Level,distribution and pollution assessment of heavy metals in urban community garden soils in Baghdad City, Iraq

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Abstract— Fourteen composite samples were collected from the gardens soils in Baghdad City in order to determine concentrations, spatial distribution and contamination assessment of heavy metals such as Cd, Cr, Cu, Ni, Fe, Pb and Zn. The mean concentrations are as follows: 18.64 mg/kg for Cd, 3.65 mg/kg for Cr, 15.64 mg/kg for Cu, 9114.28 mg/kg for Fe, 30.71 mg/kg for Ni, 1.99 mg/kg for Pb and 23.71 mg/kg for Zn. The mean concentrations of heavy metals were compared with USEPA soil guideline and the world reference value. The mean concentrations of Cd and Ni exceeded the guidelines while the other metals did not exceed. Positive and negative significant correlation relationships between the metals were reported. ANOVA showed that there were significant differences (at $p < 0.5$) in concentrations Cd, Ni and Zn metals between the sampling sites and insignificant (at $p < 0.5$) in concentrations of Cr, Cu and Pb. The metal contamination in the garden soils was also evaluated by Appling enrichment factor (EF), pollution load index (PLI), integrated pollution load index (IPLI) and geoaccumulation index (Igeo). Based on enrichment factor (EF) , the gardens soils in Baghdad city are extremely high enrichment with Cd and moderate enrichment with Cu and Ni. Pollution load index (PLI) and geoaccumulation index (I_{geo}) indicated that Baghdad gardens soils are polluted by Cd and unpolluted by other metals. The integrated pollution load index (IPLI) values showed that the gardens soils in Baghdad are polluted with heavy metals. The sources of Cd in Baghdad gardens soils may be from traffic and industrial emissions and may be from phosphate fertilizers.

Index Terms— Baghdad; urban gardens; heavy metal; metal pollution, urban soil, pollution indicators, Anthropogenic

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1 INTRODUCTION

Community gardens are community-managed spaces that are open to the [1]). Urban community gardens provide many benefits to local communities, such as, a safe place, a fresh supply of produce, opportunities for recreation and a venue for increasing community building and cohesion [2] , [3] , [4] , [5]. Urban soils can be contaminated by heavy metals and other pollutants as they are often located on old urban sites impacted by urban activities such as, road traffic, contamination, construction and manufacturing [1] , [6]. Studies of heavy metals in urban garden soils reported elevated levels of heavy metals exceeded the reference values [1] , [5] , [7] , [8] , [9] , [10] , [11] , [12]. This study is the first attempt to investigate the contents of heavy metals in the community garden soils in the study area. Limited studies have conducted to evaluate the heavy metals contents in the urban soils of Baghdad [13] , [14] , [15] , [16] , [17]. The present study aimed to (a) evaluate the levels of heavy metals in the community garden soils (b) investigate distribution of heavy metals in the study area and (c) assess the metal pollution using pollution indicators.

2 Materials and Methods

2.1Study area, soil sampling and analysis

Fourteen community urban gardens were selected randomly in Baghdad City , figure 1. The geographical coordinates of the sampling stations were listed in Table 1. In each urban garden, ten sampling points were randomly selected. Composite samples, made up of ten subsamples, were collected in each sampling points from the soil layer (0-20 cm depth) with stainless steel spade and transferred into air-tight polyethylene bags for transport to the laboratory. The soil samples were air dried and pass through a 2-mm plastic sieve. A portion of the < 2mm fraction was then digested using USEPA method [18] and analyzed for total Cd, Cr, Cu, Fe, Ni, Pb, and Zn by Atomic Absorption Spectrometry (Analytikjena).

2.2 Pollution assessment

To assess the pollution status and to evaluate the impact of anthropogenic activities, we can be employed the pollution indicators, such as enrichment factor (EF), integrated pollution load index (IPLI) and geoaccumulation index (I_{geo}).

