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Geo-Environmental Evaluation of Shewasoor Soil, Kirkuk/ NE Iraq

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Abstract

The present research aimed to evaluate contamination levels of soil by heavy metals. Eight sites were selected for the collection of soil samples. The soil samples analyzed for eight heavy metals namely As, Pb, Cd, Cr, Co, Cu, Ni, and Zn by using ICP-MS technology. The spatial distribution patterns of environmental assessment factors and indices were drawn using Geographic Information Systems (GIS), which is gives understanding for the geographical distribution of contamination levels in the area. The heavy metals contamination assessed by using several environmental factors and indices: Contamination Factor, Degree of Contamination, Pollution load Index, Enrichment Factor, Geo-accumulation Index, Nemerow Index. The environmental factors and indices showed that the soil was moderate to heavily contaminated by studied heavy metals. The EF values indicated that the metals Pb, Cr, Co, Cu, and Zn were enriched from natural sources, while the metals As, Cd, and Ni were enriched from anthropogenic sources.

Keywords: Geo-Environment, Heavy Metals, Soil, Shewasoor.

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التقييم الجيوبيئي لتربة شيواسور، كركوك/ شمال شرقي العراق

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الملخص

يهدف البحث الحالي إلى تقييم مستويات التلوث في التربة بالعناصر الثقيلة. تم اختيار ثمانية مواقع لأخذ نماذج التربة. تم تحليل ثمانية عناصر ثقيلة وهي زرنيخ، رصاص، كادميوم، كروم، كوبلت، نحاس، نيكل، و زنك في نماذج التربة باستخدام تقنية ICP–MS . و تم رسم أنماط التوزيع المكاني لعوامل و مؤشرات التقييم البيئي باستخدام نظم المعلومات الجغرافي (GIS) و التي تبين التوزيع الجغرافي لمستويات التلوث في المنطقة. تم تقييم تلوث العناصر الثقيلة باستخدام عدة عوامل ومؤشرات بيئية: عامل التلوث، درجة التلوث، مؤشر حمل التلوث، عامل الإغناء، مؤشر التراكم الجيولوجي، مؤشر نيمرو، و التي أظهرت أن تلوث في تربة المنطقة الدراسة يتراوح بين معتدل إلى عالي بالعناصر الثقيلة المدروسة. أظهرت قيم عامل الإغناء إن عناصر رصاص، كروم، كوبلت، نحاس، و زنك من مصادر طبيعية، في حين قد يكون إغناء العناصر زرنيخ، كادميوم، نيكل من مصادر بشرية المنشأ.

الكلمات الدالة: جيو بيئي، عناصر الثقيلة، تربة، شيواسور.

Kirkuk University Journal /Scientific Studies (KUJSS)
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1. Introduction

The Pollution and contamination are substances or metals that introduce into the environment have harmful effects or usually poisonous to human and ecosystem. The soil is natural body comprises of solids, liquid, and gases, it's consists of the land surface and occupies space from earth surface [1]. The pollutants introduced into the soil via several pathways [1, 2]. Heavy metals are type of trace elements that are group of metals and semi-metals with atomic mass greater than that of sodium and density above (3.5-6) g/cm^3 [1, 3]. The main sources of heavy metals [1, 4-9] are: 1) Natural or geological sources, including weathering, erosion and deposition. 2) Anthropogenic sources, including atmospheric deposition, wood combustion, land application of sewage sludge, animal manure and other organic wastes, agricultural application of fertilizers and pesticides, and fossil fuel combustion. The pollution of soil with heavy metals is one of the most environmental problems, because it is related directly to food chain security and the human health [10, 11, 12]. Fertilizers play an essential role in increasing food production. Some inorganic fertilizers are containing contaminant metals, metalloids and radionuclides (e.g. Phosphatic, nitrogenous and Potassic fertilizers). Application of these fertilizer in the agricultural lands lead to increase the heavy metals concentration in the soil and in the agricultural crops [3, 13]. Heavy metals concentration and distribution in the soil influences by soil type, topography, geology and the erosive processes [14, 15]. According to field observations in the Shewasoor area there are many natural and anthropogenic sources that are contributes to pollute the soils of study area by heavy metals are:1) Quarries 2) Large areas of geological outcrops 3) Agricultural lands 4) livestocks breeding (Cattles, Sheeps, and Poultry) 5) discharges of waste water and sewage sludge. This study aimed to: 1) Determine the levels of heavy metals in the soil of study area. 2) Environmental assessment of soil of the study area by using several indices and factors including: Index of geo-accumulation, Nemerow index, Contamination factor, Degree of contamination, Pollution load index, Enrichment factor, Potential ecological risk index, Nemerow pollution index.

2. Study Area:

The study area is located to the northeastern part of Kirkuk governorate/ NE Iraq, between longitudes (44° 30' 0.1"- 44° 40' 41.06") and latitudes (35° 41' 25"- 35° 51' 40.2"). Which lies about 39 Km from Kirkuk city, covers about 160 km^2. The study area bounded by Taqtaq Anticline from north and northeast sides, by Northern Chamchamal Anticline from west and

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southwest sides, and by topographic elevated area from south and southeast sides Fig. 1. Also, the topographic elevations of the study area ranges between (311-1186) m a.s.l.

