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The Influence of Drilling Process on the Neighboring Soils: A Cause Study in the East Baghdad Oil Field

Anhar Al-Mamory* **, Kareem Khwedim**
Department of Petroleum Geology and Minerals, College of Science, University of Diyala, Diyala- Iraq

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Abstract:

The study aims to determine the concentrations of major oxides and trace elements in the soil of East Baghdad oil field. Twenty-five soil samples were collected, 24 samples from the East Baghdad oil field and one sample was taken from Diyala governorate, far away from pollution resources (BA). The samples were analysed using X-ray fluorescence (XRF), and the result showed that SiO_2 and CaO are the most abundant, followed by other oxides (Na_2O, $Al2O_3$, Fe_2O_3, MgO, K_2O, TiO_2) with a high percentage of LOI. Trace elements showed that the average values of (Cd, Co, Cr, Cu, Mn, Ni, Pb, Sr, V, Zn) were above the international limits of the soil except for the Fe element within the international limits. High concentrations of trace elements were observed in all soil samples, exceeding the international standard limits in soil. The values of the trace elements suggest that oil industries, oil drilling and extraction operations, and human activities are the most important cause of increasing concentrations of trace elements in the soil of the study area.

Keywords: East Baghdad Oil Field, Soil pollution, Trace elements, Major oxides.

دراسة تأثير عمليات حفر الابار النفطية على ترب المناطق المجاورة في حقل شرق بغداد النفطي.

انهار فؤاد المعموري*، كريم حسين خويدم
قسم جيولوجيا النفط و المعادن، كلية العلوم، جامعة ديالى، ديالى– العراق

الخلاصة:

الهدف من الدراسة هو تحديد مستوى المعادن الثقيلة في تربة حقل شرق بغداد النفطي. تم جمع 25 عينة تربة، 24عينة من حقل شرق بغداد النفطي وعينة واحدة من تربة بعقوبة بعيدة عن مصادر التلوث (BA) لغرض المقارنة. تم تحليل العينات باستخدام جهاز الأشعة السينية وأظهرت النتائج أن SiO_2 و CaO هما الأكثر وفرة، تليهما أكاسيد أخرى بنسبة أقل (Na_2O، Al_2O_3، Fe_2O_3، MgO، K_2O، TiO_2) مع نسبة عالية من المفقود بالحرق . أظهرت متوسط القيم للعناصرالنادرة ان (Cd ، Co، Cr، Cu، Mn، Ni، Pb، Sr، V، Zn). أعلى من الحدود العالمية للتربة باستثناء عنصر الحديد كان ضمن الحدود. محتوى العناصر النادرة في عينات التربة السطحية التي حللت تمت مقارنتها مع عينة تربة اخذت من منطقة بعيدة عن مصادر التلوث, لوحظت تركيزات عالية من العناصر النادرة في جميع عينات التربة. تشير النتائج إلى أن الصناعات النفطية وعمليات التنقيب عن النفط واستخراج النفط والأنشطة البشرية هي احد أسباب زيادة تركيزات العناصر النزرة في تربة منطقة الدراسة.

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*Email: anharfuoad@gmail.com

1. Introduction:

Soil pollution is the build-up of toxic chemicals in the soil that occurs when an element's concentration is three times higher than the average level [1]. Trace elements are one example of hazardous chemical substances that can form in the soil [1]. The spread of trace elements pollution in soil may be through the intermediates such as wind, water, and absorption by plants [2]. Trace elements enter the environment as a result of anthropogenic and natural activities. Trace elements are found in soils at relatively low concentrations due to the weathering and pedogenic processes acting on the rock fragments on which the rock develops soil mother materials [3]. Soil pollution occurs with trace elements due to industrial waste, oil wells drilling effects, fertiliser application, and hydrocarbons spill [4]. Trace elements that pollute soil are classified as highly toxic: Ni, Cd, Pb, Zn, and Cu [5]. Pollution of the soil with petroleum is one of the major causes of environmental pollution. The environmental damage caused by oil drilling processes and production directly affects human life [6]. Oil is a type of important energy, and oil exploitation and storage consumption is increasing. Because of the limitation of the technological level, waste residue containing petroleum matter is discharged into the soil, resulting in an increasing problem of environmental contamination [7]. Petroleum is easily absorbed in the soil surface because of increased viscosity, lower emulsifying ability, and small density, affecting the porosity and permeability of soil [8]. The current study aims to study the probability of soil pollution by trace elements at the East Baghdad oil field. The studied area is in the East Baghdad oil field (middle of Iraq).

The study area lies within the Mesopotamian basin of the unstable shelf [9]. East Baghdad field is between latitude (44˚20'46.73") and longitude (33˚ 29'26.60"). The area of the entire East Baghdad project is 1201.00 km2. East Baghdad oil field gained great importance given that it contains reservoir rocks, especially those from the Cretaceous period, which form the basic and significant reservoirs in this field [9]. The samples were taken for six wells (EB-19, EB83, EB86, EB95, EB96, EB104) (Figure 1).

