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Assessment of heavy metals contamination of agricultural soils using pollution indicators in Thi-Qar governorate, Southern Iraq

1st Amal Ahmed Salem
Department of Chemistry, College of Science, University of Thi-Qar
Thi Qar, Iraq
amalahmadsalem1995@gmail.com

2nd Saher Abdulridha Ali
Department of Chemistry, College of Science, University of Thi-Qar
Thi Qar, Iraq
Saher21211@sci.utq.ed.iq

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***Abstract*—This study aims to assess the levels of contamination of agricultural soils with heavy elements (cobalt, copper, iron, nickel, cadmium, and lead) in three regions in Thi-Qar Governorate, Southern Iraq. These three regions are Al-Gharraf, Al-Islah, and Al-Batha. The study was done by using the pollution indicators, which are geographical pollution index (Igeo), contamination degree (Cd), contamination factor (Cf), pollution load index (PLI), potential ecological risk factor (Er), and finally, risk index (RI). From each region, four soil samples were collected from holes 25 cm deep, separated by a distance of 500 meters. After the digestion process of the samples, the concentrations of the studied elements were measured by flam atomic absorption spectrometer (FAAS). The results showed that the average heavy metal concentrations for all samples were (365.810, 96.424, 41.36, 11.919, 5.194 and 0.352 mg/kg). They were in the following order Fe > Ni > Cu >Co > Pb > Cd, respectively. The concentrations of heavy metals in the study areas were all within the limits allowed by the World Health Organization (WHO) except for 8.3% of the studied areas that were beyond the permissible limits for cadmium only. The reason for the increase in cadmium concentrations in some areas could be due to sewage, industrial emissions and agricultural practices. According to the Igeo values, the levels of minerals studied for the three regions followed the following order Cd > Cu > Co > Pb > N i> Fe. It was noted also that the maximum value of the pollution factor (Cf) is at the S10 site of the element cadmium, which is equal to 120, indicates that this soil is highly polluted, while it was noted that the minimum level of Er is in the site of soil S11 for the element nickel, which is equal to 0.425, and indicates that this site is low in pollution. By calculating the values of all the indicators that were calculated during the study, it was found that the agricultural soils that were studied in Thi-Qar Governorate are not polluted by the elements Pb, Cu, Co, Ni and Fe except for cadmium, as the soils were low to highly polluted with this element.**

***Keywords*— heavy metals, contamination, Thi-qar, Geo-accumulation Index, Contamination factor CF.**

I. INTRODUCTION

Soil degradation is global environmental phenomena that has varied interpretations in different locations [1]. Soil degradation refers to the degradation of the natural quality of any ecosystem's soil component [2]. Heavy metals, which are considered acute and hazardous environmental hazards, are one of the most prominent contributors of soil pollution. Any metal considered as hazardous or toxic is referred as a heavy metal. Toxic heavy metals (THM), which include lead (Pb), chromium (Cr), iron (Fe), cadmium (Cd), and nickel (Ni), contaminate agricultural soils and crops, such as garden vegetables, grains, and fruits, as a result of their adverse side effects from their persistence and non-biodegradability. Heavy metals (HM) are defined as transitional metals with high molecular masses, particular high density greater than 5 g/cm3, and adverse effects on ecosystems and living organisms [3,4]. These metals are emitted in low concentrations by natural soil-forming processes such as parent rock weathing and pedogenic processes. They are also emitted in high concentrations by anthropogenic sources (such as industrial, urbanization, and agricultural processes), domestic effluent, fossil fuel combustion, and atmospheric depositions [5].

Source rocks and soil characteristics have an influence on the accumulation of heavy metals in the soil. Heavy metals vary in their mobility and availability depending on their origin. For example, metals of lithogenic origin are less mobile since they are primarily related to primary minerals, but heavy metals from anthropogenic sources are typically more mobile [6,7].