2.2.1 Enrichment factor (EF)

Enrichment factor was used to differentiate between elements generating from anthropogenic origin and those from lithogenic origin and to investigate the degree of contamination and the degree of anthropogenic impact [19] , [20]). EF can reflect soil evolution in along scale [21]. The EF calculations compare each value with a given background level, either from the local site, using older soils formed under similar conditions, but without anthropogenic impact, or from a regional or global average composition [22] , [23]). The EF was calculated using the method proposed by [24] as follows:

$$EF = (C_n/C_{ref})_{sample} / (C_n/C_{ref})_{reference} \quad (1)$$

Where C_n is the concentration of metal element in soil (mg/kg) and C_{ref} is the concentration of reference element (mg/kg). In this study, Fe was adopted as reference element because it is one of the largest component of soil and the modification of iron by anthropogenic sources is difficult. Five contamination categories are classified on the basis of EF as deficiency to minimal enrichment ($EF < 2$), moderate enrichment ($2 \le EF < 5$), significant enrichment ($5 \le EF < 20$), very high enrichment ($20 \le EF < 40$), and extremely high enrichment ($EF \ge 40$).

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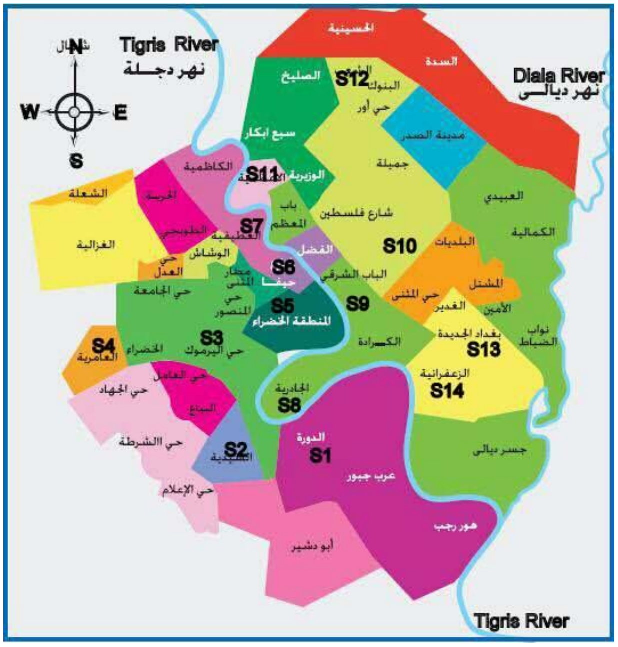


Fig. 1. Map of the residential areas in Baghdad City including the sampling stations.

Table 1. Data of soil sampling sites in urban gardens in Baghdad City.

Sampling region	Station	Coordinates		Remarks
		Latitude (N)	Longitude (E)	
Al-Dora	S1	33.249	44.384	Near to roads
Saydiyah	S2	33.27	44.339	Near to roads
Al-Yarmouk	S3	33.303	44.345	Near to residential area
Al-Iamiryah	S4	33.311	44.261	Near to residential area
Al-Zawraa	S5	33.312	44.377	Park
Hayfa st.	S6	33.337	44.376	Near to roads
Al-Etafyah	S7	33.349	44.356	Near to roads
Al-Jaderyah	S8	33.27	44.376	University of Baghdad campus
Abo-Noas	S9	33.32	44.413	Near to Tigris River
Al-Rebeey	S10	33.33	44.432	Near to residential area
Al-Adamyah	S11	33.368	44.362	Near to roads and residential area
Al-Shaab	S12	33.402	44.402	Near to roads and residential area
New Baghdad	S13	33.317	44.491	Near to residential area
AL-Zafranyah	S14	33.26	44.464	Near to residential area

2.2.2 Integrated pollution load index (IPLI)

Integrated Pollution load index (IPLI) is defined as the mean values for all the pollution indexes (PLI) of all considered metals:

$$(IPLI) = (PLI_1 + PLI_2 + PLI_3 + \ldots\ldots\ PLI_n)/ n \qquad (2)$$

Where, n is the number of metals. The PLI is defined as a ratio of heavy metal concentration in the soil and the background concentration of the metal [25] , [26]:

$$PLI = C_n / B_n \qquad (3)$$

Where Cn is the measured concentration and Bn is the background concentration. The following contamination categories are used [25]: PLI ≤ 1 is low contamination; 1≤ PLI < 3 is moderate contamination and PLI > 3 is high contamination. The background concentrations of the elements were used from the world average data ([27]. The IPLIs were classified as: IPLI ≤ 1 is low contamination; 1 < IPLI ≤ 2 is moderate contamination and IPLI > 2 is high contamination [25] , [28].

