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RESEARCH PAPER

Assessment of ecological risk potential in metal-contaminated soils of Baghdad city, Iraq

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Abstract

Metal pollution in the soil leads to the deterioration of agricultural production by negatively affecting the all properties of the soil. Because the more than 7 million people living in and the old military camp was used as residence by poor families after the war of 2003, Baghdad city has a risk factor from metal pollution. With this aim, metal pollution in the soil of Baghdad city was studied. Three different sites (farm, camp, and park) were selected. Ten soil samples were taken randomly from 0-15 cm depth on each of the sites. Concentrations of metals [calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cobalt (Co), chromium (Cr), lead (Pb), cadmium (Cd), and nickel (Ni)] of soil samples were measured using atomic absorption spectrometer (AAS). Basic soil properties such as texture class and pH were measured on the disturbed samples. Concentrations increased Cr<Ni<Fe<Co<Mg<Cd<Cu<Ca<Zn<Pb<Mn respectively. The highest coefficient of variation value is Mg (90.76%) in camp and Fe in farm (77.81%) and park (68.66%) soil samples. The lowest values were found in Ca (farm 6.12%, camp 12.51%, park 22.37%). Metal concentrations were evaluated for soil quality by Pollution (CF) and Ecological Risk Factor (E_r^i), Potential Ecological Risk Index (PERI), and Geoaccumulation Index (Igeo). For CF, only Cd was found as slightly contaminated in farm (1.89) and park (1.35) soils, and moderately contaminated in camp (2.11) soils. According to E_r^i values, a serious risk of Pb was found in farm and camp soils in two samples each and 3 samples in park soils. According to the PERI results, no risk was determined in all soils except for the extreme (21 samples) and high (6 samples) Cd risk. Similarly, Igeo values of Pb increased in the farm (1.23), camp (1.44) and park (2.11), while Cd increased in the park (5.22), farm (5.71), and camp (5.87). High concentrations in all soils of Cd (4.74, 5.29, and 3.37) and Pb (35.36, 40.71, and 64.97) were attributed to anthropogenic activities such as the population, household waste, car exhausts, and the results of 2003 war.

Introduction

The soil that makes up our terrestrial ecosystem is a natural resource that can renew itself. However, most of the main sources of soil pollution are anthropogenic (Wei & Yang, 2011) and can cause the accumulation of pollutants in large quantities beyond the regenerative capacity of the soil (Cachada et al., 2018). These accumulations originate from wrong use of fertilizer and agricultural pesticides and accumulation of chemical and biological household and factory wastes in soil that include toxic metals. On the

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other hand, anthropogenic sources of toxic elements in urban soils include emissions from vehicles, industrial waste, atmospheric deposition of dust and aerosols, domestic emissions, and incinerators (Lee et al., 2006; Luo et al., 2012). Studies confirmed that potentially toxic element pollution in soils causes the degradation of soil quality (Hu et al., 2020), threatens the living organisms in the soil, and reduces productivity (Yang et al., 2018a; Tseng et al., 2021). To remediation measures for metal pollution, it is thought that a comprehensive study of metal pollution from possible sources and their spatial distribution should be known. According to Salman et al., (2019), pollution indices are a powerful tool for environmental quality assessment. Generally, in soil pollution studies three single indices, namely index of geoaccumulation (I_{geo}), contamination factor (CF) ecological risk factor (E_r^i), and potential ecological risk index (PRI) are used. Studies on heavy metals at different scales have been conducted in the urban soils of Iraq (Ismail, 2010; Al Obaidy & Al Mashhadi, 2013). However, studies conducted on mapping metals in urban soils and using pollution indices for evaluating metal pollution were rare. The aims of this study were 1) to examine pollution levels of some metals in soil samples taken from 3 different regions in Baghdad city, 2) to investigate the environmental factors that caused pollution and their effects and the spatial distribution of metals, and 3) to calculate the Potential Ecological Risk Index (PERI) and Geo-Accumulation Index (I_{geo}) to assess soil quality in Baghdad urban soils.

Materials and Methods

The study was carried out in 3 different locations in Baghdad city, located in the center of Iraq (33° 15' 5165'' North Latitude and 44° 28' 0976'' East Longitude) (Figure 1). Soil samples were selected from different areas where different factors such as dense population and traffic, limited agricultural practice, and military camps were effective. The first sampling area is an abandoned farm that has more than 3000 m^2 area. It has desert plants such as thorns and saplings growing naturally and an apartment complex just a few meters away. The second is an old camp turned into a random residential area that does not contain municipal services or service facilities. The number of housing ranges from 200 to 300 housing approximately 2.000 people.

The third is a public park where samples were taken from the side of the street and in the park. A total of 30 sample points were determined by the Global Positioning System, 10 samples from each different area (Figure 2). After cleaning the topsoil, undisturbed samples were taken with a Kopecky steel cylinder (V=100 cm^3) (Holpp et al., 2010). Disturbed soil

Figure 1. (a) Abandoned farm (b) Residental area (c) City Park

Figure 2. Sampling points for studied locations (The map was downloaded from Google Earth, and sampling points marked according to their coordinates)

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samples were taken from 0-15 cm depth for basic soil analyses from the same points.

Soil parametric characteristics, texture class (Gee & Bouder, 1986), soil reaction (pH) (Page et al., 1982), electrical conductivity (EC), (Rhoades, 1982), total $CaCO_3$ and organic matter (OM) (Page et al., 1982), FC and WP (Klute, 1986), bulk density (D_b) (Blake & Hardge, 1986) were measured. For metal (Ca, Mg, Fe, Zn, Mn, Cu, Co, Cr, Pb, Cd, and Ni) analyses, the standards were read to the device in certain calibrations, a calibration curve was drawn, samples were burned with different solvents and made ready for the device (Izol & Inik, 2022). Jackson and Watson (1977) were used for analyzing heavy metals in soils with Atomic Absorption Spectrometry**.** SPSS 23 package program was used for descriptive statistical values of soil properties and heavy metal contents. Kabata Pendias (2001), Rose et al., (1981), and Lindsay (1979) were used for the limit values of metals in the soils. Pollution factor (CF) was calculated by Hakanson (1980) (Equation 1) and grouped into four grades. Ecological risk factor ($\mathbf{E_r^i}$) (Equation 2) is the ecological risk values from anthropogenic factors (Hakanson, 1980) and grouped into five grades (Brady et al., 2015). $\mathbf{T_r^i}$ is the toxicological response factor of heavy metals (Hakanson, 1980; Şen and Yakupoğlu, 2022). The Potential Ecological Risk Index (PERI) proposed by Hakanson (1980) was used to assess the contamination risk of metals (Equation 3) and grouped into four grades (Krisha and Mohan, 2016) (Table 1).