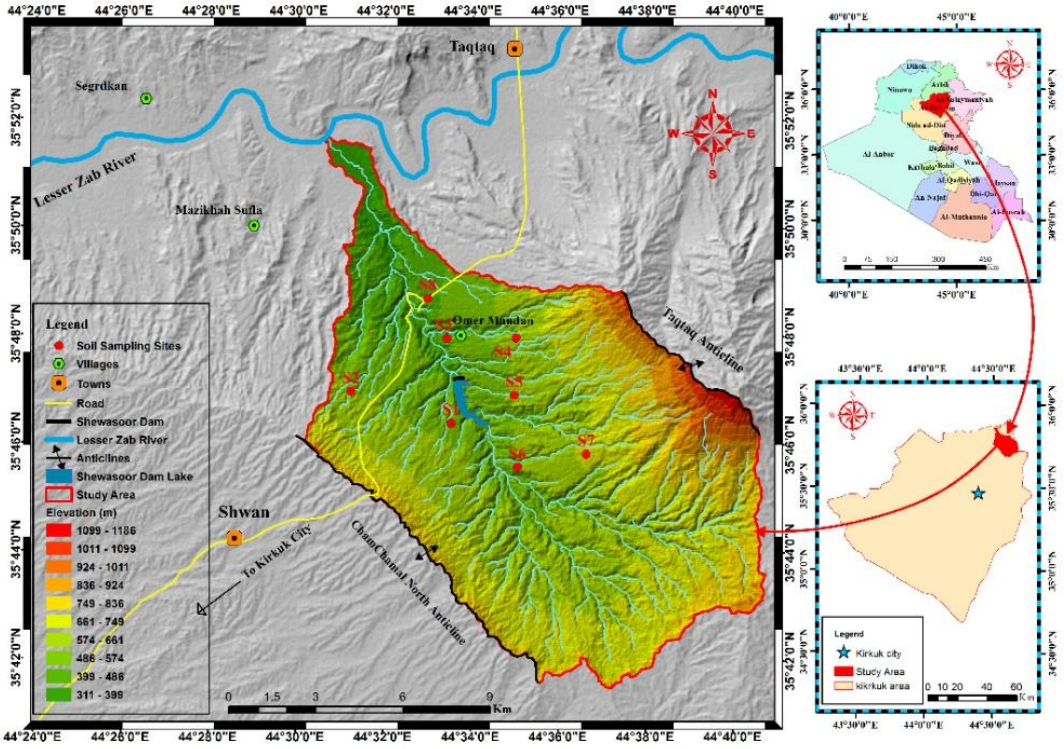

Fig. 1: The Location of Study Area and Soil Sampling Sites.

2.1 Tectonic and Geological Setting:

The study area lies in the Unstable shelf within Foothill zone in Chamchamal-Arbil subzone according to [16] tectonic division of Iraq. It has stratigraphic sequence extending from oldest (Upper Miocene) up to youngest (Quaternary deposits) [17]. The exposed formations Fig. 2 are:

Injana Formation: (Upper Miocene), it consists of gray, brown sandstone, brown claystone and siltstone of the same colour [17]. The thickness of this formation is 2000m in the center of depositional basin within Foothill zone [18].

Mukdadiya Formation: (Upper most Miocene-Pliocene), it consists of brown claystone with gray coarse-grained sandstone, brown and gray siltstone, and pebbly sandstone [17]. Its thickness is more than 2500m in the center of the depositional basin within Foothill zone [18].

Kirkuk University Journal /Scientific Studies (KUJSS)
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Bai-Hassan Formation: (Pliocene), it consists of thick and coarse conglomerates, thick brown claystone and thin sandstone [17]. Its thickness is more than 2000m in the center of depositional basin within Foothill zone [18].

Quaternary Deposition: (Pliocene-Holocene), Six types of quaternary deposits are developed in the study area, are: River terraces, Polygenetic deposits, Slope deposits, Residual gravels, Floodplain, and Valley-fill deposits [17].