Plant growth and yield would be impacted by heavy metals in the soil, metals such as copper (Cu), lead (Pb), chromium (Cr), iron (Fe), cadmium (Cd), and nickel (Ni), are hazardous to most of the plants and other organisms at greater concentrations. Besides the health risks in crops, numerous researches revealed that the exposure to heavy

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metals is related with a wide range of human ailments [8]. For instance, eating food contaminated with Cd can lead to both short-term and long-term health issues, such as arterial issues. Ingestion of Ni can result in cardiac arrest, exhaustion, heart problems, and respiratory disorders. High amounts of copper (Cu) exposure causes damage to the brain, kidneys, liver, and intestinal lining. The most prevalent HMs found in vegetables, Pb and Cd, can cause a number of health problems, including kidney, bone, and heart damage. Once heavy metals reach the body through the food chain, human health is in danger. Finally, eating food contaminated with heavy metals from soils contaminated with heavy metals poses a risk to human health [3,9].

Due to the dilemma of heavy metals accumulation in the soil which represent a real threat facing humanity and the multiplicity of their sources, and the study areas are scarce in such studies, the current study sought to evaluate the contamination of agricultural soils with some heavy elements using pollution indicators..

II. THE AREA OF THE STUDY

Thi-Qar governorate is situated in southern Iraq and it has the coordinates, latitude and longitude:31°2'38"N / 46° 15'27" E. The area of Thi–Qar is around 12900 Km2. Its map is showed in Figure 1, bordering five governorates and the five governorates are Basra governorate to the south and south-east, Wasit governorate to the north, Maysan governorate to the east, Muthanna governorate to the west, and finally, Qadissiya governorate to the north-west. Thi-Qar consist of five administrative districts and nineteen sub-districts and the five administrative districts of Thi-Qar are Suq AL-Shuyukh, Nasiriyah, Chibayish, Rafei, and Shatrah. There are about 2 million people living in Thi-Qar, both in the city and in rural areas. The governorate of Thi-Qar is situated in an arid region climatically and the winters are mild, while the summers are hot. This region experiences mostly sunny days. In certain cases, July and August temperature records surpassed 51°C (123°F), and zero in January during winter. Al-Bathah, Al-Islah and Al-Garaf are the three areas in Thi-Qar governorate that are the subject of the research [10].

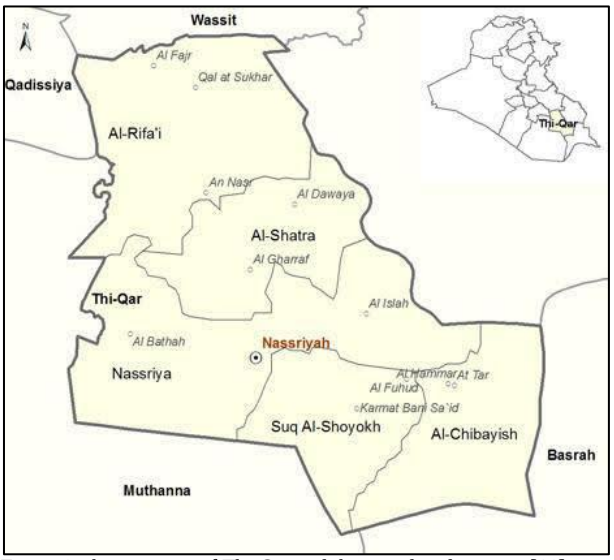

Figure 1: shows a map of Thi-Qar and the sampling locations [11].

III. EXPERIMENTAL PART:

A. *The collection of Samples*

Sampling was carried out from November 2022 to March 2023 from three areas of agricultural soil in Thi-Qar governorate. The three areas are Al-Bathah, Al-Islah and AlGaraf. Four soil samples from each area was collected from pits located at a distance of 500 m from each other and soil samples were characterized by (S1–S12). Samples were taken from the topsoil (10–25 cm depth) of farms during planting season and the collected samples were stored in a polyethylene bag at room temperature and air-dried for 72 hours. After air drying, samples were passed through 1 µm sieve to remove large debris, stones, and pebbles, and then they were stored in plastic containers and sent to the laboratory for digestion.