Table 1. Thresholds for soil quality classification for metal indices

Class	CF	Qualification	$\mathbf{E_r^i}$	Qualification	PERI	Qualification
0	CF<1	Unpolluted	$\mathbf{E_r^i}$<1	Unpolluted	PERI<150	Low ecological risk
1		Slightly		Slightly		
2	1<CF<3	Moderately	2<$\mathbf{E_r^i}$<5	Moderately	150≤ PERI<300	Modarete ecological risk
3		Heavily		Heavily		
4	3<CF<6	Severely	5<$\mathbf{E_r^i}$<20	Severely	30≤ PERI<600	Significant ecological risk
5		High	20<$\mathbf{E_r^i}$<40	High		
6	CF>6	Extreme	$\mathbf{E_r^i}$>40	Extreme	PERI>600	Very high ecological risk

CF. Pollution factor, $\mathbf{E_r^i}$: Ecological risk factor, PERI: Potential Ecological Risk Index

$$\mathrm{CF} = \frac{C_s}{C_b} \qquad (1)$$

$$E_r^i = T_r^i \times \mathrm{CF} \qquad (2)$$

$$\mathrm{PERI} = \sum_{i=1}^{n} E_r^i \qquad (3)$$

Where C_s is the concentration in soil samples, C_b is the background value of metals.

The geoaccumulation index (I_{geo}) value is used to assess the intensity (Kowalska et al., 2018) and degree of anthropogenic pollution as a source of metal pollution and is also used to understand whether a metal comes from natural or anthropogenic sources (Xu et al., 2021). I_{geo} was calculated to assess the level of metal accumulation in urban soil (Muller, 1969) (Equation 4).

$$I_{geo} = \log_2\left(\frac{C_n}{1.5B_n}\right) \qquad (4)$$

Where, C_n is the measured concentration of element n, B_n is the background value of the element in the studied soil, the constant 1.5 compensates for natural fluctuations of a given metal and minor anthropogenic impacts (Taylor & Mclennan, 1995). I_{geo} index values of metals are classified according to Yaqin et al. (2008). Horizontal distributions of metals in soils were mapped by Geostatistics Software, GS$^+$ program (Robertson et al., 2001).

Results and Discussion

Descriptive statistics of some soil variables (texture class, pH, EC, total $CaCO_3$, OM, FC, WP, D_b) and metals (Ca, Mg, Fe, Zn, Mn, Cu, Co, Cr, Pb, Cd, Ni) were given in Table 2 and 3. In general, all soils were sandy in texture, very strongly calcareous, and high in organic matter content. The bulk density values (1.32-1.59 gr cm^{-3}) are in agreement with the given limit values (1.10-1.78 gr cm^{-3}) given for sandy soils (Bruand et al., 2005). Sandy soils often have low FC and permanent WP (Huang & Hartemink, 2020). Compared with the FC and WP limit values for sandy soils (Yost & Hartemink (2019), FC was slightly high although WP was quite high in farm and camp soils.

Table 2. Descriptive statistics of some soil variables in the farm, camp, and park soils

	Soil variables	Min	Max	Mean	SD	Skewness	Kurtosis	CV(%)
Farm (n:10)	Sand (%)	37.20	79.20	51.69	15.36	1.28	0.51	29.00
	EC(dSm^{-1})	2.40	47.10	23.48	16.40	0.19	-1.35	69.00
	pH (1:2.5)	7.11	7.44	7.28	0.12	-0.15	-1.68	2.00
	$CaCO_3$ (%)	25.64	36.51	29.77	3.52	0.73	-0.44	12.00
	FC(%)	0.16	0.27	0.21	0.03	0.15	-1.20	16.00
	WP (%)	0.13	0.22	0.17	0.03	0.66	-1.20	19.00
	Bulk density (gr cm^{-3})	1.32	1.55	1.44	0.10	-0.05	-2.40	7.00
	OM (%)	3.20	5.90	4.79	0.95	-0.43	-1.33	19.00
Camp (n:10)	Sand (%)	36.00	69.20	55.40	9.37	-0.40	1.60	16.00
	EC(dSm^{-1})	3.20	133.80	48.38	47.72	0.86	-0.35	98.00
	pH (1:2.5)	7.19	8.10	7.54	0.28	0.63	0.15	3.00
	Calcium carbonate (%)	24.11	37.49	30.41	4.71	0.02	-1.50	15.00
	FC(%)	0.21	0.28	0.25	0.02	-0.54	-1.02	9.00
	WP (%)	0.18	0.23	0.21	0.01	-0.06	-1.79	8.00
	D_b(gr cm^{-3})	1.35	1.54	1.49	0.05	-1.95	4.06	4.00
	OM (%)	4.90	7.10	5.82	0.77	0.41	-0.97	13.00
Park (n:10)	Sand (%)	36.00	69.20	55.40	9.37	-0.40	1.60	16.00
	Electrical conductivity (dSm^{-1})	3.20	133.80	48.38	47.72	0.86	-0.35	98.00
	Soil reaction, pH (1:2.5)	7.19	8.10	7.54	0.28	0.63	0.15	3.00
	$CaCO_3$ (%)	24.11	37.49	30.41	4.71	0.02	-1.50	15.00
	Field capacity(%)	0.21	0.28	0.25	0.02	-0.54	-1.02	9.00
	Wilting point (%)	0.18	0.23	0.21	0.01	-0.06	-1.79	8.00
	D_b(gr cm^{-3})	1.35	1.54	1.49	0.05	-1.95	4.06	4.00
	Organic matter (%)	4.90	7.10	5.82	0.77	0.41	-0.97	13.00

n: Number of soil samples, Min: Minimum, Max: Maximum, SD: Standard deviation, CV: Coefficient of variation

Due to their proximity to the Tigris River, the groundwater level is high in some sampling sites. These soils comprise a high OM, especially on the first site, and have high values of FC. Al-Adari (2020) Indicated that the rise in groundwater leads to an increase in its moisture by filling soils' pores with water, and thus the increase in the field capacity of the soil. It was reported that higher temperatures in areas with semi-arid climates cause a rise in the water in their soils, due to the high rates of evaporation, which increases the value of water losses. This increases the ability of soil to absorb water. Soil pH ranged from 7.11 to 8.10 and had the lowest variability (1, 2, 3%). Same results were reported in other studies (Erşahin, 1999; Mulla & McBratney, 2001). EC has the highest variability (69, 98, 116%) in farm, camp, and park soil samples. It can be explained by the rather high EC values (120.6 and 133.8 dSm^{-1}), especially in a few samples in the camp soils.

