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Distribution of Some Potentially Toxic Heavy Metals in The Soil of Shoubra El Kheima, Egypt

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Abstract

This study aims to detect the effect of industrialization and urbanization on the soil content of some potentially toxic heavy metals. The soil of Shoubra El Kheima was considered one of the most fertile soils in the Nile Delta, Egypt. Forty samples from this soil were texturally categorized and chemically analyzed using inductively coupled plasma-optical emission spectroscopy (ICP-OES). The data were treated statistically and by geographic information system technique. The agricultural soils in the study area are mainly classified as clayey soil, whereas urban and industrial soil samples are varied in their classification from clayey to loamy sand. As, Cd and Zn in the soil exceed the maximum permissible limits whereas, Cu, Cr, Ni, and Pb are within the permissible limit except for some samples. The obtained data show that the concentrations of Cu, As, Zn, Pb, Ni, and Cr increase in the southeastern and southwestern parts of the study area. Urbanization, agricultural practices, and the atmospheric deposition from the different industrial activities are thought to be the main anthropogenic sources of heavy metals contamination in the study area.

Keywords: Egypt; Heavy metals; Industrialization; Shoubra El Kheima; Soil Contamination; Urbanization

1. Introduction

Environmental pollution with heavy metals is a global issue that requires great attention to combat [1-3]. The rapid population growth in Egypt especially in the Nile Delta has led to increasing industrial and commercial activity. An unorganized urbanization established in some places with no information about the hazards that will affect our natural system resources such as air, water (surface and ground), and soil creating environmental and public health problems [4-10].

Soils may become contaminated by the accumulation of pollutants through emissions from the rapidly expanding industrial areas, mine tailings, industrial effluents, petrochemicals, paints, fertilizers, animal manures, sewage sludge, pesticides…. etc. [11-16].

Heavy metals are a general term that describes a group of elements with an atomic density greater than 6 g/cm^3 [17-18]. Most of these metals are among the essential nutrients needed by plants, animals, and humans in low concentrations, but they turn into toxic substances when present in quantities exceeding the permissible limits. Heavy metals are one of the most persistent and toxic contaminants that are inserted in the soil either naturally by weathering of the parent rock or anthropogenic by urbanization and industrialization [19-20]. The mobility of the metal is controlled by pH, Eh, cation exchange capacity of the solid phase, competition with other metal ions, soil composition, and its concentration in the soil solution [17-21].

One of the most important aspects of environmental safety is monitoring the content of toxic elements in different environmental compartments. The environmental stability of heavy

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metals coupled with their great use in the study area led to the accumulation of large levels of heavy metals in the environment. A part of these metals is absorbed by plants (depending on soil type, climatic factors, and plant type) and thus enter the human food chain and another part is transferred to the groundwater which may lead to toxic effects on the environment [15-22].

The present study aims to investigate the concentrations and distribution of some potentially toxic metals in the soil of a highly industrialized and urbanized area in southeastern of the Nile Delta, Egypt. Light will be shed on their potential sources and ecological risk assessment.

2. Experimental

2.1. Study area

Shoubra El-Kheima is located in the southeastern part of the Nile delta, it measures approximately 30 km^2 on the northern corner of Greater Cairo between longitude 31° 14' 7.7''-31° 17' 45'' E and latitude 30° 6' 22.4''-30° 9' 37.5'' N (Fig. 1). It is one of the most important areas for industrial and commercial activities in Greater Cairo. The intensive applications of fertilizers, industrial emissions, and liquid wastes discharged by the industrial complexes lead to contamination of this area. Industrial activities include glass and crystal, ceramics and brick, ferrous and nonferrous metallurgical industries, chemical, textile beside two large power plants.

2.2. Soil sampling

A total of forty samples were collected by using a good plan survey for the sites along the study area. A well-constrained Global Positioning System (GPS) was used to facilitate access of the sampling sites accurately (Fig. 1). The samples were collected at depth (15-30cm) during 2019 (Table 1). They were collected in sealed polyethylene bags using a clean stainless-steel shovel to avoid any cross-contamination.

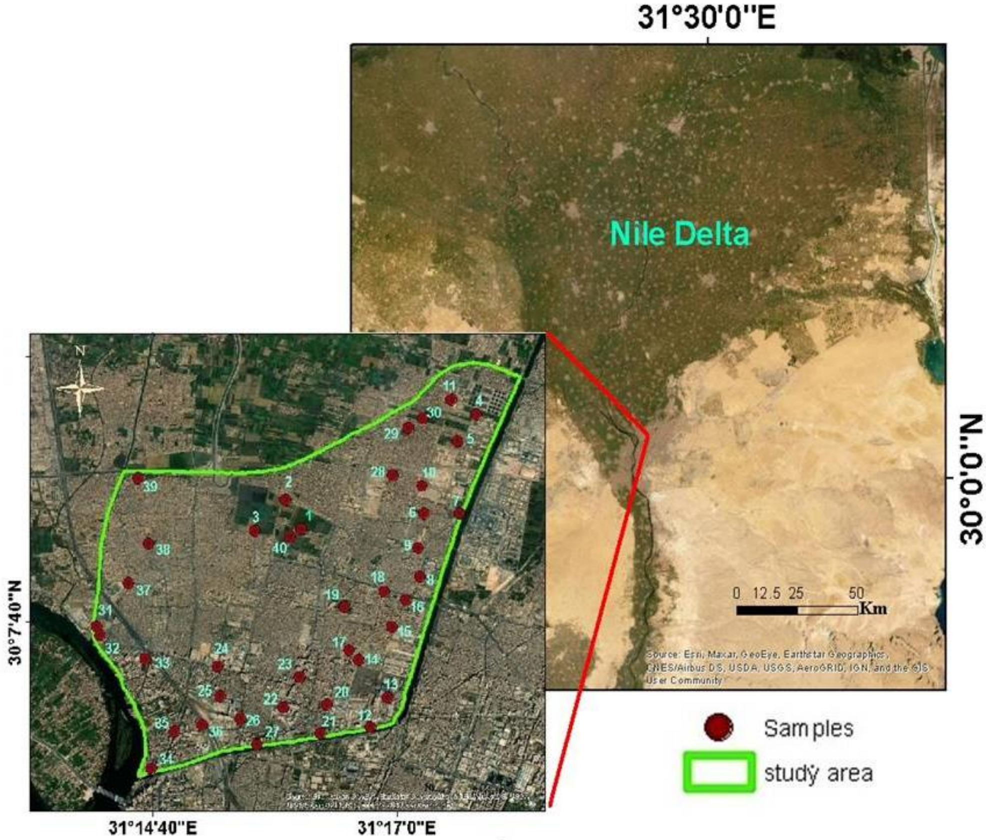

Fig. 1. Satellite images showing the location of the study area and sample sites.

2.3. Analytical techniques

The collected samples were air-dried for ten days with continuous rotation in a controlled environment to avoid cross-contaminations. After the removal of recognizable plant debris and stones, representative sub-samples were obtained by coning and quartering. Soil samples were taken and passed through a 2 mm sieve to remove large particles. The soil samples were then analyzed for selected physical and chemical properties including particle size distribution, calcium carbonate, and organic matter contents according to Carver [23].

