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CONCENTRATION OF HEAVY ELEMENTS IN CULTIVATED AND UNCULTIVATED SOIL OF BASRAH, IRAQ

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SUMMARY

This study sought to estimate the heavy elements, lead, iron, zinc, manganese, cadmium, and copper in cultivated and uncultivated soils of Basrah, Iraq. Results showed that the concentration of elements in all locations was within permissible limits on surface layers, which were higher in concentration than in deep layers due to the elements' internal transport, natural, some physical and chemical properties, i.e., pH, electrical conductivity (EC), and organic matter (OM). The soil acidity ranged between 7.70–7.25 and 7.88–7.25 for cultivated and uncultivated soils, respectively. As for the electrical conductivity, it has a range between 2.70–10.16 and 3.13–23 $dS.m^{-1}$ Organic matter extended between 0.269–1.500 and 0.349–0.816. The elements in cultivated soils were lesser than in the uncultivated grounds. The analysis of variance (ANOVA) results at the 5% significance level showed no remarkable differences in the concentration of the studied elements, while significant variations appeared in the copper content.

Keywords: Pollution agricultural soil, trace elements, organic matter

Key findings: All element values studied in the agricultural soil were within natural limits due to a concentration increase in some elements, especially iron, compared with uncultivated soils, while lead showed no effect. The unit concentration in the cultivated soils in Basra City was lower than in international soils. The elements' concentration in soil is as follows: Iron > manganese > copper > cadmium > zinc > lead.

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INTRODUCTION

The problem of environmental pollution is one of the most serious problems today. Soil contamination with heavy elements has increased through decades, and this pollution comes from natural and anthropogenic sources, including human sources, industrial, agriculture, workshops, waste burning, traffic, metal smelting, mines, and natural, such as rock decomposition and volcanic eruptions. Metal pollution is one critical and dangerous form of environmental pollution, particularly affecting human health, classified as toxic. These toxic elements are highly injurious even at low concentrations with continuous ingestion due to their accumulation in the body (Belaid *et al*., 2019).

Soil pollution with heavy elements comes from various human activities, such as different means of transportation, agricultural practices, industrial activities, and waste disposal. The soil's total concentration of heavy elements has unavailable information about their chemical nature or bioavailability (Jin *et al*., 2005). The heavy elements accumulation in agricultural soils is a growing concern because of its relationship to food safety or to leaching in groundwater and surface water, represented in nearby rivers and water bodies, which may lead to potential health risks. Similarly, the dangerous heavy elements may come from rocks making up the soil or from anthropogenic sources, such as aerosol sedimentation, agricultural activities, or industrial and urban emissions (Wilson and Pyatt, 2007).

Heavy elements, such as Pb, Cr, Cd, Ni, Cu, Zn, and Fe, are among the most severe environmental problems worldwide. The continuous disposal of hazardous substances in the soil, municipal and industrial waste dumping, natural agricultural practices, and using farm fertilizers and pesticides have contributed to the many heavy elements accumulating in the soil. Additionally, applying inorganic fertilizers that contain a high percentage of impurities, viz., phosphate fertilizers, nitrates, and potassium salt, is contributory (Savci, 2012). The dynamic nature of straws and their ability to flow within the moisture sector play a prominent role. Likewise, their transport to plant roots and access to groundwater enhance the physical and chemical properties of moisture, indicating the pressure and percentage of organic matter, highly affecting mineral movement in the soil (Alloway, 2013).

Soil pollution poses a hidden danger to the environment. It is difficult to determine directly contamination in the soil with the naked eye (Pennock, 2018). Heavy elements availability in the soil within natural values is vital in giving the soil some beneficial properties; however, an increase in their concentrations has a negative effect. Heavy elements may change the general soil properties, especially its biological properties, such as the number of microorganisms. Their diversity and activities alter soil temperature, pH, clay minerals, organic matter, inorganic cations, and chemical forms of minerals (Kumari and Mishra, 2021).

Environmental pollutants, mainly from anthropogenic industrial and agricultural activities, enter the soil system in various ways, such as atmospheric precipitation, wastewater irrigation, and slag filtration. Excessive accumulation of minerals in soil not only reduces its quality, microbial activity, and crop yields, as well as threatens environmental security and human health (Taghipour *et al.*, 2011; Dankoub *et al*., 2012; Azizi *et al*., 2022).