Table 3. Descriptive statistics of metal values in the farm, camp, and park soils

Metals (mg kg^{-1})		Min	Max	Mean	SD	Skewness	Kurtosis	CV (%)
Farm (n:10)	Manganese, Mn	58.54	99.18	79.10	14.76	-0.20	-1.57	18.66
	Copper, Cu	14.62	31.52	23.02	6.22	0.05	-1.63	27.03
	Zinc, Zn	18.45	54.29	34.90	12.12	0.15	-0.83	34.73
	Cobalt, Co	2.11	5.01	3.59	0.96	0.04	-0.64	26.92
	Chrome, Cr	0.98	1.51	1.31	0.16	-1.01	0.52	12.54
	Lead, Pb	13.47	77.25	35.36	25.46	0.88	-0.92	71.98
	Cadmium, Cd	2.27	7.12	4.74	1.80	-0.23	-1.72	37.98
	Nickel, Ni	1.00	3.46	1.84	0.69	1.44	2.78	37.35
	Iron, Fe	0.90	9.20	3.22	2.51	1.64	2.99	77.81
	Calcium, Ca	23.4	29.7	27.37	1.67	-1.37	3.53	6.12
	Magnesium, Mg	1.1	9.00	4.28	2.87	0.89	-0.67	67.10
Camp (n:10)	Manganese, Mn	61.58	125.44	97.72	19.61	-0.16	-0.07	20.07
	Copper, Cu	11.25	33.87	23.92	8.461	-0.26	-1.28	35.36
	Zinc, Zn	27.99	58.14	39.08	10.69	0.60	-1.12	27.36
	Cobalt, Co	1.54	9.32	5.00	2.43	0.41	-0.53	48.63
	Chrome, Cr	0.88	1.69	1.19	0.31	0.65	-0.78	26.23
	Lead, Pb	2.74	83.96	40.71	26.56	0.59	-0.78	65.24

	Cadmium, Cd	3.12	7.41	5.29	1.56	-0.01	-1.57	29.61
	Nickel, Ni	1.99	4.33	3.41	0.88	-0.58	-1.59	26.03
	Iron, Fe	3.00	15.10	8.32	3.57	0.55	0.14	42.87
	Calcium, Ca	21.12	30.00	26.06	3.26	-0.140	-1.44	12.51
	Magnesium, Mg	1.00	8.49	2.39	2.17	2.99	9.24	90.76
Park (n:10)	Manganese, Mn	61.55	129.32	100.85	22.10	-0.06	-0.47	21.91
	Copper, Cu	13.56	29.54	18.00	4.82	1.58	3.24	26.81
	Zinc, Zn	20.29	55.87	36.12	10.68	0.64	0.01	29.56
	Cobalt, Co	3.11	7.32	5.03	1.53	0.48	-1.03	30.47
	Chrome, Cr	0.55	1.98	1.15	0.54	0.61	-1.38	47.22
	Lead, Pb	36.99	89.32	64.97	15.83	-0.24	-0.46	24.36
	Cadmium, Cd	1.24	6.39	3.37	1.92	0.32	-1.58	57.15
	Nickel, Ni	1.10	5.00	2.83	1.36	0.42	-0.66	48.13
	Iron, Fe	0.10	8.82	4.38	3.01	-0.07	-1.19	68.66
	Calcium, Ca	15.00	29.12	24.30	5.43	-0.96	-0.97	22.37
	Magnesium, Mg	1.21	5.00	2.58	1.26	0.74	-0.30	48.94

n: Number of soil samples, Min: Minimum, Max: Maximum, SD: Standard deviation, CV: Coefficient of variation

Correlations between Soil Variables and Metals: Linear correlations between soil properties and total metal contents were carried out to assess which soil properties affected metal distribution in Tables 4, 5, and 6 for the farm, camp, and park soils, respectively. In the farm soils, the highest correlation coefficients between soil variables were found between D_b and clay content (-0.83) and D_b and sand content (0.77). In addition, in the park soils, D_b-sand content (0.68) and D_b-pH (-0.66). It was mentioned that there is a strong relation between soil bulk density and soil texture components (Chaudhari et al., 2013). As related to soil moisture properties and metals, we found correlations between WP and Co (0.95), and WP and Mn (-0.86) in farm soils. In a similar study that investigated the effects of soil water status on metals in serpentine soil (Gunarathne et al., 2019), there was a positive relation between WP and Mn and Co. They attributed it to the microbial reduction that occurs by water deficiency below the WP. Ittihad (1989) found a negative (-0.90) relation between Mn and WP on the outskirts of Baghdad and he attributed this result to the soil's properties. However, the microbial reduction caused by the wilting point did not adversely affect, on the contrary, a positive effect was observed on the amount of Co. In camp soils, there were correlations between FC and Cu (-0.68), FC and silt content (-0.71), and WP and EC (0.65). In addition, it was found that there were significant correlations between WP and $CaCO_3$ (0.80), WP and FC (0.72), and WP and Zn (-0.75) in park soils. Zheng and Zhang (2011) reported that soil moisture dynamics such as field capacity and wilting point directly affect many physicochemical properties of soils, including organic matter content, pH, and electrical conductivity, and are indirectly involved with metals in soils. Therefore they have drawn attention to the current soil water status such as field capacity and wilting point as well as the dynamics of soil moisture content should be taken into account to assess the status of metals in soils. There was a positive correlation between Cu and EC (0.80) in the park soils. Peris et al. (2008) investigated the heavy metal content and sources of agricultural soils in Castellón province (Spain), a representative area of the European Mediterranean region, and found that Cu and Pb concentrations were found to be positively correlated with EC (r=0.200; p≤0.05). Correlations between sand content and Pb (0.68) and silt content and Ni (0.78) were significant in the farm soils. The effect of texture on metal accumulation in the soil has been reported, for example, Brümmer et al., (1986), Ma and Rao (1997), Selim & Sparks (2001) noted that the severity of pollution depends not only on the total heavy metal content of the soil but also on the proportion of their mobile and bioavailable forms, which are generally controlled by the texture and other physicochemical properties of soils.