2.2.3 Geoaccumulation index (I_{geo})

The geoaccumulation index (I_{geo}) is a geochemical criterion to evaluate pollution level in soils [25]. It was calculated using the method proposed by [29]:

$$I_{geo} = \log_2 (C_n/1.5B_n) \qquad (4)$$

Where C_n is the measured concentration of element n in the sediment sample and B_n is the geochemical background value [world average data given by Bowen (1979[27])]. The factor 1.5 is introduced to include possible variation of the background values due to lithogenic effect. Muller (1981[30]) proposed seven grades or classes of the geoaccumulation index. These classes are : class 1($I_{geo} \leq 0$) is unpolluted, class 2 ($0 < I_{geo} \leq 1$) is unpolluted to moderately polluted, class 3 ($1 < I_{geo} \leq 2$) is moderately polluted, class 4 ($2 < I_{geo} \leq 3$) is moderately to strongly polluted, class 5 ($3 < I_{geo} \leq 4$) is strongly polluted, class 6 ($4 < I_{geo} \leq 5$) is strongly to extremely polluted, class 7 ($I_{geo} > 5$) is extremely polluted.

2.3 Statistical analysis and mapping

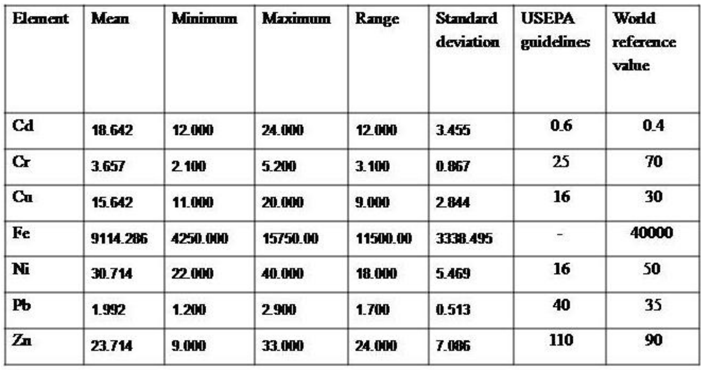
The data were statistically analyzed using the STATISTICA software [31]. The means , standard deviations, minimum, maximum , range and Pearson's correlation were calculated of the metal concentrations in soil samples. ANOVA was executed to detect any significant differences of metal contents spatially. To plot the spatial variation map of the metal contents in soil in the study area, we used the 3DField software [32].

3 Results and discussion

3.1 Concentrations of heavy metals

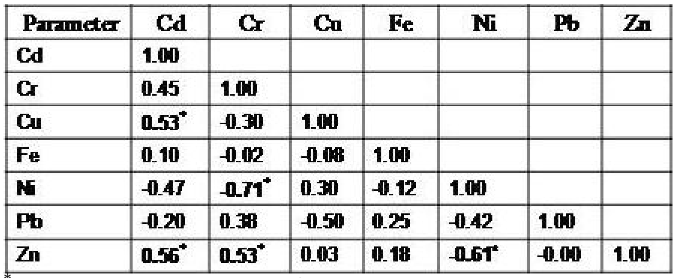
Descriptive statistics of the concentrations of heavy metals in community urban gardens soils in Baghdad City are listed in Table 2. The metals concentrations decrease in the order Ni > Zn > Cd > Cu > Cr > Pb. The mean concentration of Cd exceeded the USEPA soil guidelines and the world reference value. The mean concentration of Ni exceeded the USEPA guidelines and was less than the world reference value. The mean concentrations of the Cr, Cu, Pb and Zn did not exceed the USEPA soil guidelines and the world reference values. Results of the comparison with the soil guidelines and the world reference value suggests that the gardens soils in Baghdad City are polluted by Cd and Ni. Lower concentrations of Cr, Cu, Ni, Pb and Zn were reported in the current study as compared to those recorded in the urban soils of Baghdad City [13] , [14] , [15] [16] , [17]. Mean concentration of Cd was in good agreement with that (19mg/kg) reported in the urban soil of Baghdad as concluded by [16]) and more than those recorded in the investigations of [13] (11.45mg/kg) , [14] (0.54mg/kg), [15] (4.18mg/kg), and [17] (11.7mg/kg). The relative importance of various Cd sources to human exposure decreases in the following order: phosphate fertilizer > fossil fuel combustion > iron and steel production > natural sources > non-ferrous metals > cement production > cadmium products > incineration [33].