The importance of the research lies in showing the extent of the heavy elements concentration severity that accumulated in soil components. In addition, cultivated and uncultivated soils are a genuine danger to human health, with most agricultural soils contaminated with these elements.

MATERIALS AND METHODS

The location coordinates' validation of the study area for the province of Basra comprised of agriculturally exploited and unexploited areas (Figure 1). Their coordinates are within longitudes 30.980 and 47.460 north and

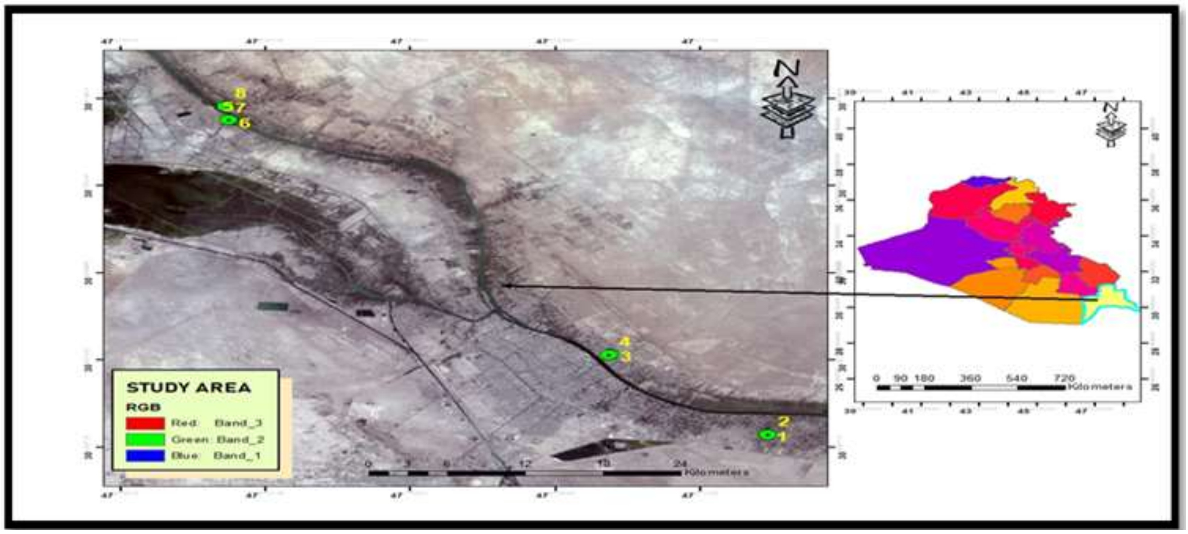

Figure 1. A map of the study area showing the soil sample collection locations.

latitudes 30° 45′2″ and 47° 96′7″ east. The study collected soil samples from these areas for anatomical section assessments.

Laboratory work

After obtaining soil samples from the study sites, they bore air-drying, with their orbits dismantled after dividing the samples into two parts. Then, passing the samples through a sieve with a diameter of 2 mm had them collected in plastic containers for their chemical and physical analyses. The soil texture estimation used the volumetric pipette method, separating the sand using a sieve with a 50-micron diameter, separating both clay and silt based on the difference in their precipitate velocity, as described by Blake (1965).

Likewise, estimating electrical conductivity employed the EC-meter (Blake, 1965). The degree of soil reaction measurement used a PH-meter (Page *et al*., 1982), and the organic matter estimation utilized the Walkley and Black method, as described by Jackson (1958) (Tables 1 and 2).

Determining heavy elements

The digestion method estimated the total content by placing dry soil sieved through a 2-mm sieve in a Teflon beaker, then adding 10 ml of 30% H_2O_2 and heating at 80 °C-90 °C until dry. As the sample cooled, adding another H_2O_2 (10 ml) with heating ensued to break the organic matter. The succeeding steps included adding 10 mL of HF acid, heating to dry, adding again 15 ml of concentrated HNO_3 acid, then 5 ml $HCLO_4$ acid before heating until a dry vapor is visible when the sample is near dryness (without complete dehydration) of 1:10 HCl, then heated for an hour at a temperature of 70 °C. Afterward, filter the sample with filter paper (40) and use a funnel with a long neck into a volumetric flask with a capacity of (50 ml), wash the Teflon baker with minimal distilled water, and collect the washing water in the flask. Thus, the samples became digested and ready to undergo the atomic absorption spectrophotometer (Soltanpour and Workman, 1979).