In this analysis, 0.5g of the powdered sample was digested using the acid mixture (HF, $HClO_4$, and HNO_3) [24]. Digestion was carried out till mushy. The mashed sample was then acidified with 20 mL of 1:1 HCI and then heated for one hour. When the solution clears, the acidified sample is transferred to a 250 mL volumetric flask and made up to the mark with de-ionized water. Total heavy metals (As, Cd, Cr, Cu, Ni, Pb, and Zn) concentrations were measured using (ICP-OES) with Synchronous Vertical Dual View (SVDV).

2.4. Statistical treatment

Descriptive statistics and multivariate statistical analysis were determined by using SPSS (version 20). Arc GIS (version 10.3) is used for the presentation of sample locations and spatial distribution patterns of heavy metals in the study area. Pearson correlation coefficient matrices were calculated to define the correlations between different heavy metals in the soil samples. Cluster analysis (CA) was used to detect factors that control the distribution of the studied heavy metals in the soil.

Table 1. List of the collected samples and their locations.

Sample No	Lat.	Long.	Location
1	30.141	31.268	Agriculture land
2	30.146	31.265	Agriculture land
3	30.141	31.261	Agriculture land
4	30.158	31.296	Agriculture land
5	30.154	31.293	Agriculture land
6	30.144	31.288	agriculture land
7	30.145	31.293	Agriculture land
8	30.134	31.287	Private garden beside industrial complex
9	30.139	31.287	Private garden from a paper company
10	30.148	31.287	Agriculture land behind a textile company
11	30.160	31.292	Agriculture land
12	30.112	31.278	private garden beside the road between companies (cement)
13	30.117	31.282	Private garden beside Iron and steel production factory
14	30.122	31.277	Private garden beside the company
15	30.127	31.271	Private garden beside industrial complex
16	30.131	31.285	Private garden between houses
17	30.124	31.276	Private garden between houses
18	30.132	31.281	Private garden between houses
19	30.130	31.275	Agriculture land
20	30.116	31.272	Private garden beside the company
21	30.111	31.271	Private garden from a school
22	30.115	31.265	Private garden beside a textile company
23	30.120	31.268	Agriculture land
24	30.121	31.255	Private garden beside glass factories
25	30.117	31.255	Private garden beside industrial complex
26	30.114	31.258	Private garden beside industrial complex
27	30.110	31.261	Private garden from a worship house
28	30.150	31.281	Agriculture land
29	30.156	31.285	Agriculture land
30	30.158	31.288	Agriculture land
31	30.127	31.235	Private garden from a school beside Shoubra El Kheima power plant
32	30.126	31.236	Private garden from Shoubra El Kheima power plant
33	30.122	31.243	Private garden from a governmental institute beside Ahmed Helmy main square
34	30.106	31.244	Private garden from Shoubra El Kheima club
35	30.112	31.248	Private garden from faculty of agriculture Ain Shams University
36	30.113	31.252	An old tree behind a railway
37	30.133	31.241	Private garden from Shoubra El Kheima water purification station
38	30.139	31.244	Private garden from Bigam club
39	30.149	31.242	Agriculture land
40	30.14	31.266	Agriculture land

2.5. Pollution assessment

To assess the pollution in the study area, three factors were calculated namely; the Enrichment factor (EF), Geo-accumulation index (I_{geo}), and Potential Ecological Risk Index (PER).

2.5.1. Enrichment Factor (EF)

The enrichment factor was calculated to detect anthropogenic inputs of heavy metals in the soils, using the equation (1) [25]:

$$\boldsymbol{EF = \frac{(\frac{M}{Al})_{Sample}}{(\frac{M}{Al})_{Cruust}}} \quad (1)$$

where M is the concentration of the concerning heavy metal, Al is the concentration of aluminum as a reference metal.Enrichment factors may beEF < 2 (no enrichment), EF = 2–5(moderate enrichment),EF 5–20 (significant enrichment),EF 20-40 (very high enrichment),EF>40 (extremely high enrichment) [26].The concentration of metals in the earth's crust is used according to Taylor and McLennan [27].

2.5.2. Geo-accumulation index (I_{geo})

The geo-accumulation index was used to quantify the heavy metal contamination in the soil samples. It was computed using equation (2) [28]:

$$\boldsymbol{I_{geo} = \log(\frac{C_n}{1.5B_n})} \quad (2)$$

where$C_n$is the concentration of metal in a soil sample, $B_n$isthe concentration of metal in the background, and n is the metal. The I_{geo} was classified into seven classes,Class 0 (I_{geo}< 0: practically uncontaminated); Class 1 (0<I_{geo}<1: uncontaminated to moderately contaminated); Class 2 (1<I_{geo}<2: moderately contaminated); Class 3 (2<I_{geo}<3: moderately to heavily contaminated); Class 4 (3<I_{geo}<4: heavily contaminated); Class 5 (4<I_{geo}<5: heavily to extremely contaminated); Class 6 (I_{geo}>5: extremely contaminated).

2.5.3. Potential Ecological Risk Index (PER)

To quantitatively evaluate the potential ecological risks posed by the heavy metals contaminations in the soils, the PER was calculated using equations adopted by Hakanson[29]:

$$\mathbf{PER = \sum_{i}^{n} E_r^i} \quad (3)$$

$$\mathbf{E_r^i = T_r^i \times C_f^i} \quad (4)$$

where E_r^i is a potential ecological risk for ith heavy metal, T_r^i is the toxic response factor of ith heavy metal, C_f^i is the contamination factor. The toxic response factor for Co, Cr, Cu, Ni, Pb, and Zn is 5, 2, 5, 5, 5, and 1, respectively. The value of contamination factor (C_f) was calculated using equation (5) [29]:

$$\boldsymbol{C_f = \frac{C_{Sample}}{C_{Background}}} \quad (5)$$

where C_{Sample} = metal concentration in a soil sample, $C_{Background}$ = concentration of that metal in the background. The PER is classified into five classes [28]. Class 1 (PER ≤ 50: low risk); Class 2 (50 <PER≤100: moderate risk); Class 3 (100<PER ≤150: high risk); Class 4 (150<PER≤ 200: very high risk); and Class 5 (PRR > 200: extreme risk).

3. Results and discussion

3.1. Soil texture

The minimum, maximum, and average percentages of clay, silt, sand, organic matters, and carbonates in the collected soil samples are shown in (Table2). Clay, silt, and sand percentages obtained from the particle size analysis are plotted on the USDA triangle (Fig. 2) [30].

All agricultural soil samples are classified as clayey soil except one sample that is classified as loam, this classification is consistent with the texture of the main Nile Delta soil which is generally characterized by low sand and high clay and silt contents [31]. Urban and industrial soil samples are varied in their classification from clayey to loamy sand. This variation probably indicates that some of these samples are transported or mixed with external particles due to industrialization and urbanization. Mixing with external and different particles eventually results in modification of the real soil texture and affects its heavy metal contents, in addition to other soil properties.