B. Digestion of Samples

2 g of pulverized soil samples were weighed in a 100 ml clean beaker using a sensitive balance and then digested on a heated plate for 4 hours after adding 16 ml of acidic solution (aqua regia) (1:3 HNO3:HCL). After cooling the mixture to the laboratory temperature, it was filtered through a cellulose acetate membrane with a mesh size of 45 µm, then the filtrate was diluted with deionized water to a volume of 50 ml using a 100 ml clean volumetric flask.. The total concentrations of Cd, Co, Cu, Ni, Pb, and Fe were determined by using flame atomic absorption spectrometer (FAAS) [12,13].

IV. ASSESSMENT OF SOIL POLLUTION LEVELS

Several indicators have been used to determine the degree of soil contamination with heavy metals. These indicators were set using the values of geochemical reference of the earth's crust. In this study, six indicators were used to assess soil pollution in Thi-Qar Governorate. The six indicators are Cf, Cd, PLI, Igeo, Er, and RI.

A. Contamination factor and degree of contamination

Contamination factor (Cif) is defined as the ratio of the measured concentration of heavy metals in the soil to the reference value for the same metal in the soil, and it is used to determine the level of pollution in the surface layer of the soil. Degree of contamination (Cd) is the sum of all contamination factor values for all soil sample sites [14]. The following are the computation equations for the contamination factor (Cif) and the degree of contamination (Cd):

$$Cif = Ci / Cin \quad \text{..... (i)}$$

$$Cd = \sum n1\ Cf \quad \text{..... (ii)}$$

(Ci) is the measured concentration of the heavy elements in soil, while (Cin) is background concentration of heavy metals in (mg/Kg) in the crust of earth.

Table 1: Background concentration of heavy metals in (mg/Kg) in the crust of earth [15,16].

Metals	Cd	Pb	Ni	Co	Cu	Fe
Background concentration of metal (PPm)	0.15	14	84	20	60	19617

The contamination factor and degree of contamination were divided into groups by Hakanson. The levels of contamination factor are characterized as C^i_f<1→ (low); 1 ≤ C^i_f < 3 → (moderate); 3 ≤ C^i_f<6→ (considerable) and C^i_f ≥ 6→ (very high). The degree of contamination defines the quality of the environment in the following values Cd<8 → (low); 8 ≤ Cd<16→ (moderate); 16 ≤ Cd<32→ (considerable) and Cd ≥ 32 → (very high) [17].

B. Pollution load index

According to Tomlinson et al., pollution load index was used to measure the extents of soil contamination with heavy metal, and the equation is as follows [18]:

PLI is equal to (Cf 1 × Cf 2 × Cf 3 × …. × Cf n) $^{1/n}$ …….(i v)

Where, n is the number of metals in this study and C^i_f is the contamination factor. The PLI of each element is divided into (PLI ≤ 1) → low, (1 < PLI ≤ 3) → middle and (PLI > 3) → high [19].

C. Geo accumulation index

The relationship between soil`s heavy metals values and reference geochemical values represents the index of geo accumulation (Igeo), which was suggested by muller to evaluate soil pollution [20]. The computation formula is:

Igeo = In (Cn /1.5Bn) …….. (vii)

Where (C_n) is the measured concentration of the studied elements and (B_n) is the geochemical background content of the same elements. The background matrix correction factor resulting from impacts of lithogeny is 1.5. This factor is added to reduce the impact of any potential changes in background values that could be attributed to anthropogenic effects. The following are the soil classifications that are based on the Igeo [21]:

(i) Igeo>5→ extreme contamination, (ii) 4–5→ strong to extreme contamination, (iii) 3–4→ strong contamination, (iv) 2–3→ moderate to strong contamination, (v) 1–2→ moderate contamination, (vi) 0–1→uncontaminated to moderate contamination, (vii) <0→ uncontamination [20].

D. Potential ecological risk factor (Er) and risk index (RI)

Using the possible ecological risk index, the characteristics and environmental behavior of heavy metals contaminants in soil are evaluated. The fundamental objective of this strategy, which was initially proposed, is to pinpoint the contaminating agents. The sum of all risk factors for identifying contamination with heavy metals in the soil is known as the RI. The RI is calculated using the following formulae [22]:

$C_r^i = C^i / C_n^i$

$E_r^i = T_r^i \times C_r^i$

$RI = \sum_{i=1}^{n} Er$

Where T^i represents the toxicity index of a single heavy element, and RI, E_r^i indicate the total potential ecological danger and the potential ecological risk of a single heavy metal, respectively.