However, no studied metals were correlated with soil pH except Fe metal in the farm soils. The pH values of all soil samples taken from all three regions are between 7.11 and 8.10, and the studied soils are characterized by alkaline. pH has a moderate level significant correlation (-0.65) with Fe at 0.05 level negatively in the farm soils (Table 4). Alloway (2012) reported that the movement and content of heavy metals in the soil can be controlled by pedogenic processes, soil management, and various anthropogenic and soil factors such as soil pH, organic matter, clay, carbonates, and salt content. In addition, studies are reporting the accumulation of Cd and Pb in alkaline soils. It was stated by Metin (2010) that lead can dissolve at a very low level in acidic and alkaline conditions. Ismail (2010) studied heavy metal concentration in neutral soils (pH=7.35) of A-Tala village in Maysan Governorate and reported the lead concentration to be approximately the same (35 mg kg^{-1}) as our study and exceeding the limit of Cd (8 mg kg^{-1}). However, she concluded that besides alkaline properties, the main factor in the development of high cadmium concentrations was pollution resulting from human activities. In our farm soil samples, the mean Cd concentration exceeding the limit value (1.5 mg kg^{-1} for

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Table 4. Corelations between soil variables and metals in farm soils (n:10)

	D_b	Sand	Silt	Clay	EC	pH	$CaCO_3$	FC	WP	OM	Mn	Cu	Zn	Co	Cr	Pb	Cd	Ni	Fe	Ca	Mg
Db(g cm³)	1																				
Sand (%)	$\mathbf{0.77}^{**}$	1																			
Silt (%)	0.49	0.03	1																		
Clay (%)	$\mathbf{-0.83}^{**}$	-0.47	$\mathbf{-0.75}^{*}$	1																	
EC	-0.11	-0.50	0.11	-0.19	1																
pH	-0.30	0.01	$\mathbf{-0.66}^{*}$	0.49	0.02	1															
$CaCO_3$	0.55	0.28	0.01	-0.50	0.49	0.22	1														
FC (%)	0.54	0.32	0.28	-0.45	0.19	-0.20	0.34	1													
WP (%)	0.17	0.55	-0.34	-0.11	-0.02	0.33	0.14	0.37	1												
OM (%)	-0.37	-0.02	-0.18	0.39	-0.57	-0.23	$\mathbf{-0.93}^{**}$	-0.36	0.04	1											
Manganese	-0.36	-0.59	0.01	0.35	0.02	-0.19	-0.42	-0.52	$\mathbf{-0.86}^{**}$	0.30	1										
Copper	0.42	0.46	0.04	-0.32	-0.07	0.48	0.49	0.55	0.51	-0.49	$\mathbf{-0.70}^{*}$	1									
Zinc	-0.11	0.01	-0.22	0.12	0.10	-0.15	-0.33	0.59	0.53	0.34	-0.31	0.05	1								
Cobalt	0.01	0.42	-0.48	0.02	0.05	0.52	0.17	0.22	$\mathbf{0.95}^{**}$	0.02	$\mathbf{-0.76}^{*}$	0.51	0.45	1							
Chrome	0.19	0.21	0.35	-0.24	-0.04	-0.27	-0.19	-0.31	-0.01	0.31	0.25	-0.43	-0.22	-0.11	1						
Lead	0.56	$\mathbf{0.68}^{*}$	0.28	-0.49	-0.44	0.15	0.04	0.10	0.37	0.12	-0.33	0.57	-0.14	0.33	0.28	1					
Cadmium	0.54	0.57	0.07	-0.43	-0.03	-0.45	0.29	0.58	0.48	-0.13	-0.61	0.09	0.41	0.248	-0.02	-0.06	1				
Nickel	0.20	-0.14	$\mathbf{0.78}^{**}$	-0.42	0.01	-0.31	0.11	0.29	-0.34	-0.35	-0.05	0.34	-0.28	-0.43	-0.12	0.15	-0.16	1			
Iron	0.20	0.06	0.49	-0.38	0.29	$\mathbf{-0.65}^{*}$	0.03	0.23	0.11	0.01	-0.11	-0.38	0.19	-0.08	0.59	-0.22	0.52	0.13	1		
Calcium	0.14	0.06	0.58	-0.25	0.00	-0.33	-0.01	0.24	-0.01	-0.04	-0.12	0.02	-0.02	-0.08	0.33	0.04	0.09	0.53	$\mathbf{0.64}^{*}$	1	
Magnesium	-0.31	-0.19	0.07	0.19	0.22	-0.06	-0.18	0.12	0.23	0.15	-0.10	-0.18	0.33	0.25	0.28	-0.27	0.02	0.04	0.60	$\mathbf{0.78}^{**}$	1

** Significant at P<0.01 *Significant at P<0.05. n: Number of samples, D_b: Bulk density, pH: Soil reaction, EC: Electrical Conductivity, $CaCO_3$: Calcium carbonate content, OM: Organic Matter, FC: Field capacity, WP: Wilting point

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Table 5. Corelations between soil variables and metals in camp soils (n:10)

	D_b	Sand	Silt	Clay	EC	pH	$CaCO_3$	FC	WP	OM	Mn	Cu	Zn	Co	Cr	Pb	Cd	Ni	Fe	Ca	Mg
D_b ($g\ cm^{-3}$)	1																				
Sand (%)	0.43	1																			
Silt (%)	-0.52	-0.34	1																		
Clay (%)	-0.24	0.24	-0.06	1																	
EC	-0.09	0.63	-0.43	0.28	1																
pH	0.15	0.01	0.45	0.12	-0.54	1															
$CaCO_3$	-0.27	0.13	0.32	-0.02	0.17	-0.45	1														
FC (%)	0.32	0.27	**-0.71***	-0.16	0.42	-0.39	-0.07	1													
WP (%)	0.03	0.51	-0.19	0.01	**0.65***	-0.38	0.18	0.42	1												
OM (%)	0.43	-0.03	-0.01	0.14	-0.59	0.57	-0.41	-0.47	-0.44	1											
Manganese	0.14	-0.10	0.10	-0.58	-0.15	-0.48	0.53	-0.13	-0.02	-0.16	1										
Copper	-0.22	0.05	0.52	-0.21	-0.29	0.35	0.15	**-0.68***	-0.36	0.33	0.27	1									
Zinc	-0.63	-0.16	0.10	0.47	-0.01	0.12	-0.09	-0.11	-0.36	-0.08	-0.36	0.25	1								
Cobalt	0.02	-0.10	-0.26	-0.16	-0.12	-0.52	0.43	-0.08	-0.32	0.15	0.62	0.31	0.13	1							
Chrome	0.36	0.29	-0.15	-0.12	-0.15	0.46	-0.22	0.20	-0.48	0.16	-0.12	0.30	0.30	0.04	1						
Lead	0.28	0.21	-0.23	-0.21	-0.11	0.23	-0.35	-0.15	-0.49	0.37	0.15	0.60	0.28	0.37	**0.71***	1					
Cadmium	-0.41	0.15	0.03	0.43	0.50	-0.39	0.08	-0.29	0.51	-0.16	0.03	-0.01	0.11	-0.01	**-0.68***	-0.22	1				
Nickel	0.14	0.38	-0.23	0.03	0.53	-0.51	0.23	0.30	0.54	-0.54	0.44	-0.33	-0.18	-0.01	-0.19	-0.12	0.47	1			
Iron	0.47	-0.28	-0.21	-0.42	-0.22	-0.29	-0.06	0.04	-0.23	-0.02	**0.63***	-0.26	-0.48	0.23	-0.03	0.11	-0.14	0.43	1		
Calcium	-0.03	-0.29	0.26	-0.26	-0.11	-0.16	0.01	-0.51	-0.25	-0.06	0.59	0.23	-0.21	0.14	-0.19	0.22	0.28	0.38	**0.71***	1	
Magnesium	0.38	0.12	0.18	-0.08	-0.24	0.08	0.01	-0.38	0.20	0.35	0.49	0.12	-0.45	0.03	-0.30	-0.01	0.36	0.46	0.46	0.50	1