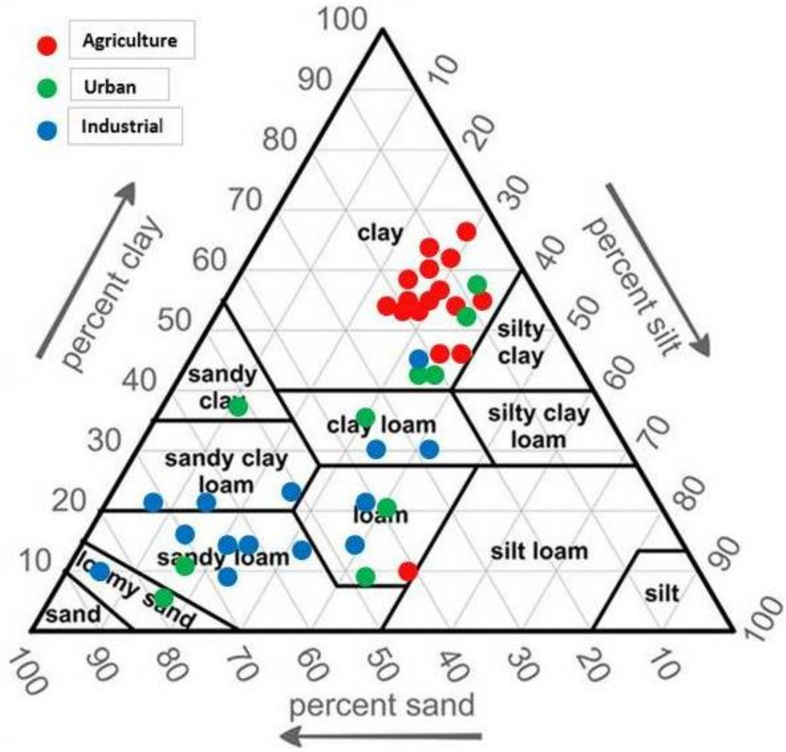

Fig. 2. Plotting of the studied soil samples on the USDA triangle [30].

The organic matter contents range was 2 to 8.9 % with an average of 4.7 %, the high percentage of organic matter is observed in agricultural soil where agricultural and domestic activities are abundant with its high sewage effluents [32]. While carbonates percentages are ranged from1.8 to 7.9 % with an average of 4.7%. A high percentage of carbonates are observed in the soils of the industrial and urban areas, this probably due to additions of different particles to the natural soil with the intensive urbanization happened in the study area.

3.2. Heavy metals distributions

The concentrations and descriptive statistical parameters (minimum, maximum, and average) of the selected heavy metals in the soil samples are listed in Table 2.Generally, the average concentrations of As, Cd, Cr, Cu, Ni, Pb, and Zn are 39.6, 8, 106.8, 90.3, 73.5, 95, and 441.7ppm in all samples, respectively. As and Zn are detected with high concentrations, while Cr, Cu, Ni, and Pb concentrations vary with different land-use types (agriculture or urban, or industrial).

In agriculture areas, the concentrations of As and Zn are detected with high concentrations range from 18.64 to 106.8ppm for As and from 136 to 285.5 ppm for Zn. The highest concentrations of As, Ni, and Zn (106.8, 128, and 285.5 ppm, respectively) is detected in the sample (39) that irrigated with wastewater (sludge) compared to that irrigated with fresh groundwater, also this sample lies beside the ring road with high traffic density. The intensive use of inorganic fertilizers (especially phosphate fertilizer) leads to the accumulation of some heavy metals such as Cd, Ni, and As in the soil [31-33]. The higher concentration of As is most probably due to fungicide residues that contain a high amount of arsenic [34, 35]. Irrigation with wastewater in some sites increases the soil content of some heavy metals such as Zn, Cr, Cu, Ni, Pb, and Cd [36, 37]. Atmospheric deposition from urban areas and industrial activity is an additional source for contamination in the agricultural area [38].

In urban areas, the average concentrations of Cd, Cr, Cu, Ni, Pb, and Zn in the soil are higher than the corresponding concentrations in the agricultural soil. The highest concentrations of As, Cd, Cr, Cu, Ni, and Zn (99.25, 217.25, 191.5, 275.5, 291.2, and 1140.3ppm, respectively) are detected in the sample (33) collected from a private garden close to the high traffic density of Ahmed Helmy main square and obviously, the owner use large amount of fertilizers for plants. Urban areas are characterized by intensive traffic density than other areas. Cd, Zn, and Ni are concentrated in the soil of urban areas due to automobile traffic [39], because of the presence of Cd and Zn in motor oil and tires. Pb is enriched in urban soils due to house paints and exhausts from petrol engines in motor vehicles. Wood preservatives (as a part of the painting) containing Cr, Cu, and As can act as contamination sources of soils in urban areas. Also, the use of fertilizers in the private garden leads to concentrate these elements in the soil.

In the industrial area, the average concentrations of Pb, Cu, and Zn in the soil are higher than the corresponding concentrations in the agriculture and urban soil. It is observed that the sample (13) collected from the complex industrial area (Iron and steel factory and lead smelter) showed the highest concentrations of Cd, Cr, Cu, Ni, Pb, and Zn (10.07, 265.25, 495.5, 150.5, 799.5, and 2578ppm, respectively). High levels of Pb, Zn, Cd, As, Ni and Cu occur in soils in the vicinity of smelters [40]. The high concentration of Pb around smelter (as a main effective source of lead pollution) mainly results from loaded lead ashes emitted from smokes stack and/or lead rich dusts blown off ore and slag piles [41]. Cd, Cu, Ni, and Zn are enriched in the soils due to the presence of power plants [42]. Atmospheric deposition from different industries as iron and steel production, glass industry, plastic, electronics, ceramics, and many companies in the study area increase the concentrations of such metals.

Table 2. Descriptive statistics of selected heavy metals (ppm) and soil main components (%) in different soil categories.

	All samples			Agriculture area			Urban area			Industrial area		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Clay%	6.4	61	33.5	8.7	61	48.9	6.4	55	29.9	8.7	41.8	18.5
Silt %	2.4	43.9	25.4	20.6	43.9	27.4	8	39.99	26.8	2.4	36	22.1
Sand %	2.7	84.3	31.7	2.7	37.3	13	6.9	72.52	35.3	19.2	84.25	50.6
O.M %	1.2	8.9	4.7	4.2	8.9	6.1	1.4	5.46	3.6	1.2	6.63	4.1
$CaCO_3$ %	1.8	7.9	4.7	3.5	5.8	4.7	2.7	6.53	4.4	1.8	7.9	4.9
As	4.2	106.8	39.6	18.6	106.8	43.9	4.2	99.25	38.4	9.5	96.3	39.9
Cd	0.1	217.3	8	0.1	4.4	2.1	0.2	217.25	23.8	0.3	10.1	2.6
Cr	37	265.3	106.8	66.5	155.6	104.3	54.5	191.5	116.4	37	265.3	97.2
Cu	14	495.5	90.3	40	90.5	67.0	14	275.5	79.9	37.5	495.5	121.2
Ni	13	291.3	73.5	49.9	128	75.8	25	291.25	95.94	20.5	150.5	65.1
Pb	11.7	799.5	95	11.8	99.8	44.6	20.1	302	64.6	20.7	799.5	174.9
Zn	133	2578	441.7	136	285	208	148	1300	561.6	133.5	2578	723.9

Comparing the obtained results (Table 2) with the average composition of the upper continental crust (CC) [27] and the world average soil (WAS) [43], the concerned heavy metals showed concentrations above these averages (Fig. 3). This is considered as an indication of the effects of anthropogenic activities in the studied soil. Compared with the maximum allowable concentrations (MAC) for agricultural soil [21, 44], As and Zn showed concentrations above the MAC, while other elements are less than the MAC (Fig. 4).