Table 2: Toxic response factor (TR) values for several metals [23].

Metals	Cd	Pb	Ni	Co	Cu	Fe
T_R	30	5	5	5	5	-------

Cni is the background value of metal n in the soil sample, and Ci is the measured concentration of metal n in the soil sample. The conditions used to indicate risk factors and RI are divided into:

(i) Eir<40 → low (ii) 40<Eir80 → moderate, (iii) 80<Eir<160 → significantly high, (iv) 160< Ei r<320 → high, (v) Ei r > 320→ very high, (vi) RI<95→ low, (vii) 95<RI<190→ moderate, (viii) 190<RI<380→ significantly high, and (ix) RI>380→ very high [17].

V. RESULTS AND DISCUSSION

A. Content of heavy metals

Concentrations and the general concentrations average of heavy metals in Thi-Qar governorate soils are showed in Table 3 and Figures (2,3,4,5,6,7,8) . The general average of the concentrations of the metals in all the study regions were (365.810, 41.36, 11.919, 9.642, 5.194, 0.352 mg kg-1), and they were in the following order Fe > Cu > Co > Ni > Pb > Cd, respectively.

The concentrations of cadmium in the agricultural soils under study showed that they are less than the permissible limit set by the World Health Organization (WHO) (0.5 mg/kg) [24] in some regions, and some of them are greater than the permissible limit in other regions (Al-islaah region).

The reason for the increase in the concentrations of cadmium in some areas can be due to waste, industrial emissions, and agricultural practices. Irrigation water also plays an important role in transporting cadmium to the soil, and its accumulation over time leads to an increase in the soil content of cadmium [25].

Ni, pb, Cu, and Fe, concentrations in study regions were all lower than the WHO mentioned limits of (50 mg/kg), (100 mg/kg), (100 mg/kg), and (50000 mg/kg), respectively [24]. In general, the reason for the decrease in heavy metals in the soil could be due to the fact that the study area is not industrial and also because there is no high concentration of the metals in the added chemical fertilizers and irrigation water, so there is no clear source of pollution with these elements.

In view of the lack of human activities that can increase the concentrations of heavy metals in Dhi Qar governorate, we note that the concentration of heavy metals in the current study is lower than previous studies in Saudi Arabia and Basra [26,27]. and it is also higher than in the areas of Babel in Iraq [28].

Table 3: The concentrations of heavy metals in Thi-Qar governorate areas.

Area	Sample name	Concentration (mg/kg)					
		Cd	Pb	Co	Ni	Cu	Fe
Battha	S1	0.275	9.375	6.775	9.565	40.150	299.525
	S2	0.200	7.950	15.825	9.222	30.900	147.075
	S3	0.350	8.400	8.400	12.015	30.050	64.975
	S4	0.275	8.575	10.333	10.267	33.700	170.525
Al Garaf	S5	0.425	2.825	16.800	9.455	48.425	456.350
	S6	0.450	3.275	12.825	9.727	36.800	255.875
	S7	0.250	2.900	10.650	10.310	33.325	331.275
	S8	0.375	3.000	13.425	9.664	39.510	347.830
Al Islaah	S9	0.325	2.550	15.300	10.645	33.300	681.350
	S10	0.600	4.075	12.900	8.782	52.650	477.825
	S11	0.300	5.400	7.800	7.185	66.650	578.050
	S12	0.408	4.008	12.000	8.870	50.860	579.075
	mean	0.352	5.194	11.919	9.642	41.36	365.810