Table 2. Results of descriptive statistics of heavy metals concentrations (mg/kg) in gardens soil in Baghdad City with the soil guidelines and the world reference value.



Element	Mean	Minimum	Maximum	Range	Standard deviation	USEPA guidelines	World reference value
Cd	18.642	12.000	24.000	12.000	3.455	0.6	0.4
Cr	3.657	2.100	5.200	3.100	0.867	25	70
Cu	15.642	11.000	20.000	9.000	2.844	16	30
Fe	9114.286	4250.000	15750.00	11500.00	3338.495	-	40000
Ni	30.714	22.000	40.000	18.000	5.469	16	50
Pb	1.992	1.200	2.900	1.700	0.513	40	35
Zn	23.714	9.000	33.000	24.000	7.086	110	90

Table 3. Pearson's correlation coefficients between heavy metals in gardens soil in Baghdad City.



Parameter	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Cd	1.00						
Cr	0.45	1.00					
Cu	0.53*	-0.30	1.00				
Fe	0.10	-0.02	-0.08	1.00			
Ni	-0.47	-0.71*	0.30	-0.12	1.00		
Pb	-0.20	0.38	-0.50	0.25	-0.42	1.00	
Zn	0.56*	0.53*	0.03	0.18	-0.61*	-0.00	1.00

*Marked correlations are significant at $p < 0.05$.

Anthropogenic inputs of Cd into soils may be of different sources, such as agricultural amendments, atmospheric deposition and sewage sludge [34]). De Miguel etal. [35] found that Cd has been associated with tire wear and traffic movement. Concentration of Cd above 0.5mg/kg could reflect the impact of anthropogenic activity [36]. Cadmium uses in different industries such as, paints, pigments, electroplating and plastic stabilizer [37]. Because of all gardens locate in the residential areas and near the roads, the anthropogenic activities are the main sources of Cd release into the garden soils. These sources include traffic emissions, atmospheric deposition and may be phosphate fertilizers used in these gardens. Rahi et al.[13] suggested the traffic activity and different industries as sources of high Cd concentration in the urban soil of Al-Waziriya region in Baghdad City. The industry together with the traffic activity were mainly responsible for metal pollution of the Baghdad urban soils [14]. The wear and tear of tires, the greater traffic density on the busy roads, industrial activities, bombing and explosive cars are sources of the release of Cd into the soils of Al-Karrada region within Baghdad City [15]. As mentioned above, the Baghdad community urban gardens soils were polluted by Ni in term of comparison with USEPA guidelines. The mean concentration of Ni reported in this current study was less than recorded in the previous studies of the Baghdad urban soils [13] , [14] , [15] , [16] , [17]. Generally, the sources of Ni in urban soils and road dusts are mainly derived from traffic emission and industrial emission [28]. The different types of detergents may be important sources of Ni in the urban soils [34]. The elevated level of Ni in the Baghdad gardens soils is attributed to the traffic and industrial emissions.

The results of the Pearson's correlation coefficients and their significant levels ($P < 0.05$) are shown in Table 3. The concentration of Cd showed significant positive relationship with Cu and Zn, 0.53 and 0.56, respectively. Zn expressed a significant positive relationship with Cr (0.53) and negative relationship with Ni (-0.61). The Ni concentration has a significant negative with Cr (-0.71). Correlation analysis provides an effective way to reveal the relationships between multiple variable and thus have been helpful for understanding the influencing factors as well as the sources of chemical components [20]. The relationship between heavy metals can provide important information on heavy metal sources and pathways [38]. Many researchers have reported the importance of natural sources of Cr, such as parent material of soils and lithogenic sources [39] , [40]. The Cd has significant positive correlation relationships with Cu and Zn suggesting that these heavy metals originate from common source Anthropogenic source). The negative correlation relationships between Ni-Cr and Ni-Zn may be indicate that Ni releases into the soil in quantities more than Zn and Cr from their common sources or it occurs ionic exchange between Ni and Zn their source .