*Significant at $P<0.05$. n: Number of samples, D_b: Bulk density, pH: Soil reaction, EC: Electrical Conductivity, $CaCO_3$: Calcium carbonate content, OM: Organic Matter, FC: Field capacity, WP: Wilting point

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Table 6. Corelations between soil variables and metals in the park soils (n:10)

	D_b	Sand	Silt	Clay	EC	pH	$CaCO_3$	FC	WP	OM	Mn	Cu	Zn	Co	Cr	Pb	Cd	Ni	Fe	Ca	Mg
D_b(g cm^3)	1																				
Sand (%)	**0.68***	1																			
Silt (%)	-0.11	-0.38	1																		
Clay (%)	-0.06	0.57	**-0.73***	1																	
EC	-0.18	0.37	-0.18	**0.66***	1																
pH	**-0.66***	**-0.67***	0.24	-0.27	-0.13	1															
$CaCO_3$	0.08	0.53	-0.13	**0.67***	**0.69***	-0.35	1														
FC (%)	-0.16	0.19	0.00	0.48	0.37	0.01	0.62	1													
WP (%)	0.14	0.22	0.09	0.33	0.26	-0.22	**0.80****	**0.72***	1												
OM (%)	0.01	-0.14	-0.12	-0.01	-0.47	0.41	-0.11	0.10	0.23	1											
Manganese	-0.18	0.17	-0.21	0.22	0.02	-0.08	0.13	-0.16	-0.19	-0.29	1										
Copper	**-0.68***	-0.09	-0.22	0.59	**0.80****	0.30	0.42	0.37	0.07	-0.34	0.22	1									
Zinc	0.04	-0.03	0.26	-0.43	-0.08	-0.05	-0.51	-0.56	**-0.75***	**-0.65***	0.40	-0.06	1								
Cobalt	**-0.64***	-0.36	-0.22	0.43	0.50	0.54	0.33	0.36	0.30	0.24	-0.21	**0.74***	-0.56	1							
Chrome	-0.19	0.28	-0.40	0.58	0.19	-0.00	0.58	0.52	0.41	0.08	0.54	0.34	-0.39	0.24	1						
Lead	-0.17	0.046	-0.32	0.26	0.17	-0.18	-0.06	0.13	-0.22	-0.54	0.54	0.39	0.44	-0.10	0.18	1					
Cadmium	-0.10	0.088	-0.27	0.50	**0.65***	0.24	0.47	0.43	0.42	0.06	-0.23	0.62	-0.40	**0.73***	0.12	0.11	1				
Nickel	0.24	0.31	0.11	0.01	0.29	-0.15	0.06	0.17	-0.08	-0.25	-0.4	-0.03	0.03	-0.11	-0.12	-0.34	-0.06	1			
Iron	0.25	0.28	0.35	-0.20	0.21	-0.06	-0.11	0.12	-0.24	-0.40	-0.34	-0.05	0.41	-0.33	-0.25	-0.09	-0.10	**0.86****	1		
Calcium	0.14	0.06	0.25	-0.18	0.03	-0.24	0.01	0.14	0.03	-0.23	-0.54	-0.21	-0.07	-0.18	-0.10	-0.40	-0.34	**0.87****	**0.65***	1	
Magnesium	0.26	0.21	0.13	-0.08	0.25	-0.20	-0.01	0.15	-0.08	-0.34	-0.60	-0.05	0.07	-0.12	-0.22	-0.24	-0.02	**0.97****	**0.85****	**0.88****	1

** Significant at $P<0.01$, *Significant at $P<0.05$. n: Number of samples, D_b: Bulk density, pH: Soil reaction, EC: Electrical Conductivity, $CaCO_3$: Calcium carbonate content, OM: Organic Matter, FC: Field capacity, WP: Wilting point pH>7 soils) was found to be 4.74 mg kg^{-1} although there was no human activity. However, there is an apartment complex just a few meters away near the abandoned farm. According to the results of such research, we can say that the higher Cd and Pb concentration in the park soils is of anthropogenic origin. Weaver and Pollard (2011) reported that the higher the percentage of organic matter in the soil, the higher the cadmium concentration with it is adsorbed on the particles of the organic matter, and when organic matter decomposes, cadmium is released into the soil. Since there were not adequate plants in the sampling areas, soil organic matter would be highly stabilized.

The Potential Ecological Risk Index (PERI) of Metals: According to CF, only Cd was found as slightly (1) in farm (1.89) and in park (1.35) soils, and moderately (2) contaminated in camp (2.11) soils. For E_r^i values, a serious risk of Pb was found in farm (5.51 and 5.40) and camp (5.99 and 5.45) soils in two samples each and 3 samples (5.59, 6.38, and 5.71) in park soils. In addition, it was determined the extreme (7 in farm, 9 in camp, 5 in park) and high (3 in farm, 1 in camp, 2 in park) ecological risk for Cd in soils. The highest E_r^i value for Cd was found in the camp sample, and for Pb in the park sample. According to the PERI results, no risk was determined in all soils except for Pb and Cd. However, the results of E_r^i showed that 70% of samples were at extreme ecological risk with Cd and 30% of samples showed severe ecological risks with Pb (Table 7). Similarly, I_{geo} values of Pb increased in the farm (1.23), camp (1.44), and park (2.11), while Cd increased in the park (5.22), farm (5.71), and camp (5.87). High concentrations in farm, camp, and park soils of Cd (4.74, 5.29, and 3.37) and Pb (35.36, 40.71, and 64.97) and high ecological risk of Cd above the unpolluted range of <40 could be related to anthropogenic activities such as household waste, burning of urban wastes (Pan et al., 2010), car exhausts, and the results of 2003. The increase in human activities with the increasing population increases the amount of metal that creates pollution (Kumar et al., 2015).

The Geoaccumulation Index (I_{geo}) of Metals: The Geoaccumulation index was calculated according to Muller's (1969) equation and classified using the Table that was given by Yaqin et al. (2008) and He et al. (2022) in Table 8. The I_{geo} values for the metals Cd > Pb > Cu > Zn > Co > Mn > Cr > Ni > Mg > Ca > Fe in the farm soils; Cd > Pb > Zn > Cu > Co > Ni > Cr > Fe > Mn > Ca > Mg in the camp soils; and Cd > Pb > Cu > Zn > Co > Mn > Cr > Ni > Fe = Ca > Mg in the park soils.