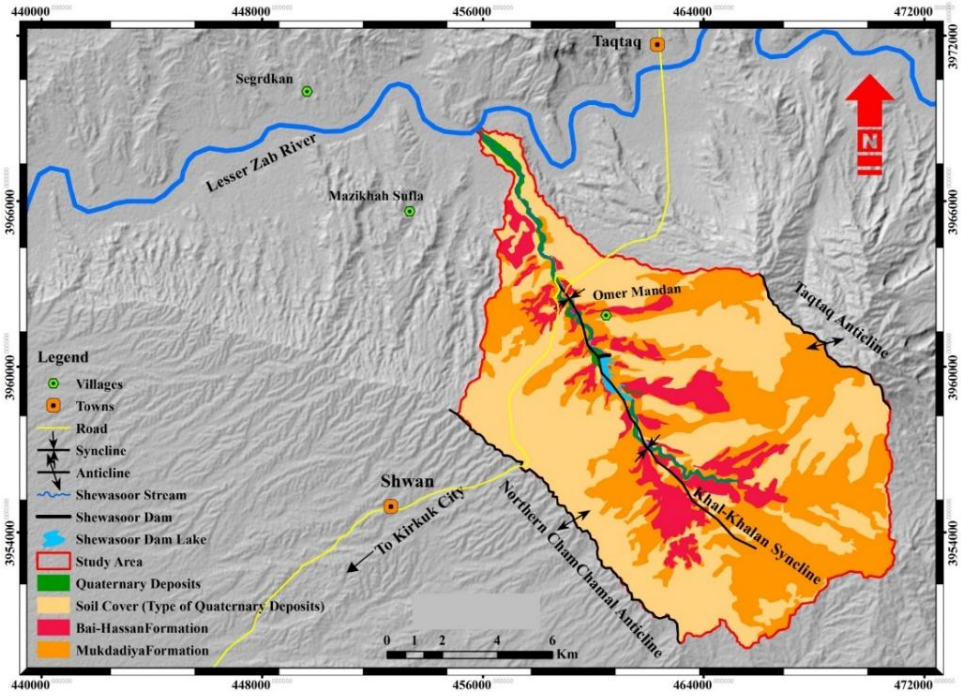

Fig. 2: Geological Map of the Study Area.

3. Materials and Methods:

3.1 Sampling and Analysis:

3.1.1 Collection of Samples: Soil samples were collected from eight sites within the study area as shown in Fig. 1 at Oct 2016. Before the sampling (Fieldwork) start, the stratified random sampling method was selected, where the study area is divided into a grid of egalitarian squares and soil samples were taken randomly from each square from (0-20) cm depth, the samples were placed in clean and new polythene bags. The large empty area in the sampling map represent the geological outcrops.

3.1.2 Preparation of Samples: Soil samples were air-dried at room temperature and sieved by (200 mesh) sieve in order to separate and remove all course materials. The weighted 2 gm of samples and placed in small polythene bags, then they were transferred to the laboratory.

Kirkuk University Journal /Scientific Studies (KUJSS)
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3.1.3 Analysis of Samples: The eight heavy metals As, Pb, Cd, Cr, Co, Cu, Ni, and Zn, were analyzed in all samples. The concentrations of heavy metals were determined using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) at Acme labs/ Vancouver, BC Canada V6P 6E5. The physicochemical characteristics of soil samples were analyzed in the Environmental Research Unit Laboratory/ College of Science/ University of Kirkuk.

3.2 Environmental Assessment Methods:

The environmental assessment of study area soil was performed by using the following environmental factors and indices, and the spatial distribution patterns of these factors and indices were drawn using ArcGIS software (version 10.2):

3.2.1 Contamination Factor and Degree of Contamination:

The contamination factor is a single-element index used to describe the contamination level of toxic metals in the soil. The contamination factor (CF) value calculated by using the following equation **[19]**, see Table 1:

$$CF = \frac{C_{Sample}}{C_{Background}} \quad (1)$$

Where: C_{Sample} is Measured Concentration of metal in soil sample, $C_{Background}$ is Background (reference) value of metal in earth crust [20].

The degree of contamination was defined as the sum of all determined contamination factors (CF) for each sample Table 1.

Table 1: Contamination factor, Degree of contamination, and Level of contamination [19].

Contamination Factor (CF)	Contamination degree (C_{deg})	Contamination level
CF < 1	$C_{deg} < 8$	Low contamination
1 < CF < 3	$8 \leq C_{deg} < 16$	Moderate Contamination factor
3 < CF < 6	$16 \leq C_{deg} < 32$	Considerable contamination factor
6 < CF	$32 \leq C_{deg}$	Very high contamination factor

3.2.2 Pollution Load Index (PLI):

The pollution load index practice to estimate the sites contamination by heavy metals. The Pollution Load Index (PLI) value was determined using the following equation [21]:

$$PLI = \sqrt[n]{CF_1 * CF_2 * CF_3 * \dots * CF_n} \quad (2)$$

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Where: CF is Contamination factor, n is Number of metals. The values of PLI > 1 indicates to pollution status by heavy metals, while PLI < 1 mean there is no pollution by heavy metals.

3.2.3 Enrichment Factor (EF):

The enrichment factor suggested by [22] to assess the level of soil contamination, which represents relative abundance of heavy metals in soil. The most common reference elements that used to determine the EF value are Sc, Mn, Ti, Al, and Fe, in the current study the iron (Fe) was selected as reference element because of its high concentration in soil of the study area, where the percentage values for iron (Fe%) in soil samples are: (S1= 2.63, S2= 2.04, S3= 2.81, S4= 2.32, S5= 2.66, S6= 2.74, S7= 3.55, S8= 2.77). The enrichment factor (EF) value was calculated by using the following equation [22], see Table 2:

$$EF = \frac{(\frac{C_m}{C_{Fe}})_{Sample}}{(\frac{C_m}{C_{Fe}})_{Background}} \quad (3)$$

Where: $(\frac{C_m}{C_{Fe}})_{Sample}$ is the ratio of concentration of measured heavy metal (C_m) to that of iron (C_{Fe}) in the soil sample, $(\frac{C_m}{C_{Fe}})_{Background}$ is the ratio of background value of measured heavy metal (C_m) to that of reference element (C_{Fe}), according to [20].

