.64	6.8	0.56	1.24	3.33	0.49	1.57

SR4	1.88	0.6	6.77	0.57	1.11	2.28	0.44	2.44
SR5	2.38	0.84	8.75	0.69	1.32	3.88	0.6	1.28
SR6	2.44	0.48	6.13	0.45	1.03	3.57	0.5	1.99
SR7	2.95	0.8	8.25	0.63	1.47	3.33	0.63	5
SR8	2.8	0.76	6.44	0.53	1.09	2.36	0.49	2.32
SR9	1.47	0.53	5	0.45	1.15	2.77	0.44	2.42
SR10	1.79	0.68	4.44	0.72	0.99	4.33	0.7	2.22
SR11	1.75	0.45	4.2	0.41	0.98	2.22	0.55	0.85
SR12	1.6	0.7	5.66	0.68	1.05	3.27	0.58	2.07
SR13	1.55	0.63	6.8	0.61	1.52	2.77	0.52	1.57
SR14	2.77	0.56	7.04	0.51	0.98	2.99	0.47	0.99
Range	1.47-2.95	0.45-0.93	4.2 - 11	0.41-0.81	0.98-1.52	2.22-6.11	0.44-0.79	0.85-5.00
Mean	2.05	0.65	6.61	0.57	1.18	3.34	0.55	1.91
PLI Category	MC.	LC.	HC	LC	MC.	HC.	LC	MC

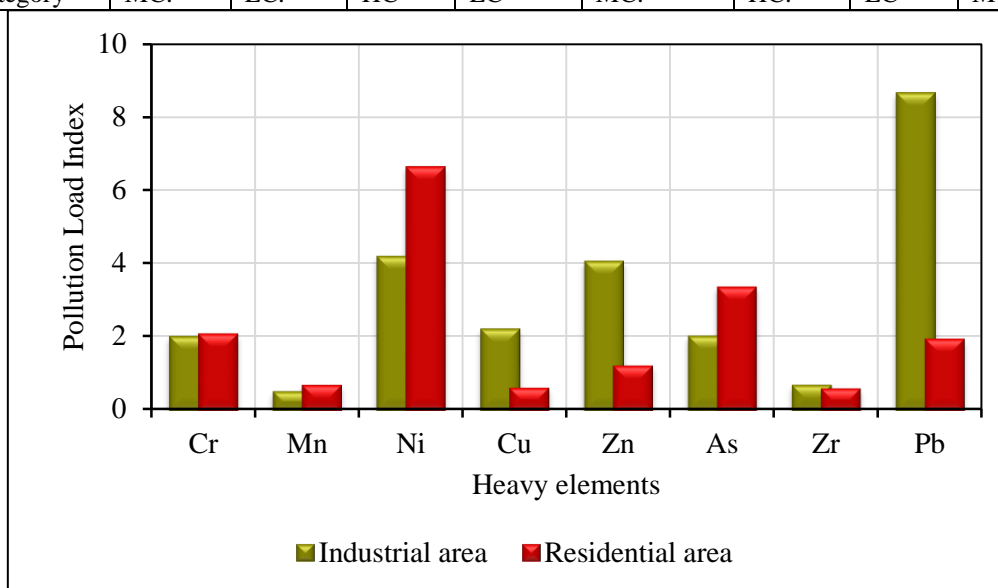


Figure 4-Pollution Load Index in Industrial area and Residential area

PLI categories for heavy elements, Ni, Zn and Pb are, reported high contamination. In contrast, the Cr, Cu and As are recorded moderate contamination, and heavy metals Mn and Zr reported low contamination in the Industrial area. Whereas in sites of the residential area are showing the metals Ni and As reported high contamination and the metals Cr, Zn and Pb recorded moderate contamination. The metals Mn, Cu and Zr reported low contamination. These results may be linked to sewage slugs, urban centers and industrialization effect in the study area, or some input from anthropogenic sources or maybe to the lithogenic source.

6.4. Integrated Pollution Load Index (IPLI)

The integrated pollution load index (IPLI) represents the mean of all pollution indexes (PLI) values for all considered metals. The Integrated Pollution Load Index results, range, mean, and pollution categories to the industrial and residential area for selected heavy elements are listed in Table 6 and Figures 5 and 6. Integrated Pollution Load Index categories for heavy elements are reported high contamination of the industrial and residential areas.