All of the I_{geo} values of metals except Cd and Pb were lower than 0. Therefore, it was concluded that the soils of Baghdad were not contaminated with these metals. I_{geo} values of Cd in the farm, camp, and park soils were larger than 5, and they were calculated to exceed the extremely contaminated class. I_{geo} values of Pb in the farm and camp soils were larger than 1, taking place in the moderately contaminated class. However, in park soils, it was larger than 2, and in the moderately to heavily contaminated class. Farm and camping areas are quite uncrowded places. The higher Pb content in the park soils than in the farms and camp was attributed to the low density of people and therefore traffic since the park is located in the center of the city. Some studies associate metal accumulations in city park soils with anthropogenic factors due to high population and traffic. He et al. (2022) stated that Cd and Pb, along with Zn and Cu, were the most studied metals in urban soils, as their concentrations are generally high. Chen et al. (2005) reported that the high metal accumulation index values in China's cities

Table 7. Ecological Risk Index (E_r^i) values of metals in farm, camp and park soils

o	Ca	Mg	Fe	Zn	Mn	Cu	Co	Cr	Pb	Cd	Ni
F1	0.99	0.45	0.19	0.31	0.10	2.21	0.24	0.02	0.96	62.52	0.08
F2	0.78	0.25	0.08	0.35	0.11	1.84	0.17	0.03	1.15	40.32	0.07
F3	0.90	0.10	0.04	0.57	0.07	2.94	0.36	0.02	5.51	76.32	0.05
F4	0.90	0.13	0.03	0.19	0.11	1.53	0.25	0.03	3.33	27.24	0.07
F5	0.96	0.06	0.02	0.41	0.07	2.97	0.31	0.02	1.42	66.48	0.10
F6	0.94	0.13	0.02	0.26	0.09	3.15	0.24	0.03	5.40	30.12	0.18
F7	0.94	0.31	0.04	0.41	0.10	2.19	0.24	0.02	0.99	35.52	0.08
F8	0.89	0.45	0.09	0.53	0.08	1.92	0.36	0.03	1.20	66.24	0.11
F9	0.90	0.14	0.01	0.41	0.10	1.46	0.15	0.03	1.58	85.44	0.12
F10	0.90	0.14	0.04	0.20	0.07	2.78	0.28	0.03	3.69	78.60	0.09
C1	1.00	0.09	0.21	0.49	0.09	1.12	0.38	0.02	0.19	88.92	0.22
C2	0.73	0.10	0.32	0.51	0.11	3.32	0.68	0.03	5.99	40.20	0.21
C3	0.96	0.07	0.17	0.31	0.07	1.74	0.11	0.02	2.14	63.48	0.13
C4	0.97	0.10	0.20	0.38	0.11	2.42	0.19	0.03	1.69	37.44	0.12

C5	0.70	0.05	0.06	0.61	0.10	3.35	0.35	0.02	2.51	76.20	0.21
C6	1.00	0.10	0.10	0.36	0.14	3.38	0.54	0.02	4.95	83.88	0.21
C7	0.84	0.10	0.26	0.30	0.14	1.23	0.54	0.02	1.57	51.00	0.15
C8	0.81	0.11	0.16	0.51	0.10	2.01	0.21	0.03	5.45	61.44	0.22
C9	0.87	0.07	0.13	0.32	0.11	2.51	0.30	0.03	2.43	49.68	0.10
C10	0.80	0.42	0.12	0.29	0.13	2.78	0.34	0.02	2.12	83.28	0.19
P1	0.97	0.25	0.01	0.35	0.15	2.95	0.53	0.04	5.59	64.92	0.25
P2	0.50	0.20	0.10	0.58	0.15	1.41	0.24	0.01	4.87	15.00	0.26
P3	0.92	0.18	0.08	0.37	0.15	1.76	0.31	0.04	6.38	52.32	0.05
P4	0.57	0.07	0.09	0.31	0.10	1.95	0.53	0.02	3.73	64.68	0.10
P5	0.60	0.11	0.14	0.29	0.10	1.35	0.32	0.01	4.89	43.80	0.16
P6	0.94	0.15	0.11	0.32	0.07	2.0	0.47	0.01	3.95	76.68	0.17
P7	0.87	0.12	0.18	0.52	0.12	1.95	0.30	0.02	5.71	26.76	0.17
P8	0.87	0.09	0.16	0.45	0.11	1.44	0.21	0.01	3.67	27.00	0.13
P9	0.97	0.06	0.02	0.37	0.10	1.75	0.38	0.02	4.94	14.88	0.06
P10	0.91	0.06	0.02	0.21	0.12	1.35	0.36	0.04	2.64	18.36	0.11
PERI	Low	Low	Low	Low	Low	Low	Low	Low	Severely	Extreme	Low

F: Farm, C: Camp, P: Park, PERI: Potential Ecological Risk Index

Table 8. I_{geo} index classes of metals in the farm, camp, and park soils

	Farm soils				
	Metals	Igeo	Class	Urban soil quality	Data sources
Farm soils	Manganese, Mn	-4.01	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Copper, Cu	-0.38	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Zinc, Zn	-1.1	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Cobalt, Co	-1.73	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Chrome, Cr	-4.18	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Lead, Pb	1.23	2	Moderately contaminated	Yaqin et al. 2008; He et al. 2022
	Cadmium, Cd	5.71	>5	Extremely contaminated	Yaqin et al. 2008; He et al. 2022
	Nickel, Ni	-5.01	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Iron, Fe	-7.96	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Calcium, Ca	-7.64	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Magnesium, Mg	-7.38	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
Camp soils	Metals	Igeo	Class	Urban soil quality	Data sources
	Manganese, Mn	-7.38	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Copper, Cu	-0.33	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Zinc, Zn	-0.09	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Cobalt, Co	-1.26	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Chrome, Cr	-4.32	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Lead, Pb	1.44	2	Moderately contaminated	Yaqin et al. 2008; He et al. 2022
	Cadmium, Cd	5.87	>5	Extremely contaminated	Yaqin et al. 2008; He et al. 2022
	Nickel, Ni	-4.13	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Iron, Fe	-6.64	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Calcium, Ca	-7.64	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Magnesium, Mg	-8.38	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
Park soils	Metals	Igeo	Class	Urban soil quality	Data sources
	Manganese, Mn	-3.66	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Copper, Cu	-0.74	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Zinc, Zn	-1.05	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Cobalt, Co	-1.25	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Chrome, Cr	-4.38	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Lead, Pb	2.11	3	Moderately to heavily contaminated	Yaqin et al. 2008; He et al. 2022
	Cadmium, Cd	5.22	>5	Extremely contaminated	Yaqin et al. 2008; He et al. 2022
	Nickel, Ni	-4.41	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Iron, Fe	-7.64	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Calcium, Ca	-7.64	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022
	Magnesium, Mg	-7.96	0	Practically uncontaminated	Yaqin et al. 2008; He et al. 2022

I_{geo}: The Geoaccumulation index

were higher in old park soils than in new parks. They noted that it was related to the exposure time. Likewise, Peng et al. (2013) reported that the concentrations of metals in residential soil was increasing with the age of the residential buildings. These reports confirm that metal concentrations were related to the increasing population in urban soils. These results agree to that there was more contamination with Pb and Cd metals in the park soils of Baghdad city. On the other hand, extremely high I_{geo} values of Cd in the farm, camp, and park soils (larger than 5) show that Cd pollution was at a very significant level in this city. Anthropogenic sources such as traffic emissions can be suspected as the main reason for the high I_{geo} values for Cd in Baghdad urban soils in Table 8.