Table 2: Enrichment factor and Level of Enrichment, modified by [23].

Enrichment Factor (EF)	Enrichment level
$EF < 2$	Deficiency to minimal enrichment
EF = 2-5	Moderate enrichment
EF = 5-20	Significant enrichment
EF = 20-40	Very high enrichment
EF > 40	Extremely high enrichment

3.2.4 Index of geo-accumulation (I_{geo}) and Nemerow index (I_N):

The geo-accumulation index (I_{geo}) was used to determine the extent of metal accumulation in soil or sediments, in current study the level of heavy metals contamination was calculated by using the following [24], see Table 3:

$$I_{geo} = log_2 \frac{C_n}{1.5 * B_n} \quad (4)$$

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Where: C_n is measured concentration of heavy metal (n) in the soil sample, B_n is Geochemical background value for the heavy metal (n), according to [20].

Because of the assessment of geo-accumulation index is only for a single heavy metal pollutant, which it cannot provide a comprehensive description of the contamination status of the study area, the Nemerow index (I_N) was developed to give comprehensive description of contamination condition for each site, which was calculated by using the following equation [25], Table 3:

$$I_N = \sqrt[2]{(I_{geo\ max})^2 + (I_{geo\ average})^2/2} \quad (5)$$

Where: I_N is Nemerow index of a sample, $(I_{geo\ max})$ is maximum I_{geo} value of each sample, and $(I_{geo\ average})$ is average value of I_{geo}.

Table 3: Geo-accumulation index classification [26], and I_N classification [25].

Class	I_{geo} value	I_N value	Soil quality
0	$I_{geo} \leq 0$	$0 < I_N < 0.5$	Uncontaminated
1	$0 < I_{geo} < 1$	$0.5 < I_N < 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} < 2$	$1 < I_N < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	$2 < I_N < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	$3 < I_N < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	$4 < I_N < 5$	Heavily to extremely contaminated
6	$I_{geo} > 5$	$I_N > 5$	Extremely contaminated

4. Results and Discussion:

4.1 Concentrations of Heavy Metals in Soil Samples:

The concentration of selected heavy metals in the studied soil samples were shown in Table 4. The abundance trend of average concentrations of heavy metals in the soil samples in order of Ni> Cr> Zn> Cu> Co> Pb> As> Cd, ranges as follows: As (5.3-9.7 mg/kg), Pb (8.08-14.66 mg/kg), Cd (0.15-0.27 mg/kg), Cr (61.6-99.1 mg/kg), Co (14.4-21.8 mg/kg), Cu (19.55-33.72 mg/kg), Ni (82-143.2 mg/kg), and Zn (36.1-76.0 mg/kg), The concentrations of As, Cd, and Ni in all soil samples exceeded the geochemical background values, whereas the concentrations of Pb, Cr, Co, and Zn in all samples lower than the geochemical background values, except Zn at the site (S7), exceeded the same value. The concentration of Cu at (S1,

Kirkuk University Journal /Scientific Studies (KUJSS)
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ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

S2, and S4) did not exceed the geochemical background value, but its concentration exceeded the compared value at other sites.

Table 4: Concentrations of Heavy Metals in Soil Samples of Study Area, Geochemical . Background values of Heavy Metals (ppm) [20].

Site Name	As	Pb	Cd	Cr	Co	Cu	Ni	Zn
S1	6.7	10.07	0.25	79.8	17.6	23.15	118	49.2
S2	5.3	8.08	0.17	61.6	20.2	25.56	94.5	36.1
S3	8.7	13.56	0.15	78.4	19.1	29.98	129.7	56.7
S4	9.7	10.92	0.16	64.6	14.4	19.55	82	39.4
S5	7.3	11.53	0.15	69.5	16.3	25.08	108.9	52.5
S6	6.9	12.59	0.27	80.1	17.1	27.77	132	57
S7	7.1	14.66	0.27	99.1	21.8	33.72	143.2	76
S8	6.1	11.29	0.27	79.1	17.5	27.39	128.9	51.2
Median	7.0	11.41	0.21	78.75	17.55	26.475	123.45	51.85
Average	7.225	11.587	0.211	76.525	18	26.525	117.15	52.263
Min	5.3	8.08	0.15	61.6	14.4	19.55	82	36.1
Max	9.7	14.66	0.27	99.1	21.8	33.72	143.2	76
Geochemical Background Value [a]	1.7	14.8	0.1	136	24	25	56	65

4.2 Correlation Coefficient of Heavy Metals in Soil of the Study Area:

The Pearson's correlation coefficient is a statistical method which describe the strength and direction of the relationship between two variables Table 5 [27], were employed to evaluate the relations among heavy metals Table 6, showed strong positive relation between heavy metals pairs of Pb-Zn (r = 0.894), Cr-Ni (r = 0.891), Cr-Zn (r = 0.942), Cu-Ni (r = 0.859), Cu-Zn (r = 0.835), Ni-Zn (r = 0.872), and Co-Cu (r = 0.810). While, the moderate positive relations observed between heavy metals pairs of Pb-Cr (r = 0.783), Pb-Ni (r = 0.733), Cr-Cu (r = 0.774), Pb-Cu (r = 0.7), Cd-Cr (r = 0.705), Cd-Ni (r = 0.663), Cd-Zn (r = 0.509), Cr-Co (r = 0.549), Co-Ni (r = 0.547), Co-Zn (r = 0.520). The high positive correlations among heavy metals indicated that the heavy metals are originated from the same common pollution source, while the weak correlations denoted to differences in sources and geochemical behavior of metals [28, 29].