Statistical analysis

The results’ statistical analysis used the SPSS (Statistical Program for the Social Sciences) Version (15) (Zeng *et al*., 2011). Analyzing the variance (ANOVA) distinguishes the significant differences between the means by calculating the least significant difference (LSD) value at a 5% significant level, adding Pearson correlations between the quantities of the studied elements with each other.

Table 1. Some of the physical and chemical properties of the study area's cultivated soils.

Analysis of the site	Number of layers	pH	EC	OM	Soil Texture	Clay% g kg^{-1}	Silt% g kg^{-1}	Sand% g kg^{-1}
AbuAl- Khaseeb Planted	C1	7.695	10.160	0.408	Silty clay loam	95.6	591.34	96.09
	C2	7.25	6.120	0.349	Silty clay loam	275.9	551.82	149.9
	C3	7.500	9.90	0.269	Silty clay loam	275.9	551.81	149.6
Al Tannumah Planted	A	7.541	7.67	0.422	Silty clay loam	256.13	512.27	202.77
	C1	7.448	33.9	1.500	Silty clay loam	200	640	132
	C2	7.412	7.94	0.845	Silty clay loam	267.55	624.31	94.76
Al Dayr planted	A	7.490	4.87	0.466	Clay	577.13	355.16	75.47
	C1	7.461	4.66	0.553	Silty clay loam	303.35	563.38	139.76
	C2	7.433	5.08	0.568	Silty clay loam	319.27	547.32	69.5
	C3	7.566	5.56	0.524	Silty clay loam	393.01	349.34	267.46
Al Nashwa planted	A	7.458	2.70	0.859	Silty clay loam	439.56	488.4	0
	C1	7.478	6.90	0.786	Silty clay loam	376.56	585.78	50.2
	C2	7.602	8.93	0.728	Silty clay loam	334.12	525.06	119.33

Table 2. Some physical and chemical properties of the study area's uncultivated soils.

Analysis of the site	Number of layers	PH	Ec	OM	Soil Texture	Clay% g kg^{-1}	Silt% g kg^{-1}	Sand% g kg^{-1}
AbuAl- Khaseeb is uncultivated	A	7.324	16.33	0.408	Loam	256.13	486.13	302.77
	C1	7.25	6.52	0.529	Silty loam	228.11	581.79	196.03
	C2	7.390	9.66	0.364	Silty clay loam	247.42	536.08	193.8
Al Tannumah is uncultivated	C3	7.468	11.57	0.816	Silty loam	180.79	723.16	91.52
	A	7.882	40.7	0.466	Sand clay loam	258.06	214.55	537.05
	C1	7.768	16.22	0.539	Silty loam	120	800	70
Al Dayr is uncultivated	C2	7.738	12.43	0.378	Silty loam	151.15	768.85	87.62
	A	7.578	11.18	0.568	Silty loam	85.37	768.41	136.6
	C1	7.62	7.515	0.364	clay loam	465.11	465.12	77.53
	C2	7.661	3.13	0.51	Silty loam	280	560	159
AlNashwa is uncultivated	C3	7.317	4.57	0.349	Clay	894.56	42.6	34.07
	A	7.743	23.00	0.786	Silty clay loam	181.2	634.2	100
	C1	7.780	12.97	0.670	Silty clay loam	366.97	570.84	62.18

RESULTS AND DISCUSSION

The soil's physical and chemical characteristics in the study area are available in Tables 1 and 2. The soil PH has a range of 7.25–7.70. The electrical conductivity was low in the studied soil, where the EC values ranged between 2.70–33.9 dSm^{-1}. The results also showed that the percentage of organic matter in the studied samples ranged between 0.269–1.500 g kg^{-1}, between poor and medium.

The soil texture showed a different pattern because of the sedimentary environment in the following table: clay and silt content between 95.6–640 g kg^{-1}. The sand content ranged between 0–267.46 g kg^{-1} due to the site's influence helping deposit clay and fine silt in large quantities with the weak movement of the conveying water because of the distance from the main source (Manzoor *et al*., 2024). There is a gradation in textures for most soil peduncles, as the silty loam was the dominant soil (Tables 1 and 2).