3.2 Spatial distribution of heavy metals

ANOVA showed that there were significant differences (at $p < 0.5$) in concentrations Cd, Ni and Zn metals between the sampling sites and insignificant (at $p < 0.5$) in concentrations of Cr, Cu and Pb, Table 4. The significant differences suggest that there are local pollution sources in the study area. 3DField software was used to construct spatial distribution maps and to assess the potential sources of enrichment and to identify hotspots with high metal concentrations in the urban soils of the study area. The spatial distribution maps of Cd, Cr, Cu, Ni, Pb, and Zn are presented in figures 2, 3, 4, 5, 6,7, respectively. Several hotspots (positive anomalies) of metal concentration were identified by the geochemical maps. In these maps, Cd showed high anomalies (hot spots) at sampling sites S1 and S11 and low anomaly at S8. Hot spots of Zn locate at S4 and S14 with minimum concentration in S5. The geochemical map of Ni showed that there is a hot spot at S14 with minimum concentration at S6. The spatial distribution maps of Cr, Cu and Pb did not any hot spots and reflect distribution patterns are different from those for Cd, Ni and Zn. This result confirmed the results of Pearson's correlation analysis mentioned above.

3.3 Pollution assessment

The enrichment factor for heavy metals in urban gardens soil in Baghdad City was listed in Table 5. The mean values of EF for Cd, Cr, Cu, Ni, Pb and Zn are 231.35, 0.25, 2.59, 3.01, 0.27 and 1.29, respectively. EF value less than 1.5 suggests that metal has lithogenic origin while EF greater than 1.5 indicates to anthropogenic origin [41]. The mean value of EF for Cr, Pb and Zn are less than 1.5 This result suggests that Cr, Pb and Zn contents in gardens

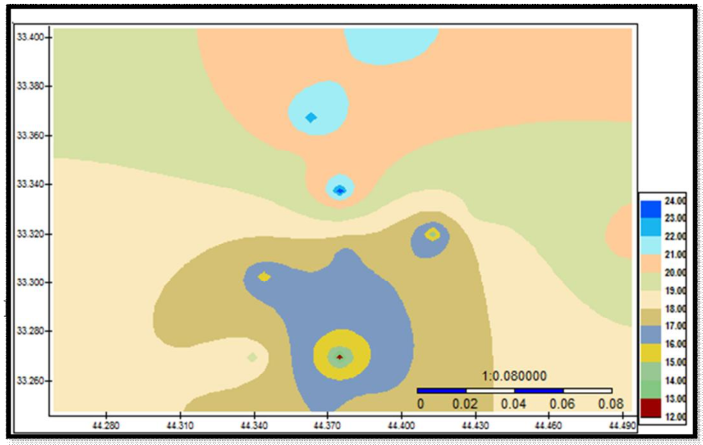


Fig. 2. Spatial distribution map of Cd metal in Baghdad gardens soil.

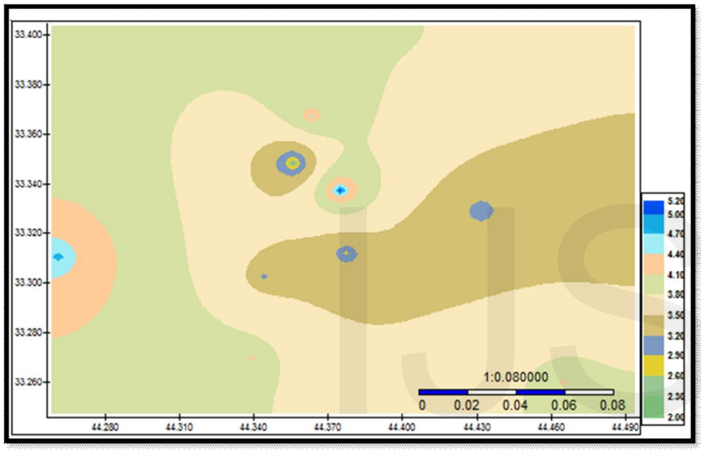


Fig. 3. Spatial distribution map of Cr metal in Baghdad gardens soil.