3.3. Statistical Analysis

The agricultural soils represent the real soil in the study area. Soils are generally considered as the major sink for heavy metals released into the environment by anthropogenic activities. The fate and transport of heavy metals in soil depend significantly on the chemical form and speciation of the metal [2]. To investigate the relations between heavy metals and the components of the agricultural soil in the study area, correlation coefficients were calculated using the analyses of 16 soil samples (Table 3). Generally, weak correlations exist between heavy metals, heavy minerals percentages, clay, carbonates, and organic matter contents. Organic matter contents show only a strong positive correlation with manganese (Fig. 5).

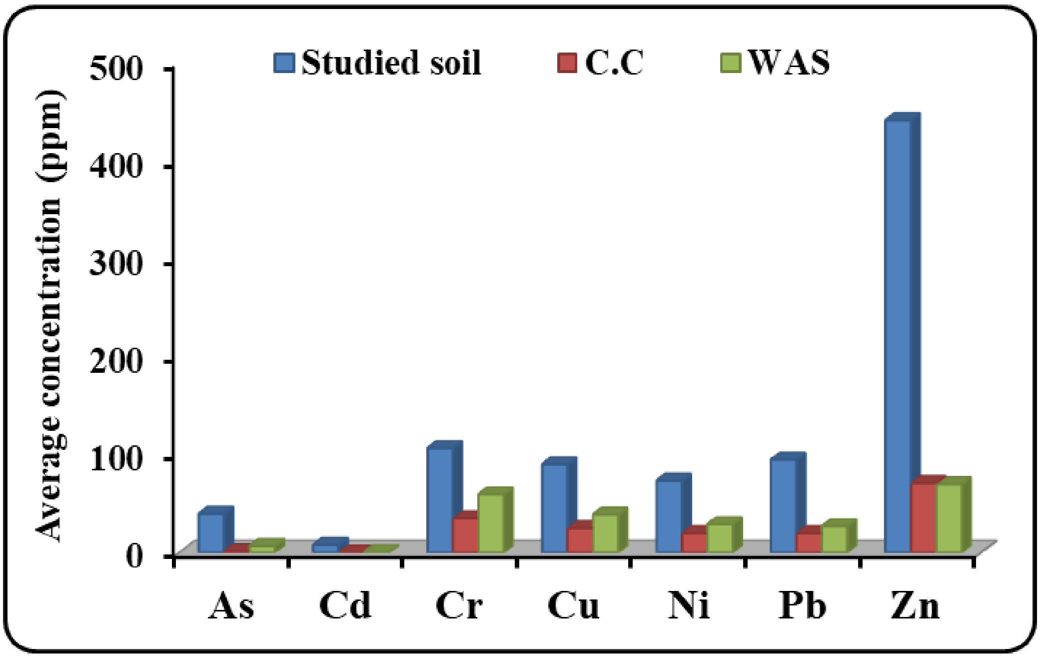

Fig. 3. Comparison of the concentrations of studied elements with (CC) [27] and (WAS) [41].

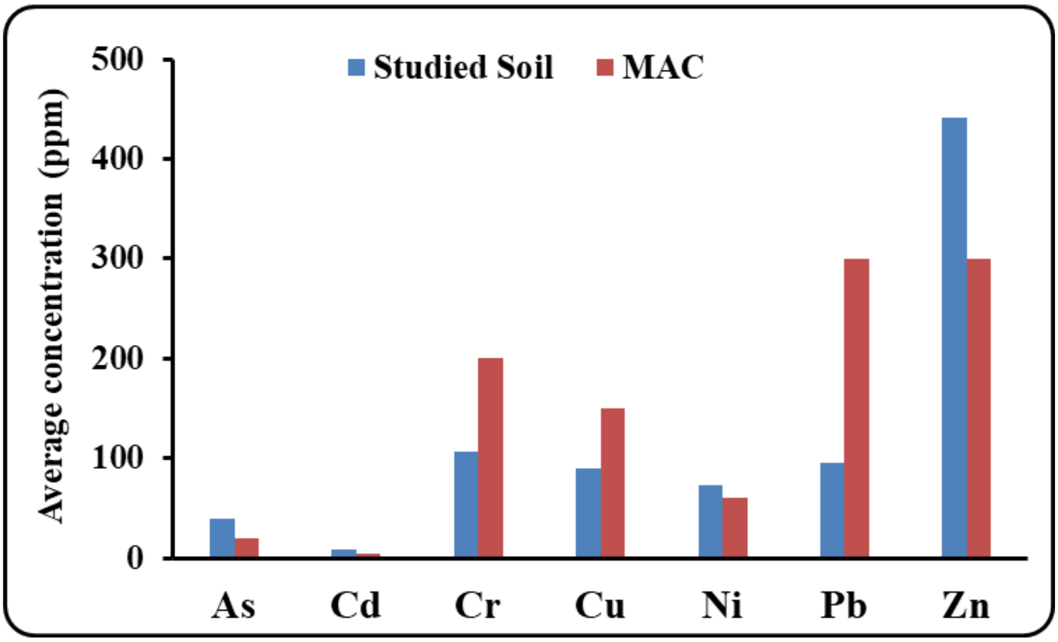

Fig. 4. Comparison of the concentrations of studied elements with (MAC) [21, 44].

On the other hand, heavy minerals percentages show strong positive correlations with iron and arsenic. The latter positive correlations are strongly affected by anthropogenic activities. These correlations are turned to be weak when remove one contaminated sample (number 39) from the calculation (Fig. 6). This sample was collected close to the ring road with sludge water irrigation.

The correlation coefficients (Table 3) strongly suggests that the heavy metals in the agricultural soil of the study area exist as either free (uncomplexed) metal ions (e.g., Cd^{2+}, Zn^{2+}, Cr^{3+}), in various soluble complexes with inorganic complexes (e.g., $ZnSO_4$, $CdSO_4$, $ZnCl^+$, $CdCl_3^-$, $Cr(OH)_4^-$), or associated with mobile inorganic colloidal materials. Common inorganic ligands in similar cases were reported as SO_4^{2-}, Cl^-, OH^-, $PO4^{3-}$, OH^- and NO_3^- [45].

Table 3. Correlation coefficients of heavy metals and agriculture soil components.