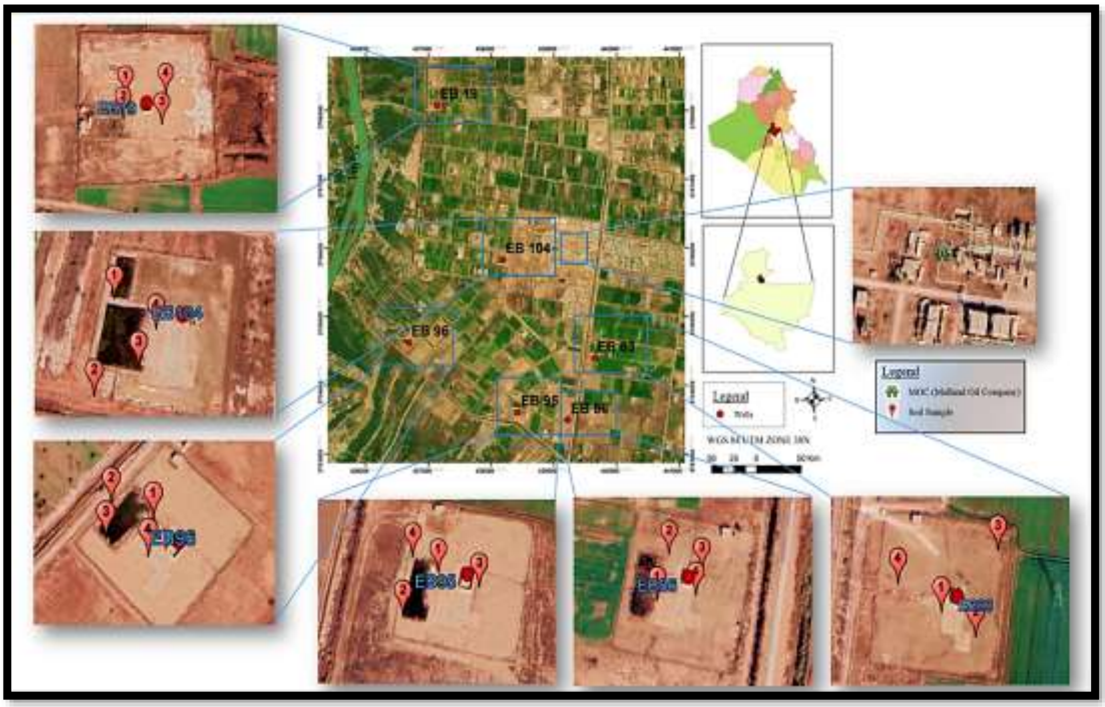

Figure 1: Location map of the study area

Table 1: Coordinates of the sampling from the East Baghdad oil field

Symbols	Sample type	Coordinates	
		Latitude	Longitude
EB19-S1	Soil	44˚19'22.44"	33˚30'37.65"
EB19-S2	Soil	44˚19'22.36"	33˚30'36.94"
EB19-S3	Soil	44˚19'24.03"	33˚30'36.78"
EB19-S4	Soil	44˚19'24.18"	33˚30'37.76"
EB83-S1	Soil	44˚21'1.18"	33˚28'37.75"
EB83-S2	Soil	44˚21'2.49"	33˚28'37.03"
EB83-S3	Soil	44˚21'3.34"	33˚28'39.52"
EB83-S4	Soil	44˚20'59.52"	33˚28'38.58"
EB86-S1	Soil	44˚20'44.17"	33˚28'8.32"
EB86-S2	Soil	44˚20'44.61"	33˚28'9.80"
EB86-S3	Soil	44˚20'46.01"	33˚28'9.27"
EB86-S4	Soil	44˚20'45.77"	33˚28'8.49"
EB95-S1	Soil	44˚20'13.16"	33˚28'12.59"
EB95-S2	Soil	44˚20'11.78"	33˚28'11.24"
EB95-S3	Soil	44˚20'14.86"	33˚28'12.14"
EB95-S4	Soil	44˚20'12.07"	33˚28'13.11"
EB96-S1	Soil	44˚19'5.18"	33˚28'45.57"
EB96-S2	Soil	44˚19'3.42"	33˚28'46.04"
EB96-S3	Soil	44˚19'3.29"	33˚28'44.94"
EB96-S4	Soil	44˚19'5.03"	33˚28'44.39"
EB104-S1	Soil	44˚20'1.56"	33˚29'25.24"
EB104-S2	Soil	44˚20'1.02"	33˚29'22.07"
EB104-S3	Soil	44˚20'2.74"	33˚29'22.97"
EB104-S4	Soil	44˚20'3.40"	33˚29'24.21"

2. Methodology:

After obtaining the map of the study site, six oil-producing wells were selected from the East Baghdad oil field (EB-19, EB-83, EB-86, EB-95, EB-96, and EB-104) to be sampled. The sampling process was conducted by collecting 24 soil samples with a 5 to 30-cm depth. Soil samples were compared with one sample taken from an area in the Diyala governorate far away from pollution resources (BA).