Spatial Distribution of Metals: The kriging maps were built for depicting spatial distribution pattern of metals in farm, camp, and park soils (Figures 3, 4, and 5). He et al. (2022) reported that heavy metal contents in soils have strong spatial variability, and their statistical distributions are useful indicators of the long-term characteristics of urban pollution. Concentrations of Mn, Fe, and Ca have an increasing trends in the same direction while Mg has trended in the opposite direction on the farm site. These trends in farm soils can be attributed to the distribution of household and farm wastes since the site was used as a farm before. Concentrations of Zn and Mg showed a patchy distribution. Similarly, the concentration of Cd showed an increasing trend in the opposite direction with Cu, Pb, and Ca trends in the camp soils, and Zn and Ni showed patchy distribution. Fe is high in the camp soils compared to farm and park soils and is mostly evenly distributed. The high concentration of Fe may be due to the long-term use of the campsite as a military area. As related to the park soils, Cu, Co, Cd, and Ca had a trend in the opposite direction with Mn and Pb. Zn, Co, Pb, and Ca showed patchy distribution in the park soils. Ca Co, Zn, Cu, Pb, and Mn concentrations were greater in park soils than in farms and camps. It may be attributed to the fact that the mostly higher concentration of metals are in the park soils that it is in the center of the city, and that human-related factors such as traffic are effective. Besides human-induced pollution, dry climatic conditions, low rainfall, and vegetation can be important. Imperato et al. (2003) reported that urban soil pollution would result from the accumulation of nonsoil originated pollutants as

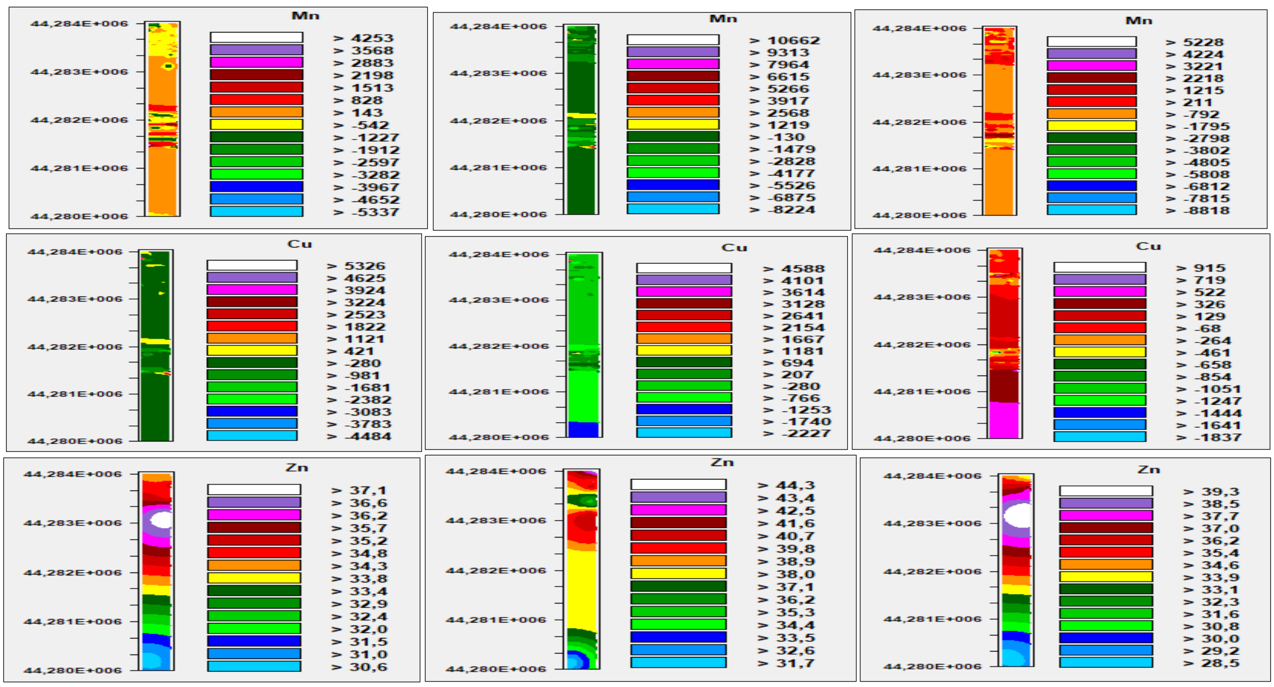

Figure 3. The spatial distributions of the Mn, Cu, and Zn metals in the farm (left), camp (middle), and park(right) soils