	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Clay	-.11	.30	.31	.22	-.33	.17	.14	.21	.22
Silt	.16	-.37	-.15	.02	.42	-.10	-.09	.01	-.33
Sand	.10	-.15	-.34	-.36	.28	-.28	-.13	-.38	-.09
Heavy fractions%	**.74****	-.16	.04	-.13	**.58***	.13	.39	-.09	.32
Organic matters%	-.09	-.15	.19	-.02	-.35	**.63****	.34	.15	-.09
Carbonates %	-.32	-.02	**-.57***	.01	-.38	-.11	**-.60***	.2	.11

**Correlation is significant at the 0.01 level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed)
Bold values are significant

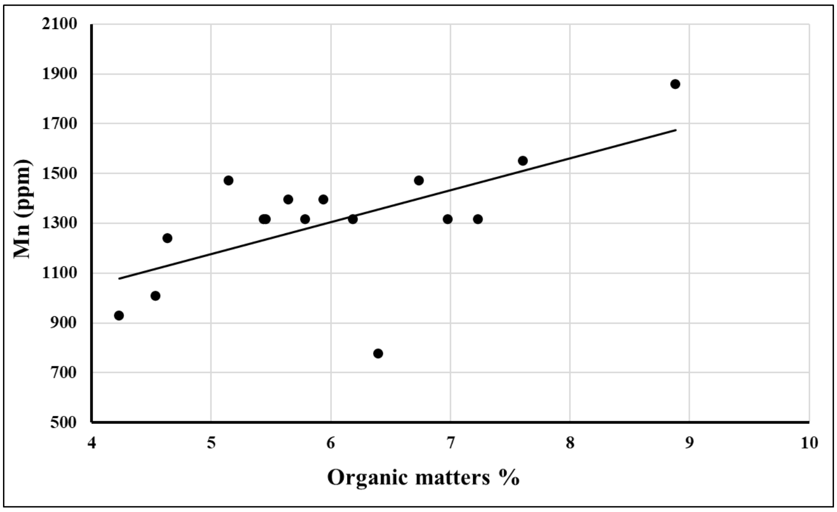

Fig. 5. Positive correlation between organic matters contents and Mn in the agriculture soil of the study area.

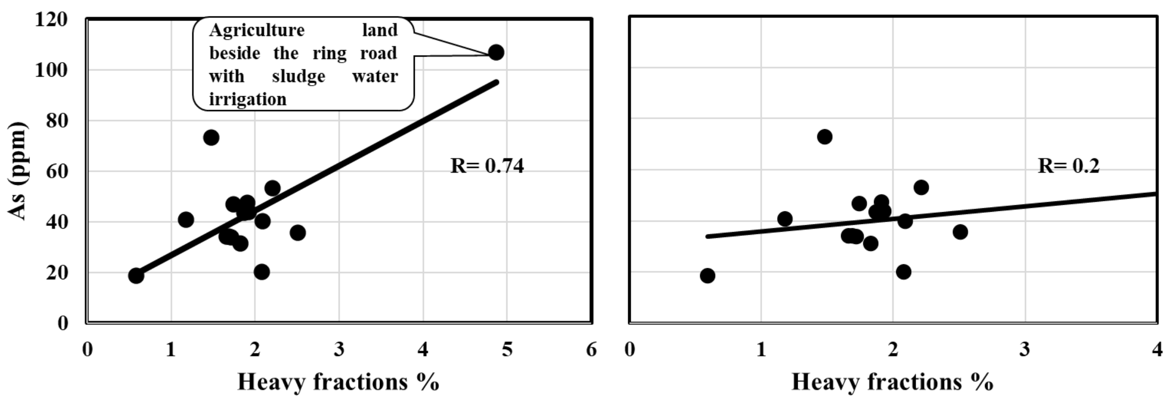

Fig. 6. Positive correlation between As and heavy fractions in the agriculture soil from the study area. The correlation coefficient is significantly affected by anthropogenic activities.

The interrelationships between heavy metals were examined to explore the potential source of these metals [46]. Pearson's correlation coefficient (PCC) analysis and hierarchical cluster analysis (HCA) are also studied in this regard.

The Pearson's correlation coefficients are shown in Tables 4, 5, and 6. The analysis was performed for each land-use category. The significant positive correlations between Zn, Cu, Cd, Cr, and Ni in industrial and urban soil samples indicate that these heavy metals have one common source. However, most of the heavy metals showed insignificant correlations with each other in agricultural soil samples, which indicates more than one source for these metals [47]. The different anthropogenic sources of heavy metals are based on many parameters such as the land use (industrial, urban or agricultural area), irrigation water (fresh surface water, groundwater, waste, or sludge water), organic and inorganic fertilizer contents, and pesticide input.

The cluster analysis was conducted using Ward's method to identify the association of the heavy metals and recognize the reasons that affect their distributions and concentrations through the studied soil types (Fig. 7). The elements were hierarchically clustered based on the concentrations of heavy metals in the samples. Two main categories are developed in the study area.

Table 4. Correlation matrix of heavy metals in industrial area (n=14).

	As	Cd	Cr	Cu	Ni	Pb	Zn	Fe	Mn
As	1	.081	.275	-.123	.343	-.209	-.259	.043	.238
Cd		1	**.818****	**.870****	**.708****	**.902****	**.754****	.180	.427
Cr			1	**.762****	**.927****	**.727****	**.545***	.349	.461
Cu				1	**.569***	**.939****	**.758****	.393	.419
Ni					1	.535*	.371	.350	.426
Pb						1	**.873****	.246	.439
Zn							1	.188	.349
Fe								1	.431
Mn									1

**Correlation is significant at the 0.01 level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed)
Bold values are significant

Table 5. Correlation matrix of heavy metals in urban area (n=10).

	As	Cd	Cr	Cu	Ni	Pb	Zn	Fe	Mn
As	1	**.782****	.591	**.838****	**.708***	.120	**.659***	.235	.249
Cd		1	.336	**.936****	**.905****	-.152	**.753***	.231	.103
Cr			1	.396	.450	-.272	-.024	.380	.439
Cu				1	**.865****	-.082	**.868****	.015	.118
Ni					1	-.134	**.679***	.401	.263
Pb						1	.120	.175	.291
Zn							1	-.228	-.099
Fe								1	.521
Mn									1

**Correlation is significant at the 0.01 level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed)
Bold values are significant

Table 6. Correlation matrix of heavy metals in agriculture area (n=16).

	As	Cd	Cr	Cu	Ni	Pb	Zn	Fe	Mn
As	1	.198	.215	-.075	**.521***	-.081	.363	**.598***	.007
Cd		1	.322	.039	.020	.249	.331	-.157	-.167
Cr			1	**.515***	**.585***	**.580***	.324	.343	.220
Cu				1	.103	**.686****	.109	.199	-.103
Ni					1	.097	.494	.255	.366
Pb						1	.372	-.123	-.067
Zn							1	-.017	.025
Fe								1	-.066
Mn									1

**Correlation is significant at the 0.01 level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed)
Bold values are significant