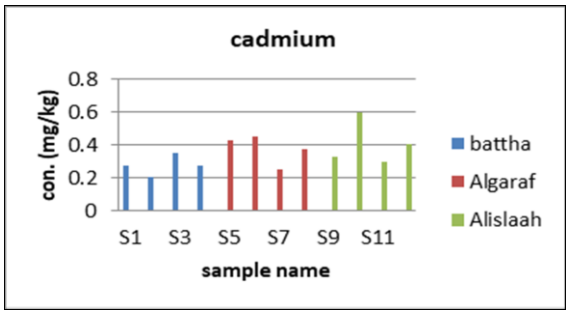

Figure 2 :concentrations of cadmium in the soil

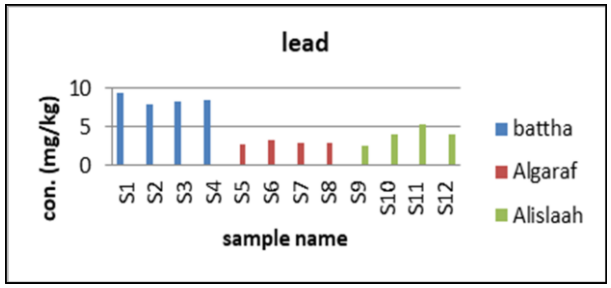

Figure 3:concentrations of lead in the soil

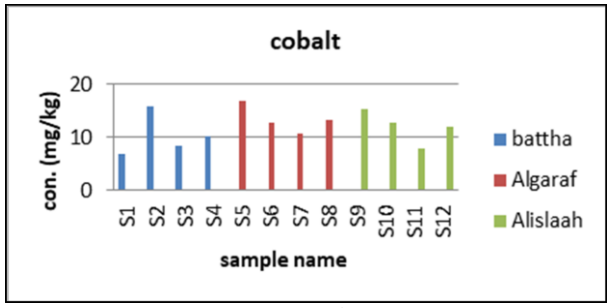

Figure 4 :concentrations of cobalt in the soil

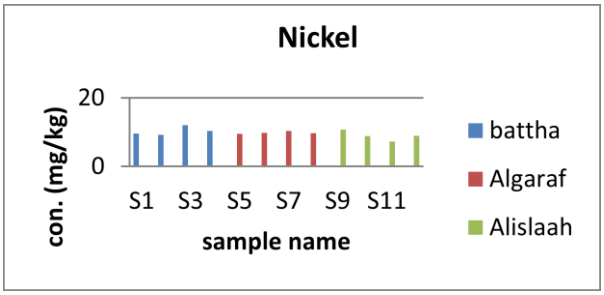

Figure 5 :concentrations of nickel in the soil .

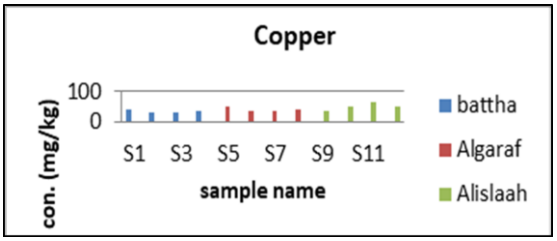

Figure 6:concentrations of copper in the soil .

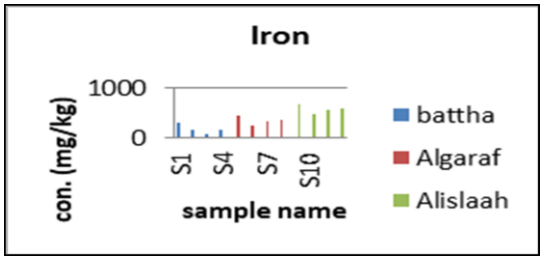

Figure 7:concentrations of iron in the soil .