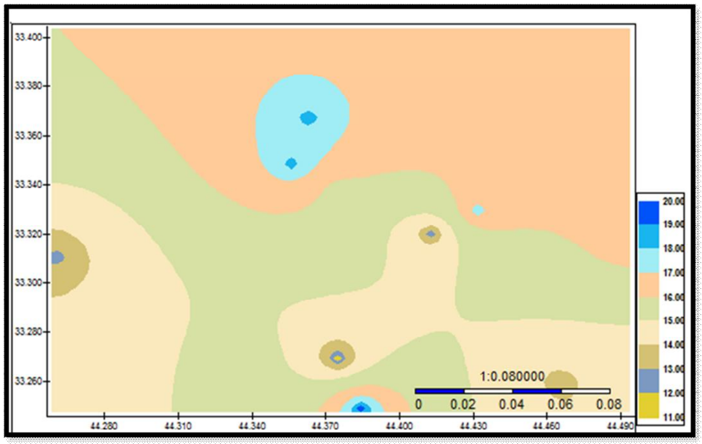


Fig. 4. Spatial distribution map of Cu metal in Baghdad gardens soil.

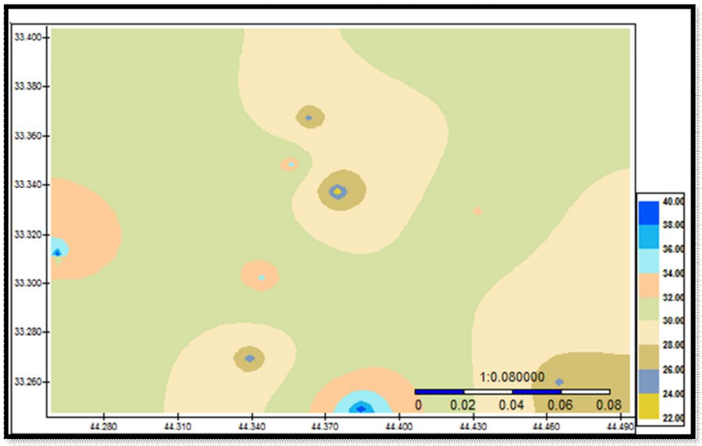


Fig.5. Spatial distribution map of Ni metal in Baghdad gardens soil.

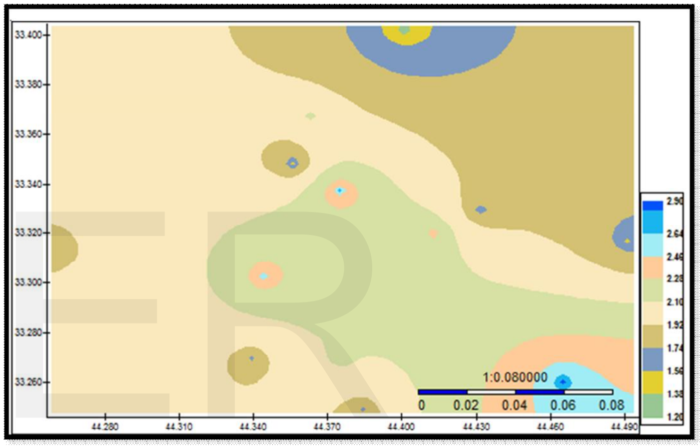


Fig. 6. Spatial distribution map of Pb metal in Baghdad gardens soil.