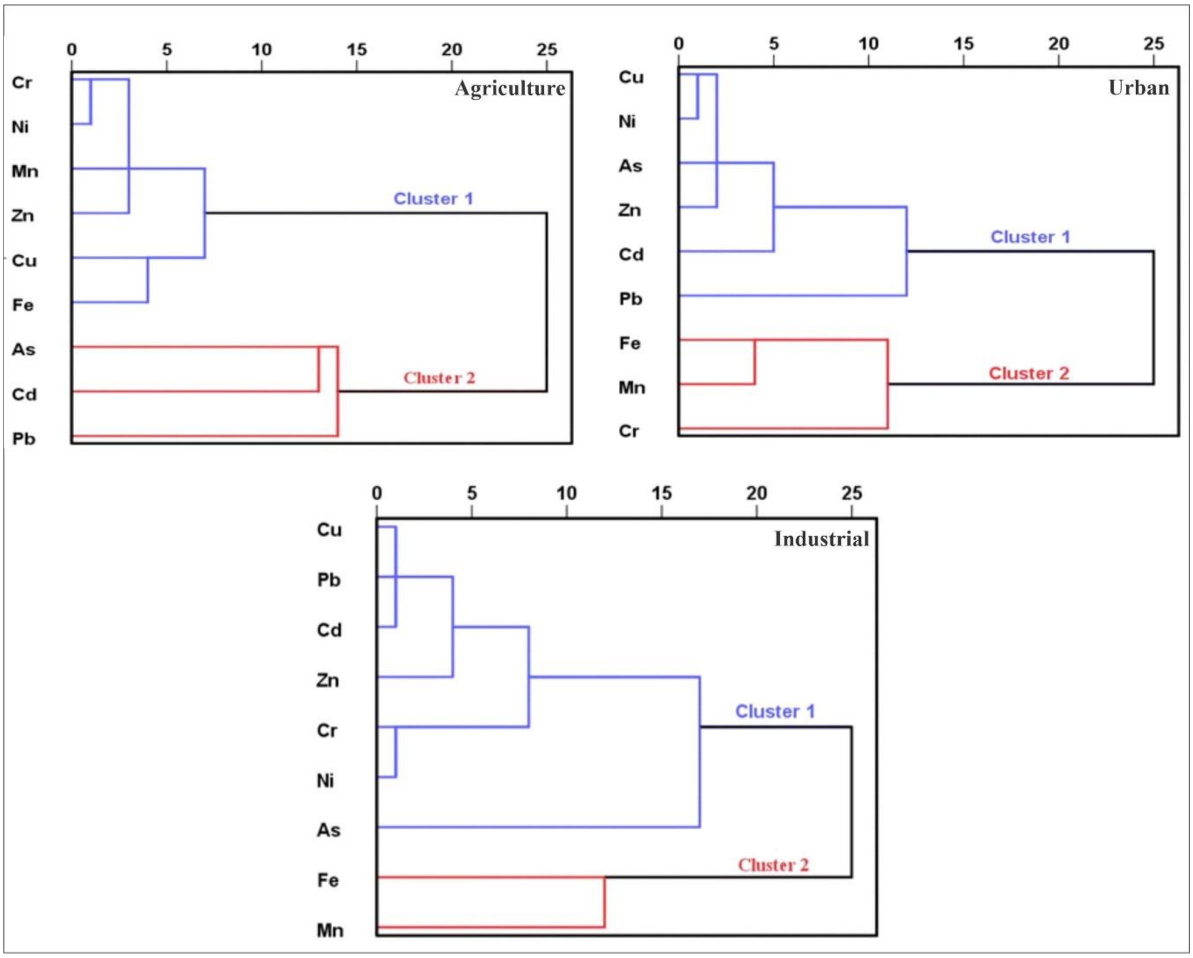

Fig. 7. Dendrograms of hierarchical cluster analysis for heavy metals in the different land use areas.

In the agriculture area, cluster 1contains a group of Fe, Mn, Ni, and Cr that are the main chemical components of mafic source parent rocks [37], and Cu and Zn That are the main nutrients for plants[21, 22], while cluster 2 contains a group of As, Pb, and Cd that are mainly results of the anthropogenic source.

In urban and industrial areas, cluster 2 contains a group of Fe and Mn, in addition to Cr in the urban area only, while cluster 1 contains a group of As, Pb, Cd, Ni, Zn, Cu, and Cr. This reflects that the high concentrations of heavy metals in the study area are mainly of anthropogenic origin due to urbanization, industrialization, and other agriculture applications.

Spatial distribution maps (Fig. 8) show that the concentrations of the investigated metals increase in the southeastern, southwestern, and western parts of the study area. This could be attributed to the complex industries such as (smelters, iron and steel production, and cement) in the southeastern area. These complex industries increase the concentration of heavy metals. On the other hand, the southwestern and western parts were mainly affected by the two high-way roads with intensive traffic density, two large power plants, and the high population density in the middle of this area.

3.4. Risk Assessment

The EF values of the investigated metals were calculated to evaluate the anthropogenic influences on heavy metals of the investigated soil. The EF values <2 propose the geological origin of the concerned metal, while EF values >2 indicate that the metal may be derived from anthropogenic activities [26]. The EF values in the three different categories of the study area show that, in agriculture areas, the EF values of Cr, Cu, Pb, and Zn are< 2indicating no enrichment; while those of As and Cd are 5-20, indicating significant enrichment (Fig. 9).

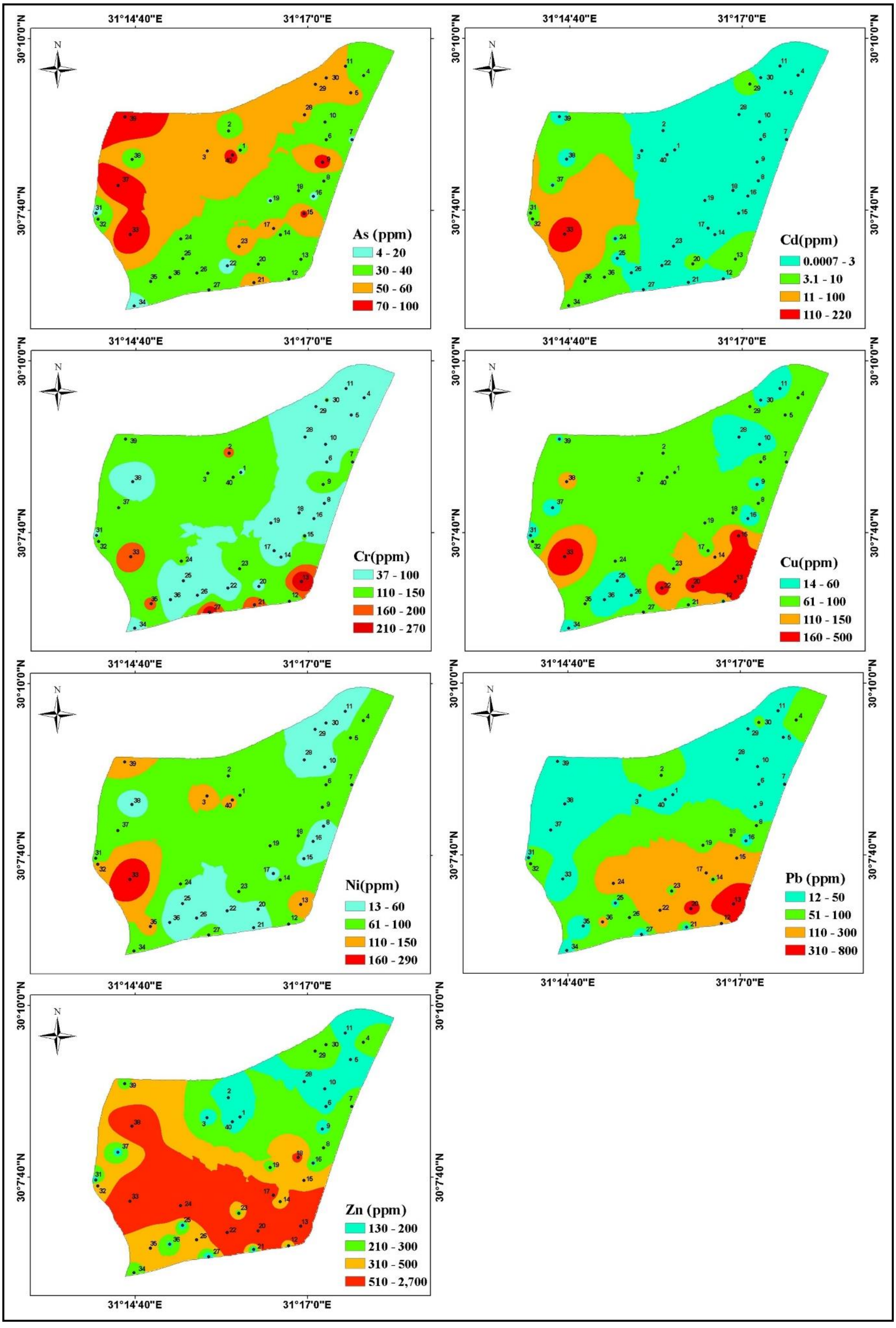

Fig. 8. Spatial distribution maps of the studied heavy metals in the study area.