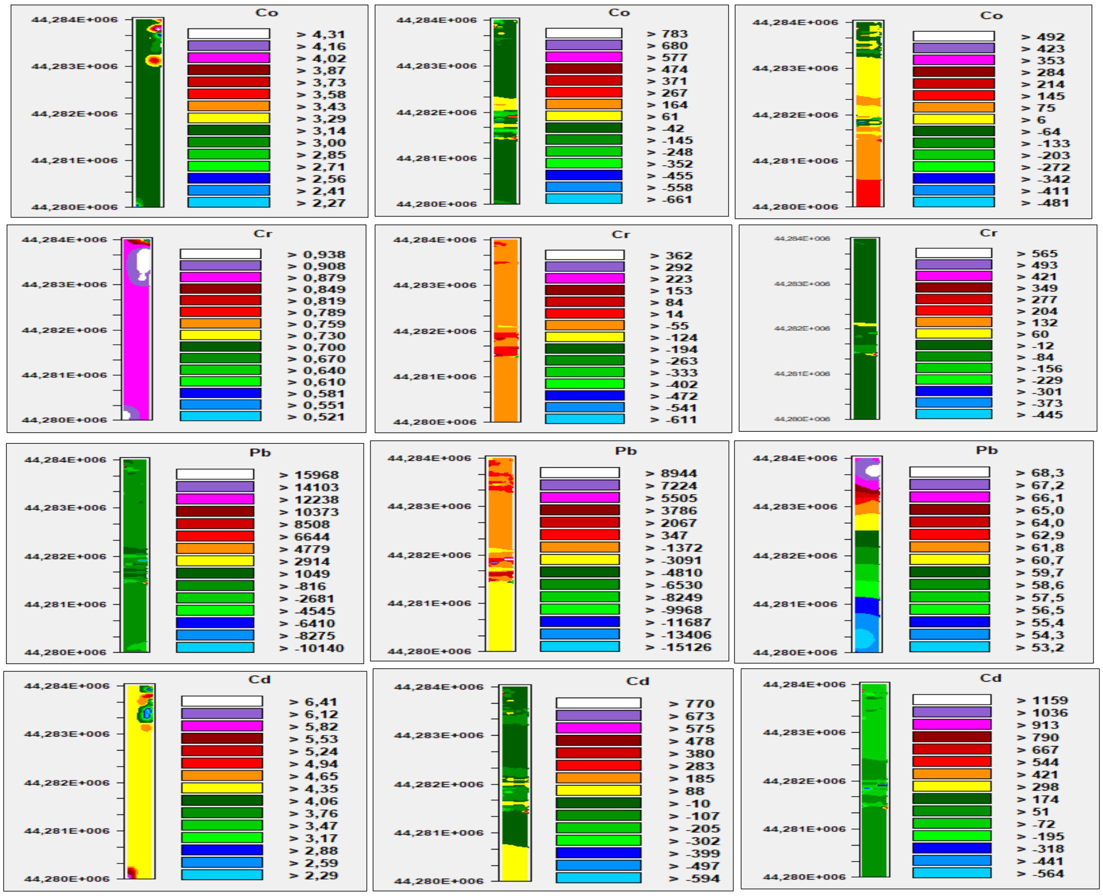

Figure 4. The spatial distributions of the Co, Cr, Pb, and Cd metals in the farm (left), camp (middle), and park (right) soils

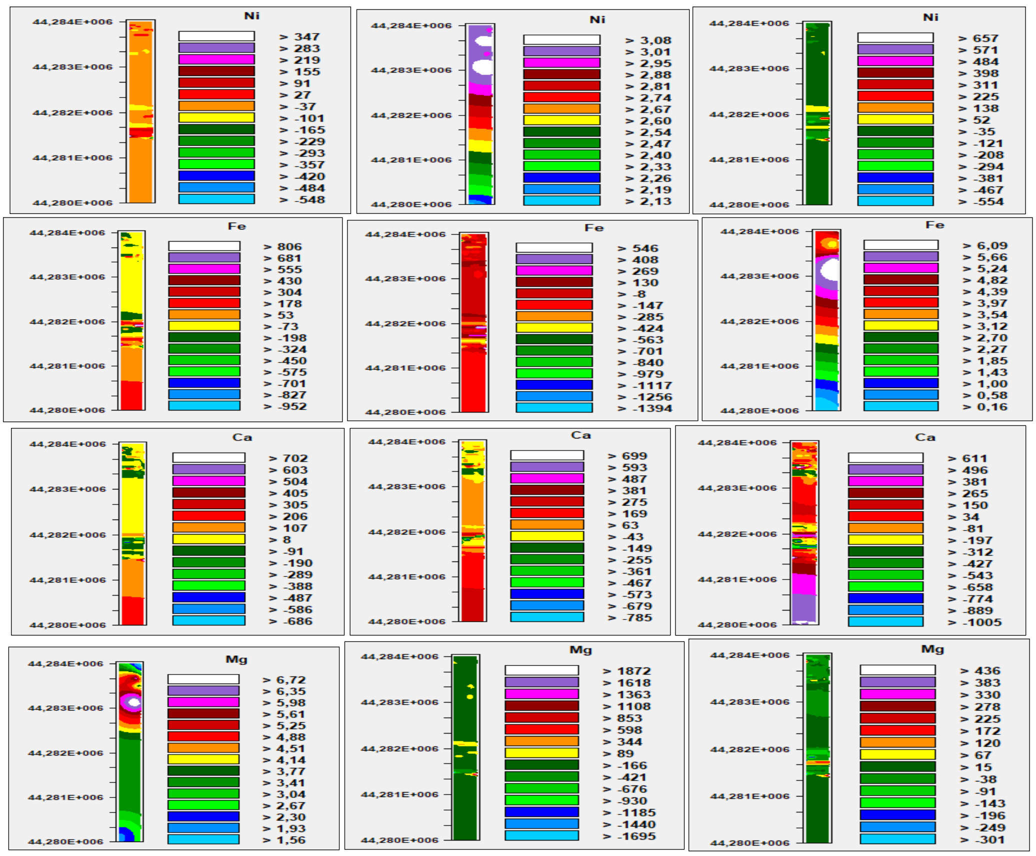

Figure 5. The spatial distributions of the Ni, Fe, Ca, and Mg metals in the farm (left), camp (middle), and park (right) soils (continue)

well as where was little vegetation cover or dry conditions subsist.

Conclusion

In this study, metal (Ca, Mg, Fe, Zn, Mn, Cu, Co, Cr, Pb, Cd, and Ni) pollution levels in soils of Baghdad city were evaluated under three different land uses (farm, camp, and city park site). The results revealed that urban soils in Baghdad city were polluted by Cd and Pb. Cd was the most seriously polluting metal with 3.37%, 4.74%, and 5.29% of the pollution in the park, farm, and camp soil, respevtively. Pb was significant with 35.36%, 40.71%, and 64.97% of the pollution in the farm, camp, and park soils. The high rates of soil pollution with Cd and Pb resulted from the accumulation of household waste, sewage water, and gases emitted from cars all triggered by increased population. In addition, the accumulation of industrial waste from factories, blacksmithing workshops, and car repairs in soil and its failure to decompose are the reasons. Therefore, human activity played an important role in the high levels of Cd and Pb besides natural factors such as soil texture components and soil dust in Baghdad. Since urban soil is considered a sink for metals, these metals are an increasingly serious problem for human health besides soil quality. Especially metals, which are chemical warfare agents such as lead, have toxic properties on the nervous system and organs. These results must lead us to assess the health risk caused by exposure to metals in the urban soils, especially park soils in Baghdad City since children and adults spend a substantial time on those sites. The recommendations are to impose environmental and health control over factories, power stations, blacksmiths, and car repair workshops and provide to dispose of industrial waste correctly, reduce the use of pesticides and chemical fertilizers, and use of especially plant that reduces pollution with heavy metals. Along with these practices, more attention should be paid to metal pollution in city soils with dense populations and traffic.

Authors contributions

GK: Conceptualization, Data Curation, Formal Analysis, Methodology, Supervision, Validation, Visualization, Writing-original draft, Writing-review and editing. **HAHA:** Data Curation, Investigation, Resources, Writing-review.

Conflict of Interest

The authors declare that there is no conflict of interest.

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