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (82 - 100)
ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

Table 5: Interpretation of Pearson's Correlation Coefficient (Zou et al., 2003).

Correlation value	Strength and Direction of Correlation
(-0.8) – (-1.0)	Strongly negative
(-0.5) – (-0.8)	Moderately negative
(-0.2) – (-0.5)	Weakly negative
(+0.2) – (-0.2)	No association
(+0.2) – (+0.5)	Weakly positive
(+0.5) – (+0.8)	Moderately positive
(+0.8) – (+1.0)	Strongly positive

Table 6: Pearson's Correlation Matrix Among Heavy Metals in Soil of Study Area.

Metal	**As**	**Pb**	**Cd**	**Cr**	**Co**	**Cu**	**Ni**	**Zn**
As	1							
Pb	0.420	1						
Cd	-0.448	0.269	1					
Cr	-0.062	0.783	0.705	1				
Co	-0.488	0.255	0.271	0.549	1			
Cu	-0.260	0.700	0.395	0.774	0.810	1		
Ni	-0.233	0.733	0.663	0.891	0.547	0.859	1	
Zn	0.035	0.894	0.509	0.942	0.520	0.835	0.872	1

4.3 Contamination Factor and Degree of Contamination:

The results of calculated contamination factor (CF) listed in Table 7, and the spatial variation of CF values for heavy metals shown in Fig. 3. The average values of CF for heavy metals in all samples decreasing in order of As> Cd> Ni> Cu> Zn> Pb> Co> Cr. The results show there are low levels of contamination for Pb, Cr, Co, and Zn at all sites, except site (S7) contaminated moderately by Zn, whereas moderate levels of contamination recorded at all sites for Ni, Cd, and Cu, but S1 and S4 are shown low levels of Cu contamination, while all sites contaminated considerably with As. The degree of contamination (Cdeg) for heavy metals Table 7, shown a moderate degree of contamination at all sites, and the spatial distribution of C_{deg} presented in Fig. 4.

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Volume 13, Issue 2, June 2018, pp. (82 - 100)
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4.4 Pollution Load Index (PLI):

The Table 7 shows the computed values of *PLI*, and the spatial distribution of *PLI* shown in Fig. 4, the results show *PLI* values higher than 1 (*PLI* > 1) at all sites, which implies all sites are contaminated with heavy metals to some extent.

Table 7: Contamination Factor, Degree of Contamination, and Pollution Load Index of . Heavy Metals in Soil Samples of Study Area.

Site Name	Contamination Factor (CF)								C_{deg}	PLI
	As	Pb	Cd	Cr	Co	Cu	Ni	Zn		
S1	3.941	0.680	2.5	0.587	0.733	0.926	2.107	0.757	12.23	1.199
S2	3.118	0.546	1.7	0.453	0.842	1.022	1.688	0.555	9.92	1.007
S3	5.118	0.916	1.5	0.576	0.796	1.199	2.316	0.872	13.29	1.293
S4	5.706	0.738	1.6	0.475	0.600	0.782	1.464	0.606	11.97	1.037
S5	4.294	0.779	1.5	0.511	0.679	1.003	1.945	0.808	11.52	1.134
S6	4.059	0.851	2.7	0.589	0.713	1.111	2.357	0.877	13.26	1.316
S7	4.176	0.991	2.7	0.729	0.908	1.349	2.557	1.169	14.58	1.529
S8	3.588	0.763	2.7	0.582	0.729	1.096	2.302	0.788	12.55	1.257