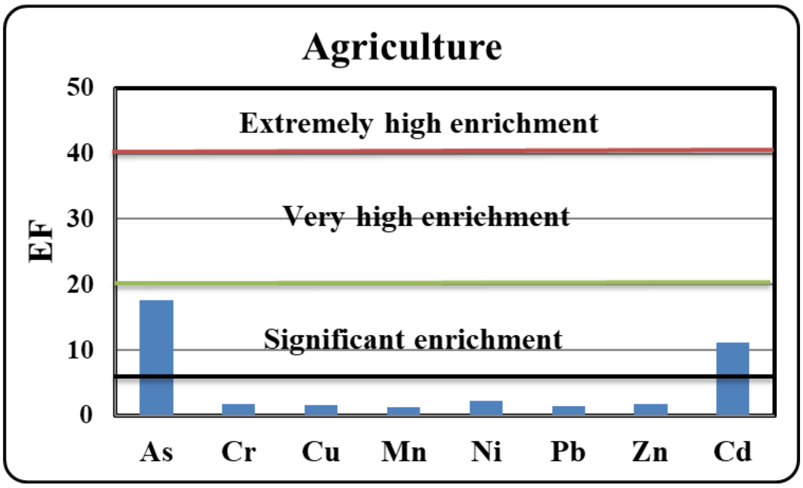

Fig. 9. Enrichment factor of heavy metals for agriculture areas.

In urban areas, EF values of Cr, Cu, Pb, and Ni are2-5, indicating moderate enrichment, while EF values of As and Zn are 5-20, indicating significant enrichment, and EF values of Cd are>40indicating extremely high enrichment (Fig. 10).

In industrial areas, the EF values of Cu and Ni are 2-5, indicating moderate enrichment, while EF values of As, Pb, Zn, and Cd are 5-20, indicating significant enrichment (Fig. 11).

The index of geo-accumulation (I_{geo}) is calculated for the studied heavy metals. The I_{geo} values of more than zero propose the anthropogenic origin of the metals contamination in the soil [25, 38, 48].

In agriculture areas, the average values of $I_{geo}$for Cu, Zn, Pb, and Ni are between 0 and 1 (class 1) indicating almost uncontaminated to moderately contaminated. I_{geo} average value of Cd lies between 3 and 4 (class 4), indicating heavy contamination. On the other hand, the average value of As is more than 5 (class 6), indicating extremely contamination (Fig. 12).

In urban areas, the I_{geo}average values of Cu, Pb, and Ni are between 0 and 1 (class 1) indicating almost uncontaminated to moderately contaminated. While the I_{geo}average value of As is found in (class 5) indicating heavily to extremely contamination and for Cd is higher than 5 (class 6) indicating extremely contamination (Fig. 12).

In industrial areas, the I_{geo} average values of Cu and Ni are between 0 and 1 (class 1) indicating almost uncontaminated to moderately contaminated. While the I_{geo} average values of As and Cd are higher than 5 (class 6) indicating extremely contamination (Fig. 12).

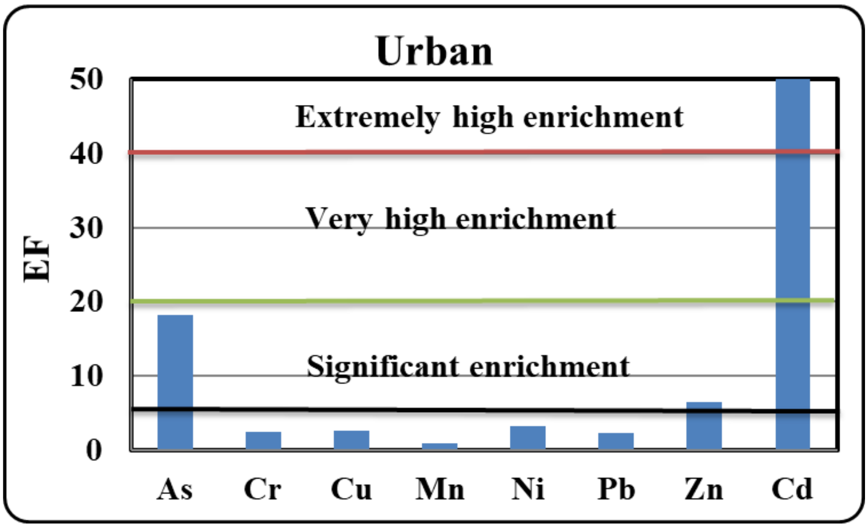

Fig. 10. Enrichment factor of heavy metals for urban areas.

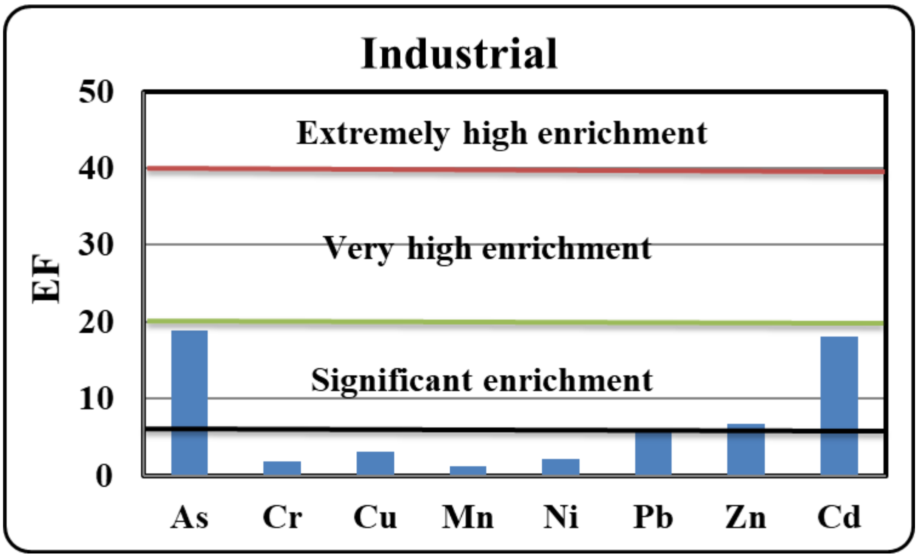

Fig. 11. Enrichment factor of heavy metals for industrial areas.