The concentration of heavy elements in soil samples

Cadmium

Cadmium exists naturally in all types of organic soils, and the cadmium in the soil was between 0.1–1 mg/kg, depending on the type of parent rock, as the cadmium deposits in the upper sedimentary rock. From the defensive content of black, it also varies according to depth. The surface soil has a higher content of this coal than the surface layer. As noted in Table 3, the cadmium element ranges between 0.028–0.058 ppm for the cultivated soil, where the value was 0.028 for Abu al-Khaseeb for the surface layer A and C3, as well as the horizon C2 for al-Tannumah. Meanwhile, the value of 0.058 was for Abu al-Khaseeb horizontal C1, followed by layer A for al-Tannumah and the horizon C3 for al-Dayr. The monastery attributed the presence of cadmium in cultivated soil samples. As for the uncultivated soils, the concentration of the cadmium element ranged between 0.026–0.046 ppm for the surface layer of horizon A and C3 horizons of Abu al-Khaseeb, respectively, while the concentration was equal to 0.04 for each of the horizons A of Abu al-Khaseeb, and C1 and C2 horizons of al-Tannumah.

Copper

Copper element is among the rare elements in nature, and it occurs in all natural soils in minimal concentrations that do not exceed one ppm. The estimated Iraqi soil content of copper is 23.5–54 ppm. Its importance lies in the formation of chlorophyll and the synthesis of enzymes in plants, which constitutes about 0.1% of the weight of the plant (Abdelaziz *et al*., 2000). The concentration of the copper element ranged between 0.054–0.0248 ppm, as the low concentration was in Abu Al-Khaseeb A.

The low content of copper in the soil is because the study area is not industrial, as well as the absence of any concentration of copper in the added chemical fertilizers and irrigation water. Copper pollution refers to various human activities, such as excessive use of chemical fertilizers and poor quality irrigation water (Huang and Jin, 2008; Marković *et al*., 2010; Bhatti *et al*., 2015). The higher concentration was in the horizontal Tannumah C2 for the cultivated soils. As for the uncultivated soils, the concentration of copper was 0.021–0.120 ppm in the Horizontal A and 0.120 for the Al Tannumah, with equal concentration of the Horizontal Dayr Bedon C2 and C3 for uncultivated soils.

Zinc

The high zinc content characterizes the wastes of industrial areas, which are present in their dissolved phase and with a volume of less than 0.45 micrometers. When pollution sources are prevalent, zinc becomes one of the primary inorganic evidence. Moreover, the excretion of heavy wastewater resulting from human uses, the decomposition of organic materials, and animal wastes are sources of zinc in the river waters. Zinc, along with copper, is distinctive in its ability to remain in the solution and travel long distances without sedimentation (Ryadh 2004).

Table 3. Concentration of heavy metals in the study area's uncultivated soil.

Analysis of the site	Number of layers	Cd ppm	Cu ppm	Zn ppm	Fe ppm	Mn PPm	Pb ppm
AbuAl- Khaseeb	A	0.04	0.103	0.078	20.083	0.818	0
is uncultivated	C1	0.038	0.116	0.045	20.370	1.087	0
	C2	0.041	0.105	0.060	20.760	1.157	0
Al Tannumah	C3	0.046	0.095	0.058	21.827	1.567	0
is uncultivated	A	0.046	0.120	0.048	20.790	1.138	0
	C1	0.04	0.070	0.060	21.474	1.773	0
Al Dayr is uncultivated	C2	0.04	0.087	0.050	21.827	2.233	0
	A	0.026	0.099	0.161	18.251	1.068	0
	C1	0.033	0.070	0.132	18.362	0.612	0
	C2	0.043	0.091	0.039	20.613	1.126	0
AlNashwa is	C3	0.043	0.091	0.039	20.613	1.126	0
uncultivated	A	0.028	0.021	0.116	18.604	0.522	0
	C1	0.033	0.066	0.136	19.576	0.916	0

Table 4. The concentration of heavy metals in the study area's cultivated soil.

Analysis of the site	Number of layers	Cd ppm	Cu ppm	Zn ppm	Fe ppm	Mn ppm	Pb ppm
AbuAl- Khaseeb	A	0.028	0.054	0.118	18.825	0.623	0
planted	C1	0.058	0.068	0.153	19.653	0.886	0
	C2	0.03	0.062	0.169	20.135	1.894	0
Al Tannumah	C3	0.028	0.083	0.186	20.481	1.150	0
planted	A	0.046	0.120	0.048	20.79	1.138	0
	C1	0.03	0.140	0.159	20.701	1.305	0
Al Dayr planted	C2	0.028	0.248	0.250	21.717	2.307	0
	A	0.038	0.095	0.048	22.070	1.664	0
	C1	0.038	0.095	0.058	20.437	1.052	0
	C2	0.041	0.099	0.050	20.790	1.372	0
AlNashwa planted	C3	0.045	0.070	0.619	19.068	0.565	0
	A	0.036	0.075	0.087	19.620	0.740	0
	C1	0.038	0.09	0.064	21.96	1.025	0