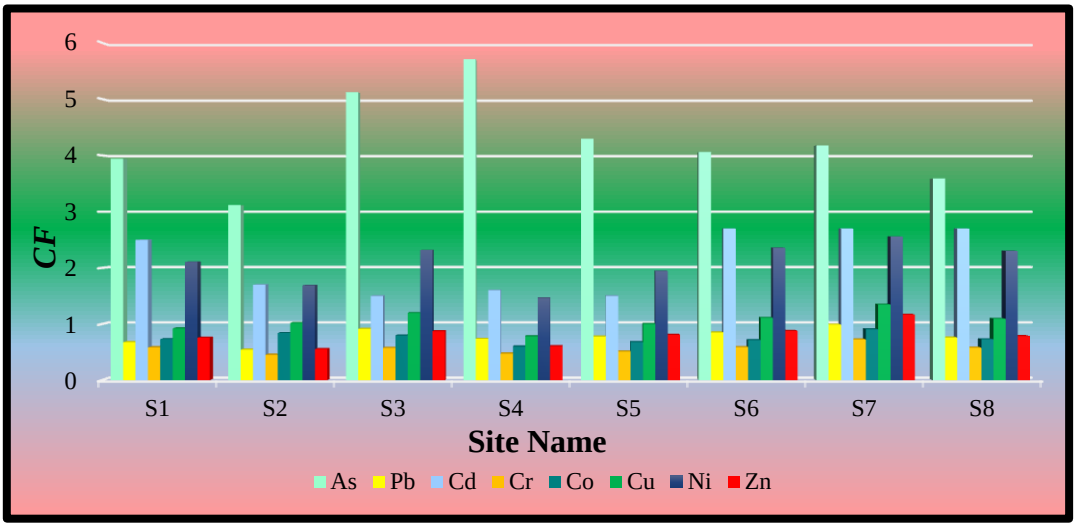

Fig. 3: Variation of *CF* for Heavy Metals in Soil of the Study Area.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (82 - 100)
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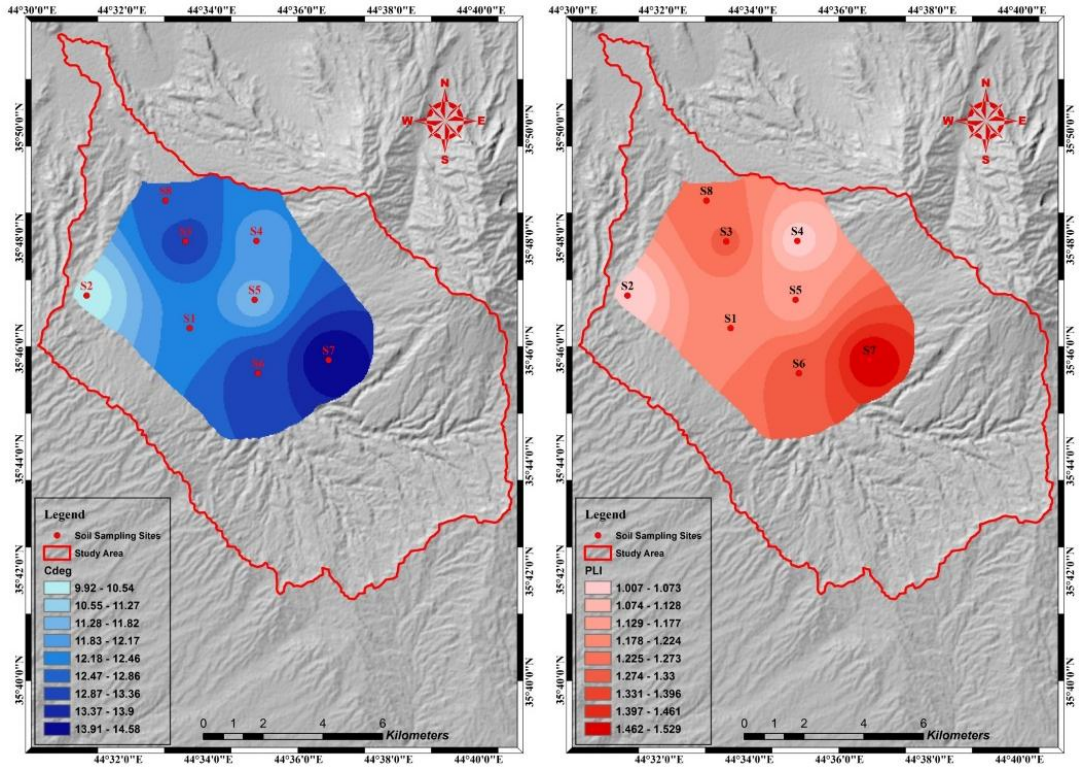

Fig. 4: Spatial Distribution of C_{deg} and *PLI* in Soil of Study Area.

4.5 Enrichment Factor (EF):

The results of *EF* for selected heavy metals of eight soil samples are listed in the Table 8, and the spatial variation of *EF* values for heavy metals shown in Fig. 5. The average values of *EF* for heavy metals in all samples increasing in order of As> Cd> Ni> Cu> Zn> Pb> Co> Cr. The enrichment factor values if less than two (*EF* < 2) indicate that the heavy metals are enriched from natural sources, while (*EF* > 2) indicate that the heavy metals enriched by anthropogenic sources [30, 31, 32, 33]. The results showed there are minimal enrichment (*EF* < 2) for Pb, Cr, Co, Cu and Zn at all sites, except S2 enriched moderately by Cu, these low values of *EF* indicate that these metals enriched from natural sources, whereas all sites enriched moderate with Cd and Ni, and Significantly with As, which means there are anthropogenic sources were enriched these metals.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (82 - 100)
ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

Table 8: Enrichment Factor (*EF*) of Heavy Metals in Soil Samples of Study Area.