Table 6- Integrated Pollution Load Index (IPLI), Range, Mean and Integrated Pollution Load Index Categories values for heavy metals in the study area.

Sam.	Area	Heavy metals								IPLI
		Cr	Mn	Ni	Cu	Zn	As	Zr	Pb	
SI1	Industrial Land Use	1.88	0.37	2.55	0.98	3.66	1.55	0.55	6.77	2.28
SI2		2.73	0.68	6.3	2.07	3	3.88	0.72	10.07	3.68
SI3		2.11	0.43	3.11	1.66	4.65	2	0.65	4.55	2.39
SI4		1.37	0.35	2.8	3.96	6	0.29	0.7	25.5	5.12
SI5		1.77	0.55	4.13	2.07	2.22	0.99	0.54	6.66	2.36
SI6		2.38	0.68	6.4	0.9	1.62	2.77	0.7	3.92	2.42
SI7		1.4	0.39	5.43	2.66	3.46	1.03	0.58	7.88	2.85
SI8		1.75	0.5	4.65	4.65	7.55	3.33	0.46	9.85	4.09
SI9		2.04	0.45	3.66	1.43	6.43	1.87	0.49	8.33	3.08
SI10		2.4	0.4	2.75	1.61	1.82	2.22	1.14	2.92	1.9
Range value										1.90- 5.12
IPLI Mean value										3.017
IPLI Category		High contamination								
SR1	Residential Land Use	1.73	0.93	11	0.81	1.4	6.11	0.79	1.07	2.98
SR2		1.66	0.56	5.33	0.48	1.22	3.67	0.5	1.05	1.8
SR3		1.97	0.64	6.8	0.56	1.24	3.33	0.49	1.57	2.07
SR4		1.88	0.6	6.77	0.57	1.11	2.28	0.44	2.44	2.01
SR5		2.38	0.84	8.75	0.69	1.32	3.88	0.6	1.28	2.46
SR6		2.44	0.48	6.13	0.45	1.03	3.57	0.5	1.99	2.07
SR7		2.95	0.8	8.25	0.63	1.47	3.33	0.63	5	2.88
SR8		2.8	0.76	6.44	0.53	1.09	2.36	0.49	2.32	2.09
SR9		1.47	0.53	5	0.45	1.15	2.77	0.44	2.42	1.77
SR10		1.79	0.68	4.44	0.72	0.99	4.33	0.7	2.22	1.98
SR11		1.75	0.45	4.2	0.41	0.98	2.22	0.55	0.85	1.42
SR12		1.6	0.7	5.66	0.68	1.05	3.27	0.58	2.07	1.95
SR13		1.55	0.63	6.8	0.61	1.52	2.77	0.52	1.57	1.99
SR14		2.77	0.56	7.04	0.51	0.98	2.99	0.47	0.99	2.03
Range										1.42- 2.98
IPLI Mean										2.1
IPLI Category		High contamination								