The concentration of zinc in cultivated soil ranged between 0.048–0.250 ppm, with the low concentration in the Al-Tannumah and Al-Dayr beds of horizon A with a value of 0.048, and the high concentration in the Al-Tanuma field of the horizon C2 concerning cultivated soils. As for the uncultivated soils, the zinc concentration ranged between 0.039–0.161 ppm, with 0.039 in AlDayr for horizon C2 and 0.161 in AlDayr for horizon A.

Manganese

The manganese concentration in cultivated soils ranged between 0.565–2.307 ppm, as the low concentration was in Al-Dayr of horizon C3. The low content of manganese in the soil is attributable to a less industrialized study area. Meanwhile, the higher concentration was in AlTannumah of horizon C2. As for the uncultivated soils, the manganese concentration ranged between 0.522–2.233 ppm, with a low concentration in Al Nashwa at horizon A and a high concentration in Al Tannumah at horizon C2. There was an equal concentration of Al-Dyar corresponding to C2 and C3 for the uncultivated soils. The cultivated soil was probably due to the addition of chemical fertilizers. Previous reports also indicated a decrease in zinc concentration in soil samples from Accra and Ghana (Fosu-Mensah *et al*., 2017).

Table 5. Correlations of heavy elements in the study area's uncultivated soil.

Site	Pearson Correlation	The site	Cd ppm	Cu ppm	Zn ppm	Fe ppm	Mn ppm
	Sig. (2-tailed)	1	0.144	0.033	-0.082	0.328	-0.179
			0.638	0.914	0.791	0.273	0.558
	N	13	13	13	13	13	13
Cd ppm	Pearson Correlation	0.144	1	-0.281	0.069	-0.147	-0.388
	Sig. (2-tailed)	0.638		0.352	0.822	0.632	0.191
	N	13	13	13	13	13	13
Cu ppm	Pearson Correlation	0.033	-0.281	1	0.028	0.569*	0.682*
	Sig. (2-tailed)	0.914	0.352		0.928	0.042	0.010
	N	13	13	13	13	13	13
Zn ppm	Pearson Correlation	-0.082	0.069	0.028	1	-0.414	-0.170
	Sig. (2-tailed)	0.791	0.822	0.928		0.160	0.579
	N	13	13	13	13	13	13
Fe ppm	Pearson Correlation	0.328	-0.147	0.569*	-0.414	1	0.668*
	Sig. (2-tailed)	0.273	0.632	0.042	0.160		0.013
	N	13	13	13	13	13	13
Mn ppm	Pearson Correlation	0-.179	-0.388	0.682*	-0.170	0.668*	1
	Sig. (2-tailed)	0.558	0.191	0.010	0.579	0.013	
	N	13	13	13	13	13	13
Pb ppm	Pearson Correlation	a	a	a	a	a	a
	Sig. (2-tailed)	0	0	0	0	0	0
	N	13	13	13	13	13	13

Table 6. Correlations of heavy elements in the study area's cultivated soil.

Site	Pearson Correlation	Site	Cd ppm	Cu ppm	Zn ppm	Fe ppm	Mn ppm
	Sig. (2-tailed)	1	-0.597*	-0.701**	0.567*	-0.601*	-0.401
			0.031	0.008	0.043	.030	0.175
	N	13	13	13	13	13	13
Cd ppm	Pearson Correlation	-0.597*	1	0.563*	-0.884**	0.855**	0.472
	Sig. (2-tailed)	0.031		0.045	0.000	0.000	0.104
	N	13	13	13	13	13	13
Cu ppm	Pearson Correlation	-0.701**	0.563*	1	-0.461	0.401	0.273
	Sig. (2-tailed)	0.008	0.045		0.113	0.175	0.367
	N	13	13	13	13	13	13
Zn ppm	Pearson Correlation	0.567*	-0.884**	-0.461	1	-0.843**	-0.505
	Sig. (2-tailed)	0.043	.000	0.113		0.000	0.079
	N	13	13	13	13	13	13
Fe ppm	Pearson Correlation	-0.601*	0.855**	0.401	-0.843**	1	0.808**
	Sig. (2-tailed)	0.030	0.000	0.175	0.000		0.001
	N	13	13	13	13	13	13
Mn ppm	Pearson Correlation	-0.401	0.472	0.273	-0.505	0.808**	1
	Sig. (2-tailed)	0.175	0.104	0.367	0.079	0.001	
	N	13	13	13	13	13	13
Pb ppm	Pearson Correlation	c	c	c	c	c	c
	Sig. (2-tailed)	0	0	0	0	0	0
	N	13	13	13	13	13	13

Table 7. Analysis of variance.