Site Name	Enrichment Factor (*EF*)							
	As	Pb	Cd	Cr	Co	Cu	Ni	Zn
S1	6.474	1.118	4.106	0.964	1.205	1.521	3.461	1.243
S2	6.602	1.156	3.600	0.959	1.782	2.165	3.574	1.176
S3	7.868	1.409	2.306	0.886	1.223	1.844	3.561	1.341
S4	10.625	1.374	2.979	0.884	1.117	1.456	2.727	1.129
S5	6.974	1.265	2.436	0.830	1.103	1.629	3.158	1.312
S6	6.399	1.341	4.257	0.929	1.123	1.751	3.716	1.383
S7	5.082	1.205	3.286	0.887	1.105	1.641	3.112	1.423
S8	5.596	1.190	4.211	0.907	1.137	1.709	3.590	1.228

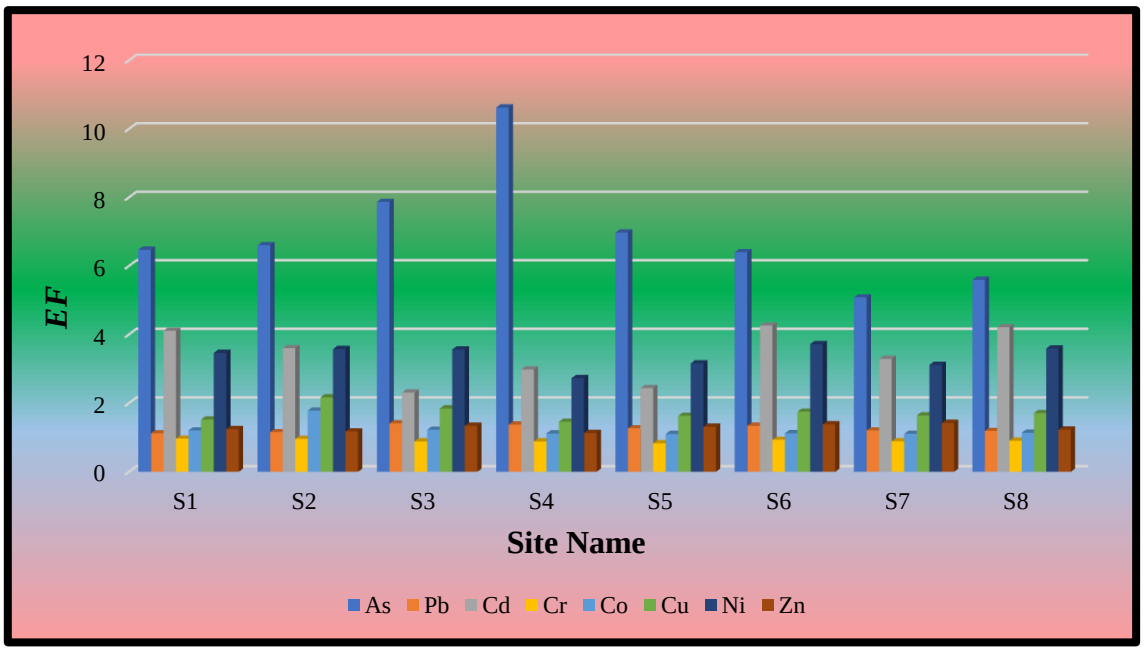

Fig. 5: Variation of *EF* for Heavy Metals in Soil of Study Area.

4.6 Index of geo-accumulation (I_{geo}) and Nemerow index (I_N):

The geo-accumulation index (I_{geo}) results of heavy metals were showed in Table 9, and Fig. 6 showed a spatial variation of I_{geo} for heavy metals in the soil of study area. The average values of I_{geo} in all soil samples increasing as follows: As> Ni> Cd> Cu> Zn> Pb> Co> Cr. According to (Müller, 1981) classification for I_{geo}, the all sites are uncontaminated with Pb, Cr, Co, Cu, and Zn, whereas all sites were classified as uncontaminated to moderately contaminated for Cd and Ni, except S4 uncontaminated with Ni. While the results showed

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (82 - 100)
ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

moderate contamination for As at all sites. The results of Nemerow index (I_N) Table 9 showed moderate contamination at all sites, except S2 and S8 classified as uncontaminated to moderately contaminated. The spatial distribution of I_N shown in Fig. 7.

Table 9: Geo-accumulation Index (I_{geo}) and Nemerow index (I_N) of Heavy Metals in Soil Samples.