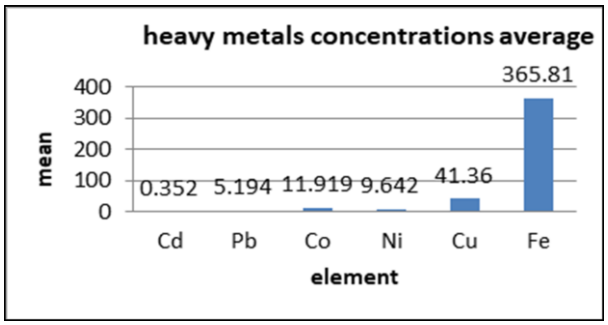

Figure 8: heavy metals concentrations average in the soil

B. Contamination factor (Cf) and degree of contamination (Cd) and pollution load Index (PLI)

The average CF values for heavy metals (Cd,Pb,Co,Ni,Cu,Fe) in the soil of Thi-Qar are (2.350, 0.370, 0.595, 1.147, 0.688, 0.018), respectively. The maximum value of the contamination factor for Cd was found in the soil at site S10, which equals 4. This indicates that this soil is significantly contaminated because 3 ≤ Cif <6, while the minimum CF was found for Fe at soil site number 3, which equals 0.003. This indicates that this site is lowly contaminated because Cf <1. For pb, Co, Cu, Ni and Fe, there was a little contamination in all studied soil sites. The values of the contamination factor (Cf) depend on the reference values of the elements, and these values are variable according to their sources. For example, the reference value for cadmium is 0.15 [15] and its value according to [29] is 0.8, so the pollution factor for cadmium is according to the first value is greater than 1 in 83.3% of the soil sites and means that it is moderately polluted, while as for the second value, it is slightly polluted. S6 and S10 are considerable contaminated in Cd. Pollution may be attributed to household waste or fertilizers and agricultural pesticides, in addition to high temperatures and winds that work to

transport pollutants over long distances, which over time lead to increased soil pollution with cadmium [7,30]. According to Table 4, the soil site S10 had the highest value for the degree of contamination, which is 5.936 while the soil site S7 had the lowest value for the degree of contamination, which is 3.09. Every site's PLI value is less than 1, as shown in Table 4, which is not considered heavy elements contamination.

Table 4: Contamination factor (CF), Degree of contamination(Cd) and pollution load Index(PLI) of soil samples collected from Thi-Qar.

Area	Sample name	Contamination factor CF						(Cd.)	PLI
		Cd	Pb	Co	Ni	Cu	Fe		
Battha	S1	1.833	0.669	0.33	0.113	0.669	0.015	3.629	0.277
	S2	1.333	0.567	0.79	0.109	0.515	0.007	3.321	0.248
	S3	2.333	0.6	0.42	0.143	0.500	0.003	3.999	0.223
	S4	1.833	0.612	0.51	0.122	0.561	0.008	3.646	0.260
Al- Garaf	S5	2.833	0.201	0.84	0.112	0.807	0.023	4.816	0.315
	S6	3.00	0.233	0.64	0.115	0.613	0.013	4.614	0.272
	S7	1.66	0.207	0.53	0.122	0.555	0.016	3.09	0.241
	S8	2.5	0.214	0.67	0.115	0.658	0.017	4.174	0.277
Al- Islah	S9	2.166	0.182	0.76	0.126	0.555	0.034	3.823	0.298
	S10	4.00	0.291	0.64	0.104	0.877	0.024	5.936	0.343
	S11	2.00	0.385	0.39	0.085	1.110	0.029	3.999	0.304
	S12	2.72	0.286	0.60	0.105	0.847	0.029	4.587	0.326
	Mea.	2.350	0.370	0.593	0.114	0.688	0.018	4.136	0.282

C. Geo-accumulation index

Table 5 contains a list of values (Igeo) of each metal for all sites where soil samples were taken. At all areas of the studied soil, we found values that ranged from practically unpolluted by pb, Co, Ni, Cu, and Fe to moderately and sometimes significantly unpolluted by Cd. The average Igeo values for the heavy metals were arranged in the following level: Cd, Cu, Co, Pb, Ni, and Fe.

Table 5: Geo-accumulation Index (I-geo values) of heavy metals in the soil of Thi Qar area.

Area	Sample name	Geo-accumulation Index					
		Cd	Pd	Co	Ni	Cu	Fe
Battha	S1	0.200	-0.806	-1.487	-2.578	-0.807	-4.587
	S2	-0.117	-0.971	-0.639	-2.614	-1.069	-5.298
	S3	0.441	-0.916	-1.270	-2.350	-1.096	-6.115
	S4	0.200	-0.895	-1.060	-2.507	-0.982	-5.150
Al- Garaf	S5	0.635	-2.006	-0.579	-2.589	-0.619	-4.166
	S6	0.693	-1.858	-0.849	-2.561	-0.894	-4.744
	S7	0.105	-1.979	-1.035	-2.503	-0.993	-4.486
	S8	0.510	-1.945	-0.804	-2.567	-0.823	-4.347
Al- Islaah	S9	0.367	-2.108	-0.673	-2.471	-0.994	-3.765
	S10	0.980	-1.639	-0.843	-2.663	-0.536	-4.120
	S11	0.287	-1.358	-1.347	-2.864	-0.300	-3.292
	S12	0.595	-1.656	-0.916	-2.653	-0.570	-3.928
	mean	0.408	-1.511	-0.958	-2.576	-0.806	-4.499