Mn_3	Treatment groups	Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	0.662	3	0.221	0.826	0.512
	Within Groups	2.405	9	0.267		
	Total	3.067	12			
Fe_3	Between Groups	3.280	3	1.093	1.037	0.422
	Within Groups	9.487	9	1.054		
	Total	12.767	12			
Zn_3	Between Groups	0.019	3	0.006	0.212	0.886
	Within Groups	0.264	9	0.029		
	Total	0.283	12			
Cu3	Between Groups	0.020	3	0.007	5.638	0.019
	Within Groups	0.011	9	0.001		
	Total	0.030	12			
Cd3	Between Groups	0.000	3	0.000	0.235	0.870
	Within Groups	0.001	9	0.000		
	Total	0.001	12			
Mn_4	Between Groups	1.437	3	0.479	3.729	0.054
	Within Groups	1.156	9	0.128		
	Total	2.593	12			
Fe4	Between Groups	9.950	3	3.317	3.683	0.056
	Within Groups	8.103	9	0.900		
	Total	18.053	12			
Zn4	Between Groups	0.009	3	0.003	2.028	0.181
	Within Groups	0.013	9	0.001		
	Total	0.021	12			
Cu4	Between Groups	0.005	3	0.002	5.144	0.024
	Within Groups	0.003	9	0.000		
	Total	0.008	12			
Cd4	Between Groups	0.000	3	0.000	2.313	0.145
	Within Groups	0.000	9	0.000		
	Total	0.000	12			

Iron

Iron is one of the common elements in the rocks and soils of the earth's crust necessary for the growth of plants and animals. It is harmless because of its spontaneous oxidization to un-dissolved iron. Its concentration in groundwater reaches less than 0.5 ppm, and its concentration may reach 10 ppm when its pH is less than 8, especially in an acidic environment. The degree of its solubility in water also depends on the pH value of the oxidation rate, and the properties of iron and its concentration vary according to depth (Plasmans *et al*., 2007).

Lead

Lead is one of the dangerous heavy elements, characterized by its weak movement in the soil compared with other elements. Its natural amount in the soil is 13-17 ppm. Agricultural soils generally have a value of less than 32 ppm for the type of parent rock on which the soil originated. Among the heavy elements studied in cultivated and uncultivated soil samples was lead, which was undetected in soil samples (Tables 3 and 4). The possible reason for this is due to the use of groundwater irrigation and lead-free chemical fertilizers. The study area is also far from any source of these elements, such as heavy traffic, industrial processes, or the use of any wastewater types for irrigation, which likely has lead contaminants.

Relationship among the studied elements

Correlation Tables 5 and 6 and 7 show a significant positive correlation between the copper element with iron and manganese, with values of 0.569 and 0.682, respectively, for the cultivated soils. The amount of iron in the studied soils was the maximum among the heavy elements studied, consistent with the results of Jena *et al*. (2013), where they measured the content of different soils containing several heavy elements. In uncultivated soils, only an exceptionally significant positive correlation between iron with both cadmium and manganese occurred with values of 0.855** and 0.808**, respectively, and a significant negative correlation between zinc and cadmium -0.884. Likewise, a notable negative correlation emerged between cadmium and copper, with values of 0.563*, while a highly significant negative correlation between zinc with both cadmium and iron (-0.884** and -0.843**, respectively).

CONCLUSIONS

A large discrepancy in the studied soil element concentration values appeared between the cultivated and the uncultivated soils, as the laboratory analysis results showed they were within the permissible limits. The percentage in uncultivated soil increased in some heavy element concentrations, especially iron, while without lead effect. The heavy elements concentration in the cultivated soils of Basra was less than in the international soils. The analyses showed a high rate of clay and silt values for all samples, which made the studied soils a mixture of clay and silty, with low permeability and little aeration, reducing the self-decomposition of pollutants. The soil-heavy elements were within the permissible limits except iron. The arrangement of the elements according to their concentration was Fe > Mn > Cu > Cd > Zn > Pb.

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