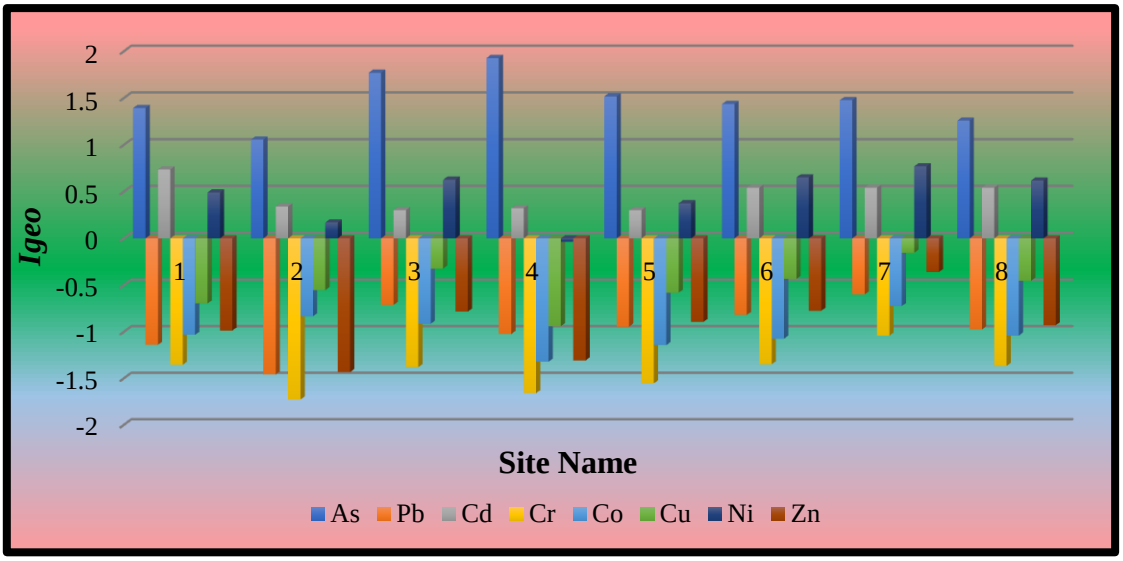

Fig. 6: Variation of I_{geo} for Heavy Metals in Soil of Study Area.

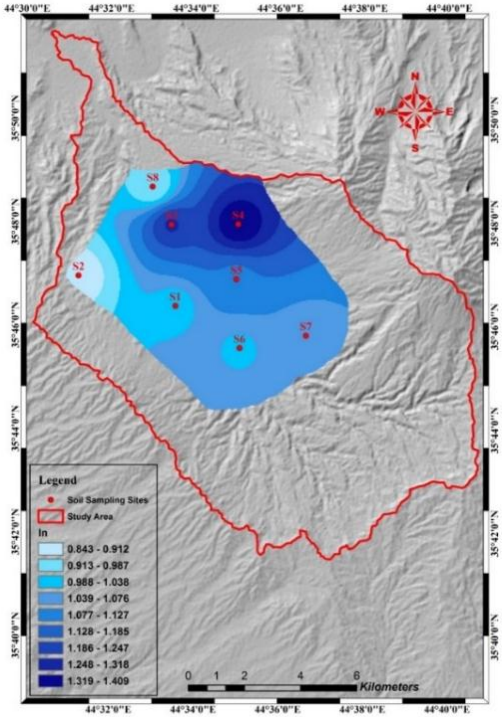

Fig. 7: Spatial Distribution of I_N in Soil of Study Area.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (82 - 100)
ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

Geo-environmental assessment of the study area showed that the area is moderate to heavily contaminate by heavy metals, these attributed to:

1) The land use of study area generally is agricultural, the farmers use inorganic fertilizers, pesticides, and manure as organic fertilizers, these materials contribute to increasing the heavy metals concentrations in soil of the study area.
2) The large areas covered by geological outcrops, where the weathering and erosion processes of rock materials contribute to increasing the concentrations of heavy metals in the soil of the study area.
3) livestock breeding, where the animal wastes contribute to pollution the soil too.
4) Because of in the study area there is no wastewater and sewage sludge discharge nets, the populations in the study area discharge these wastes to open areas, which largely pollute the soil also have negative effects on the human health that are residing in this area.

5. Conclusion

In a current study several environmental indices were used to the assessment of heavy metals contaminations and determine the environmental quality is soil of study area, the results of this study summarized as follows:

1) The abundance trend of average concentrations of heavy metals increasing in order of Ni> Cr> Zn> Cu> Co> Pb> As> Cd. The concentrations of As, Cd, and Ni exceeded the geochemical background values at all sites, whereas concentrations of Pb, Cr, Co, and Zn are lower than the geochemical background values, except Zn at S7 exceeded the same value.

2) Pearson's correlation analysis revealed there is a strong positive correlation among Pb, Co, Cu, Zn, Cr, and Ni indicates these metals have similar origins mostly anthropogenic, while the positive weak correlation was observed between (As-Pb), (Cd-Cu), (Pb-Cd), (Cd-Co), and (Pb-Co) which indicate that these metals are from different origins, also the negative weak correlation noticed for As with Cd, Co, Cu, and Ni.

3) Low levels of contamination were observed for Pb, Cr, Co, and Zn, and moderate contamination for Cd, Cu, and Ni at all sites, except S1 and S4, shows a low level of Cu contamination, while all sites contaminated considerably with As. The C_{deg} showed moderate contamination of heavy metals at all sites, as well as showed $PLI > 1$ indicate to the soil contaminated with heavy metals.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (82 - 100)
ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

4) According to *EF*, there is a minimal enrichment for Pb, Cr, Co, Cu, and Zn at all sites which indicate these metals enriched from natural sources, except S2 enriched moderately by Cu, whereas all sites enriched moderately with Cd, and Ni, and significantly with As. According to I_{geo} where all sites uncontaminated with Pb, Cr, Co, Cu, and Zn, whereas these sites classified as uncontaminated to moderately contaminated for Cd and Ni, except S4 uncontaminated with Ni, also all sites contaminated moderately with As. According to I_N where all sites contaminated moderately, except S2 and S8 classified as uncontaminated to moderately contaminated.

The results of assessment factors and indices *CF*, C_{deg}, *PLI*, and I_{geo} showed moderate contamination of heavy metals at all site, which is in agreement with each other and with the results of *EF*. This study reveals that the soil of the study area moderately to heavily contaminated by heavy metals. These metals originated from anthropogenic and natural sources, but the anthropogenic sources contribute to soil contamination more than natural sources.

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