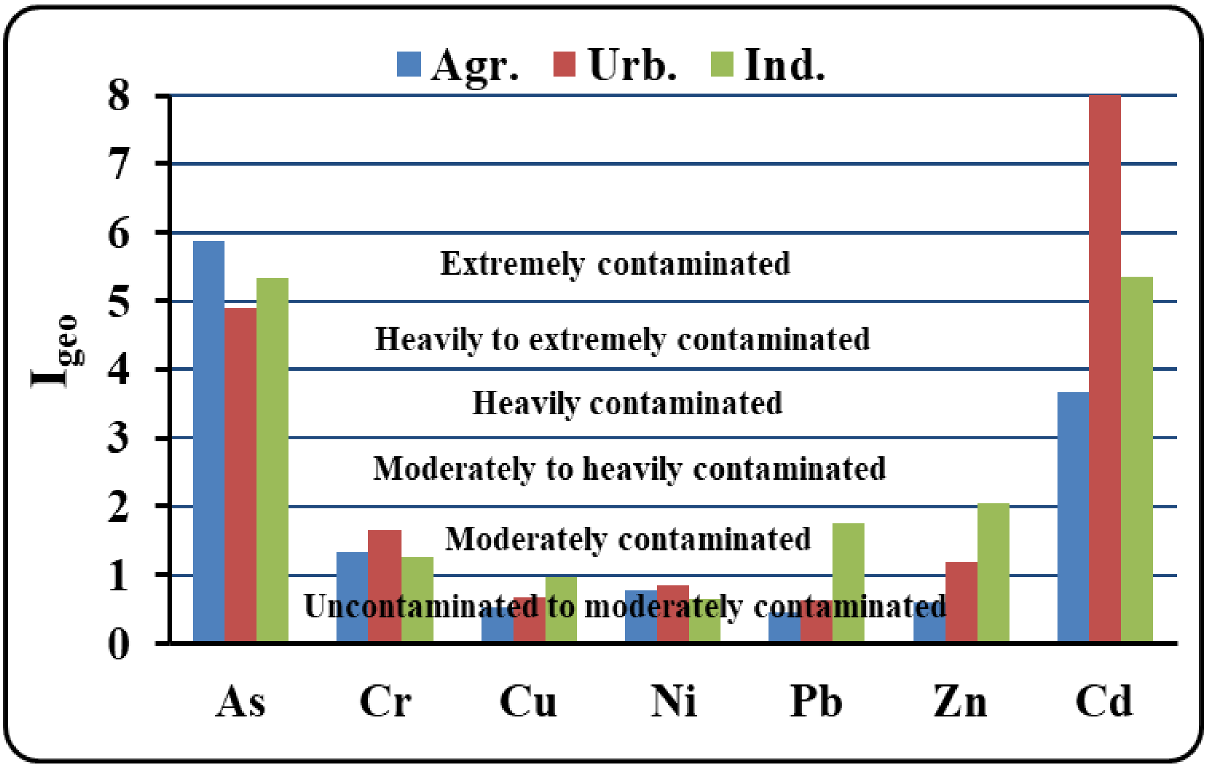

Fig. 12.I_{geo}values of the studied heavy metals in the different land use of the study area.

The PER calculation is used to evaluate the heavy metals pollution level [49] the results of PER show that, About 70% of samples sites showed very high PER (PER > 200, class 5) indicating extreme risk, while 15% of the samples sites are within the level of the high risk (100< PER ≤ 150) and 15% of samples sites are within the level of moderate potential risk (50 < PER ≤ 100)(Fig.13).

4. Recommendations

In order to reduce the risk of heavy metals pollution in the study area, recommendations have to

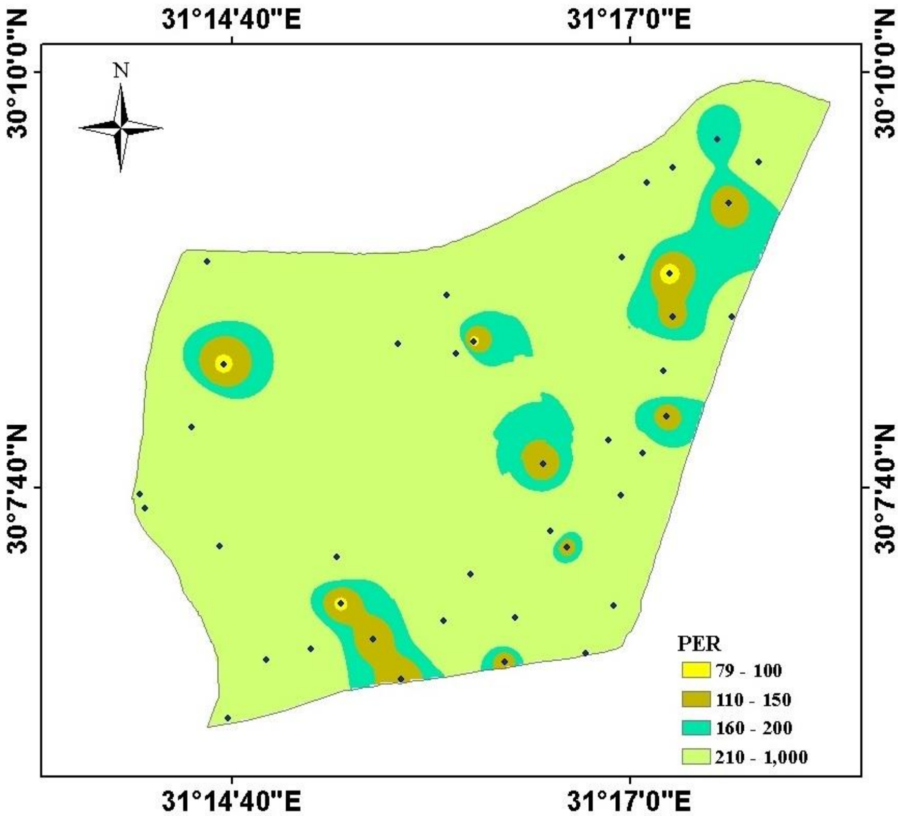

Fig. 13. Spatial distribution map of PER in the study area.

be made to accelerate transporting of factories to new industrial areas, encouraging people in the study area to migrate to the new cities, educating farmers about the side effect of fertilizers and pesticides and find the applicable method for remediation and cleaning soil that suffers from contamination.

5. Conclusions

The agricultural soils in the study area are mainly classified as clayey soil which is consistent with the texture of the main Nile Delta soil. Urban and industrial soil samples are varied in their classification from clayey to loamy sand. This variation probably indicates that some of these samples are mixed with external particles due to industrialization and urbanization. From the obtained data, it concluded that:

1) As, Cd and Zn in the soil exceed the maximum permissible limits whereas, Cu, Cr, Ni and Pb are within the permissible limit except for some samples.
2) Spatial distribution maps show that the concentrations of Cu, As, Zn, Pb, Ni and Cr increase in the southeastern, southwestern and western parts of the study area.
3) About 70% of sample sites showed very high PER indicating extreme risk.
4) The soils in agricultural areas are less contaminated than the soils in urban and industrial areas.
5) The enrichment of the studied heavy metals in the soil of Shoubra El Kheima is mainly due to anthropogenic activities, including atmospheric deposition from intense traffic density and complex industries, intensive use of inorganic fertilizers and pesticides in the agriculture processes and irrigation with wastewater or sludge for a long time in some places.

6. Conflicts of interest

There are no conflicts to declare.

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