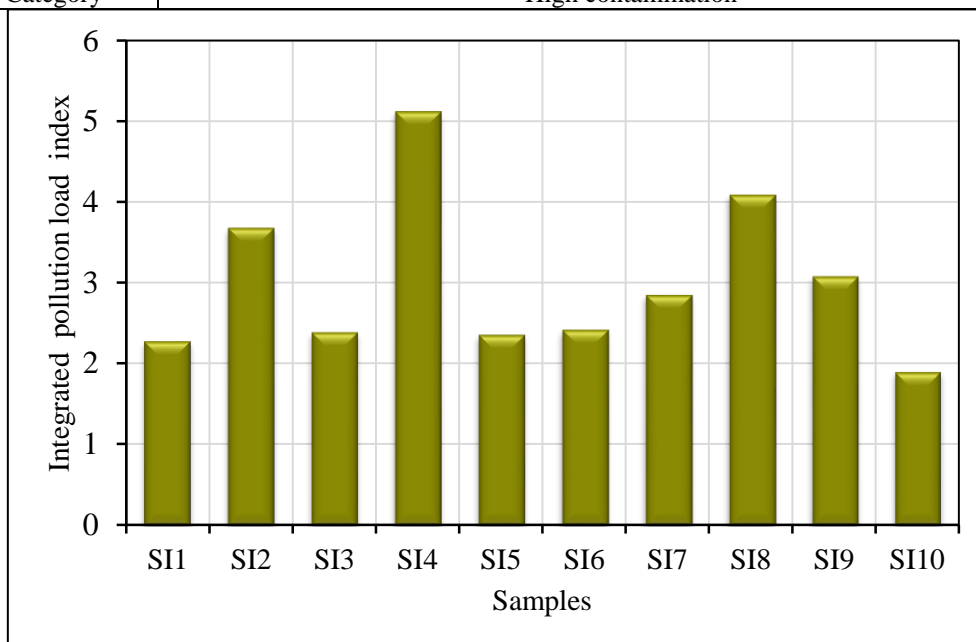


Figure 5-Integrated Pollution Load Index in Industrial area

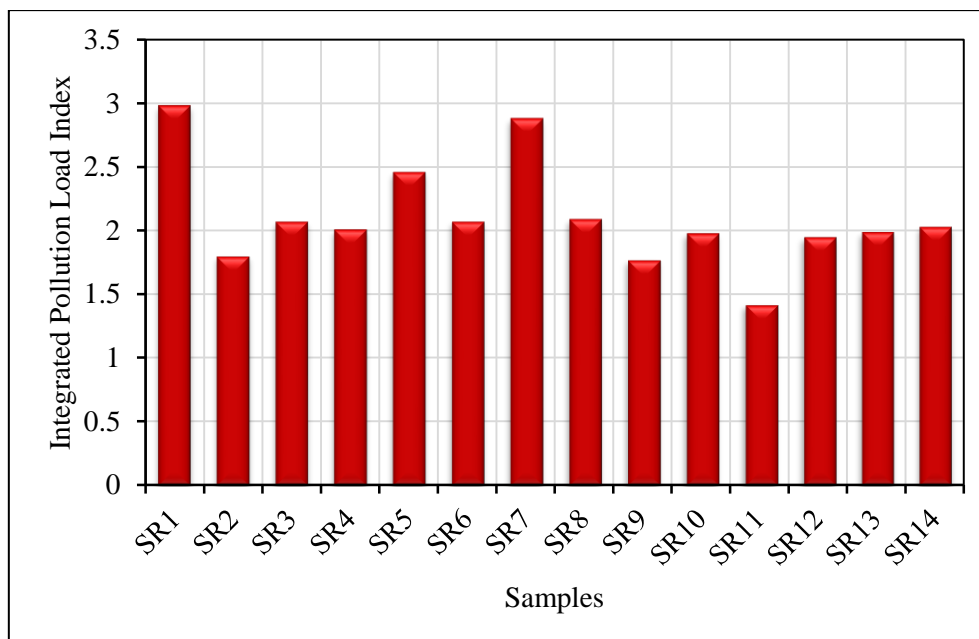


Figure 6-Integrated Pollution Load Index in Residential area.

7. Conclusion

The result of the enrichment factor indicated that Pb significantly enriched all soil samples in industrial area use, whereas, in the residential area, Nickel is characterized by significant enrichment as a result of oil combustion and domestic waste accumulation.

Index of geo accumulation for Mn element values characterized by moderately polluted Industrial and residential areas, in addition to, I-geo mean values of heavy elements in the industrial area may be ordered in the following: Mn> Pb> Ni>Zn > Cu> As> Cr> Zr. While in residential area may be ordered in the following: Mn> Ni> As> Cr> Pb> Zn> Cu> Zr.

Depending on the Pollution Load Index results, high contamination is recorded for the mean of Ni, Zn, Pb, while the heavy elements Cr, Cu, and As indicate major to moderate contamination. Mn and Zr heavy elements are considerably low contamination in the mean values in the industrial area. In comparison, the heavy elements Ni and As were high contamination. Cr, Zn and Pb are reported moderate contamination, but the Mn, Cu and Zr elements are of low mean contamination values in the residential area.

According to the results, IPLI categories are high contaminated in industrial and residential areas for the study area. The main contaminated heavy elements in the studied area are Cr, Cu, Ni, As, Zn and Pb; lithological origin or various anthropogenic origins may be the key sources of these.

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