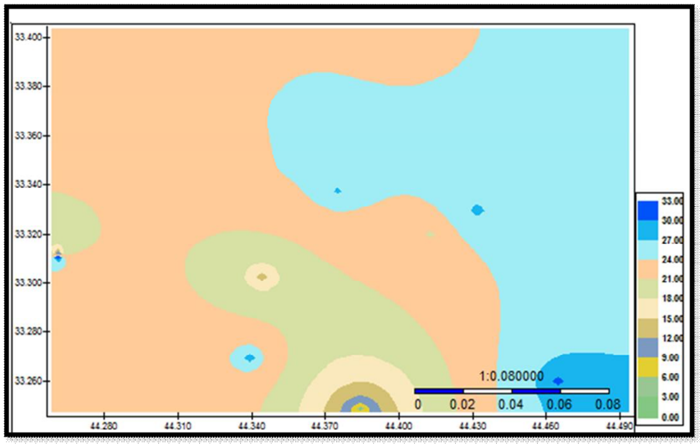


Fig. 7. Spatial distribution map of Zn metal in Baghdad gardens soil.

Table 4. ANOVA results of heavy metals concentrations in gardens soil in Baghdad City.

Parameter	Between SS	df	Within SS	df	F	Significant p
Cd	103.2143	1	52.0000	12	23.81868	0.000378*
Cr	1.4863	1	8.3080	12	2.14678	0.168574
Cu	5.5254	1	99.6889	12	0.66512	0.430650
Ni	142.8571	1	246.0000	12	6.96864	0.021581*
Pb	0.1684	1	3.2609	12	0.61970	0.446430
Zn	416.1016	1	236.7556	12	21.09019	0.000619*

Table 5. Enrichment factor (EF) for heavy metals in Baghdad gardens soil.

Sampling Station	Enrichment Factor					
	Cd	Cr	Cu	Ni	Pb	Zn
S1	194.59	0.21	2.88	3.45	0.21	1.105
S2	250	0.3	2.66	2.4	0.24	1.66
S3	153.85	0.18	2.05	2.87	0.304	0.54
S4	240	0.37	2.13	3.2	0.28	1.95
S5	172.97	0.17	2.306	3.37	0.22	0.43
S6	228.57	0.28	1.90	1.67	0.29	1.18
S7	304	0.19	4.05	4.48	0.27	1.77
S8	184	0.307	2.25	3.69	0.38	1.23
S9	176.1	0.23	2.01	3.11	0.34	1.11
S10	187.79	0.15	2.25	2.47	0.17	1.21
S11	541.18	0.605	5.96	4.705	0.59	2.71
S12	352	0.35	3.41	4.09	0.21	1.56
S13	133.33	0.11	1.43	1.47	0.108	0.705
S14	120.63	0.15	1.10	1.26	0.21	0.902
Mean	231.35	0.25	2.59	3.01	0.27	1.29
Minimum	120.63	0.11	1.10	1.26	0.10	0.43
Maximum	541.1800	0.60	5.96	4.70	0.59	2.71

soil were added from lithogenic sources. According to the classification conducted on the basis of EF, soils in Baghdad urban gardens are extremely high contaminated with Cd and moderately contaminated with Cu and Ni. Cd is typical anthropogenic metal affected by human activities [42] and showed severe enrichment. In this current study, traffic emission, industrial emission and may be phosphate fertilizer are anthropogenic sources of Cd.

The IPLI values for heavy metals in urban gardens soil in Baghdad City are listed in Table 6. The PLI mean value of Cd in gardens soil of Baghdad City was 46.57 which indicated high contamination level. The PLI values for Cr, Cu, Ni, Pb and Zn were less than 1 indicating low contamination level. Table 5 shows that IPLI values were more than 2 for all heavy metals and for all sampling sites. According to IPLI values, gardens soils in Baghdad City are high contaminated with heavy metals.

Table 7 showed the I_{geo} values for metals in Baghdad urban gardens soil. The I_{geo} values are less than zero for Cr, Cu, Ni, Pb, Zn and more than zero for Cd indicating that the Baghdad gardens soils are uncontaminated by Cr, Cu, Ni, Pb and Zn and is extremely contaminated by Cd.

4 Conclusions

In this study, we investigated the levels, distribution and pollution assessment of heavy metals including Cd, Cr, Cu, Fe, Ni, Pb and Zn,, in urban gardens soils in Baghdad City. The results shows that the mean concentrations of Cd and Ni are higher than the USEPA guidelines whereas the other metals (Cr, Cu, Ni , Pb and Zn). According to USEPA guidelines, the gardens soils in Baghdad City are polluted by Cd and Ni. The correlation analysis of mean concentrations showed good positive correlations among Cd-Cu, Cd-Zn and Zn-Cr suggesting that these metals have common sources. ANOVA showed that there were significant differences (at $p < 0.5$) in concentrations Cd, Ni and Zn metals between the sampling sites suggesting local pollution sources in

Table 6. Pollution Load Index (PLI) and Integrated Pollution Load Index (IPLI) values for heavy metals in Baghdad gardens soil.