D. Potential environmental risk factor (Er) and risk index (RI)

The environmental risk values for various heavy metals in the soil samples of Thi Qar governorate are showed in Table 6. It shows that the highest value for Cd was noted at site S10, which equals 120, representing that this soil is significantly high because $80 < E^{i}_{r} < 160$, while the lowest ER was noted for Ni at site S11, which equals 0.425, representing that this site is low contamination because $E^{i}_{r}<40$. Low contamination levels were found at all soil sites for lead, cobalt, nickel, and copper in the current study. Except for soils of sites S5, S6, S10, and S12, which had significantly high pollution for cadmium, and other soil sites in cadmium were moderately contaminated. Pesticides and fertilizers used and atmospheric deposition of combustion emissions, may be the cause of the extremely high Cd contamination [31]. As shown in Table 6, the soil of site S2 was equal to 49.905, got the lowest value for RI, suggesting that this soil is low contamination because RI<150, whereas the soil of site S10 was equal to 129.56, obtained the highest value of RI, representing that this soil is moderate contamination.

Table 6: The values of the environmental risk factor and the potential environmental risk index of the trace elements in the surface soil of the study area.

Area	Sample name	Potential ecological risk factor (Er)					
		Cd	Pb	Co	Ni	Cu	RI
Battha	S1	54.99	3.345	1.65	0.565	3.345	63.895
	S2	40	2.835	3.95	0.545	2.575	49.905
	S3	69.99	3	2.1	0.715	2.5	78.305
	S4	54.99	3.06	2.55	0.61	2.805	64.015
Al- Garaf	S5	84.99	1.005	4.2	0.56	4.035	94.79
	S6	90	1.165	3.2	0.575	3.065	98.005
	S7	49.8	1.035	2.65	0.61	2.775	56.87
	S8	75	1.07	3.35	0.575	3.29	83.285
Al- Islaah	S9	64.98	0.91	3.8	0.63	2.775	73.095
	S10	120	1.455	3.2	0.52	4.385	129.56
	S11	60	1.925	1.95	0.425	5.55	69.85
	S12	81.6	1.43	3	0.525	4.235	90.79
	mean	70.528	1.852	2.966	0.571	3.444	79.363

V. CONCLUSIONS

1. The general average of the concentrations of the elements in all the study regions were (365.810, 41.36, 11.919, 9.642, 5.194, 0.352 mg kg-1), and they were in the following order (Fe > Cu > Co > Ni > Pb> Cd), respectively.
2. All elements are within the permitted limits of WHO, except 8.3% of the studied areas were higher than the permissible limits for cadmium only.
3. The highest contamination factor for Cd was found in the soil at site number 10, which equals 4, while the lowest CF for Fe was found at site number 3, which equals 0.003.
4. The highest result for the degree of contamination was noted at soil site number 10, while the lowest value was at soil site number 7.
5. The level of the metals studied was in the following sequence, according the values (Igeo): Cd, Cu, Co, Pb, Ni, and Fe.
6. The maximum ecological risk (ER) for Cd was

recorded in soil at site number 10, which equals 120, representing that this soil, is extremely high. In contrast, the minimum ER for Ni was recorded at site number 11, which equals 0.425, showing that this site is minimal in pollution.

7. By assigning the values of all the indicators that were calculated during the study, it was found that the agricultural soils that were studied in Thi-Qar are not contaminated with the elements Pb, Cu, Co, Ni and Fe, except cadmium, as these values indicated that the soil was contaminated with this element, between low pollution to considerable pollution.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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