Sampling Station	Pollution Load Index (PLI)						IPLI
	Cd	Cr	Cu	Ni	Pb	Zn	
S1	45	0.05	0.66	0.8	0.04	0.25	6.71
S2	50	0.06	0.53	0.48	0.04	0.33	7.37
S3	37	0.044	0.5	0.7	0.07	0.13	5.52
S4	45	0.07	0.4	0.6	0.05	0.36	6.72
S5	40	0.04	0.53	0.78	0.05	0.1	5.96
S6	60	0.074	0.5	0.44	0.07	0.31	8.80
S7	47.5	0.03	0.63	0.7	0.04	0.27	7.04
S8	30	0.05	0.36	0.6	0.06	0.2	4.49
S9	35	0.045	0.4	0.62	0.06	0.22	5.21
S10	50	0.041	0.6	0.66	0.04	0.32	7.41
S11	57.5	0.064	0.63	0.5	0.06	0.28	8.44
S12	55	0.055	0.53	0.64	0.03	0.24	8.09
S13	52.5	0.045	0.56	0.58	0.04	0.27	7.76
S14	47.5	0.06	0.43	0.5	0.08	0.35	7.04
Mean	46.57	0.05	0.51	0.61	0.05	0.25	6.89
Minimum	30.00	0.03	0.36	0.44	0.03	0.10	4.49
Maximum	60.00	0.07	0.66	0.80	0.08	0.36	8.80

Table 7. Geoaccumulation index (I_{geo}) values for heavy metals in Baghdad gardens soil.

Sampling Station	Geoaccumulation Index (I_{geo})					
	Cd	Cr	Cu	Ni	Pb	Zn
S1	4.90	-4.92	-1.18	-1.83	-4.96	-2.55
S2	5.05	-4.64	-1.51	-1.64	-4.96	-2.18
S3	4.64	-5.10	-1.59	-1.12	-4.35	-3.64
S4	4.90	-4.44	-1.94	-1.32	-4.79	-2.05
S5	4.73	-5.26	-1.51	-0.94	-4.87	-4.05
S6	5.32	-4.35	-1.59	-1.78	-4.32	-2.32
S7	4.98	-5.64	-1.25	-1.12	-5.15	-2.47
S8	4.32	-4.92	-2.05	-1.32	-4.64	-2.94
S9	4.54	-5.05	-1.94	-1.28	-4.47	-2.83
S10	5.05	-5.21	-1.32	-1.18	-5.05	-2.25
S11	5.25	-4.57	-1.25	-1.59	-4.60	-2.39
S12	5.19	-4.75	-1.51	-1.25	-5.50	-2.64
S13	5.12	-5.05	-1.43	-1.39	-5.15	-2.47
S14	4.98	-4.64	-1.83	-1.59	-4.18	-2.12
Mean	4.92	-4.89	-1.56	-1.38	-4.78	-2.63
Minimum	4.32	-5.64	-2.05	-1.83	-5.50	-4.05
Maximum	5.32	-4.35	-1.18	-0.94	-4.18	-2.05

the study area. The geochemical maps of Cd, Ni and Zn showed that there are several high anomalies (hot spots) at some sampling gardens. Contamination assessment based on pollution load index (PLI) and geoaccumulation index (I_{geo}), showed that the gardens soils in Baghdad City are contaminated by Cd and unpolluted by Cr, Cu, Ni, Pb and Zn. The EF values indicated that the soils in Baghdad urban gardens are extremely high contaminated with Cd and moderately contaminated with Cu and Ni. The IPLI values suggests that gardens soils in Baghdad City are high contaminated with heavy metals. The anthropogenic sources of Cd in Baghdad gardens soils are traffic emission, industrial emission and may be phosphate fertilizer.

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