2.1 X-ray fluorescence:

Twenty-four soil samples from six oil wells in the East Baghdad oil field (EB-19, EB-83, EB-86, EB-95, EB-96, and EB-104) were selected with depth (5- 30 cm), soil samples were compared with one sample taken from an area in Diyala governorate far away from pollution resources (BA). All the soil samples were put in plastic bags and then transported to the lab for chemical analysis in German-Iraqi Laboratory at the Department of Geology, College of Science, University of Baghdad. Soil samples were analysed by (XRF) (type Spectro Xepos). Powder was compressed and turned into pellets using a special piston with a pressure of 5 tons.

2.2 XRD analysis:

Clay minerals were diagnosed for six soil samples highest 3 soil samples in trace elements content (EB19-S1, EB83-S3, EB86-S1) and the lowest 3 soil samples (EB95-S1, EB96-S1, EB104-S4) to be analyzed by XRD to realise the type and ratio of clay minerals. The selected samples were analysed using the XRD technique (type Shiamatzu XRD-6000) at the University of Baghdad- College of Science- Department of Geology. The preparation of oriented samples were used according to [10],[11],[12], and]13].

3. Results and Discussions

3.1 Geochemistry

3.2 Major oxides:

The concentration of major oxides calculated in the tested soil samples (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2) and LOI, Table-2.

3.2.1 Silica (SiO_2):

The concentration of SiO_2 in the studied soil ranged from (11.91 at EB96-S1- 50.65 at EB95-S3 %) with an average of 35.95%, which is the most abundant oxide in the study area (Table 2). Its concentration in BA sample was 21.08%. There are positive correlations between silica and Fe_2O_3(0.473), TiO_2 (0.453), K_2O (0.357), and strong positive with Al_2O_3(0.927), suggesting the presence of free silica [14]. The negative correlation of silica with Na_2O (- 0.581) and CaO (- 0.430), Table- 3, appears due to the gradual decrease in silica and the subsequent enrichment of calcite [15], (Figure 2).

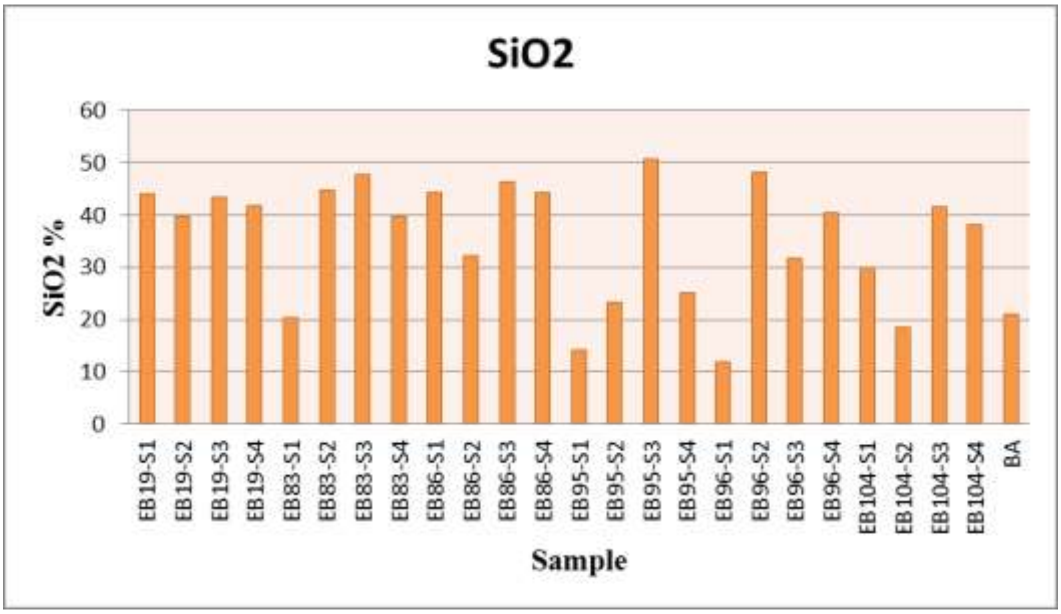

Figure 2- The distribution of SiO_2 in the study area

3.2.2 Aluminium oxide (Al_2O_3)

Alumina (Al_2O_3) is a common oxide in silicate minerals that weathering may release [16]. Aluminum oxide concentration is restricted between (2.7 at EB96-S1 - 11.8 at EB83-S3 %) with an average of 7.70% (Table 2), its concentration in BA sample was 3.66%. Low concentration of Al_2O_3 in some soil samples (EB83-S1, EB95-S1, EB96-S1) due to carbonate minerals [17]. There is a strong positive correlation between aluminum oxide and TiO_2 (0.650) related to the internal composition of illite. Aluminum oxide has a strong positive correlation with SiO_2 (0.927). It has a positive correlation with Fe2O3 (0.651) which enters the chemical composition of montmorillonite and illite [19]. It has a negative correlation coefficient with Na2O (- 0.537) and CaO (-0.440) and a negative correlation with L.O.I (- 0.079), (Table 3), (Figure 3). These oxides represent the major components of mica and clay minerals [18].

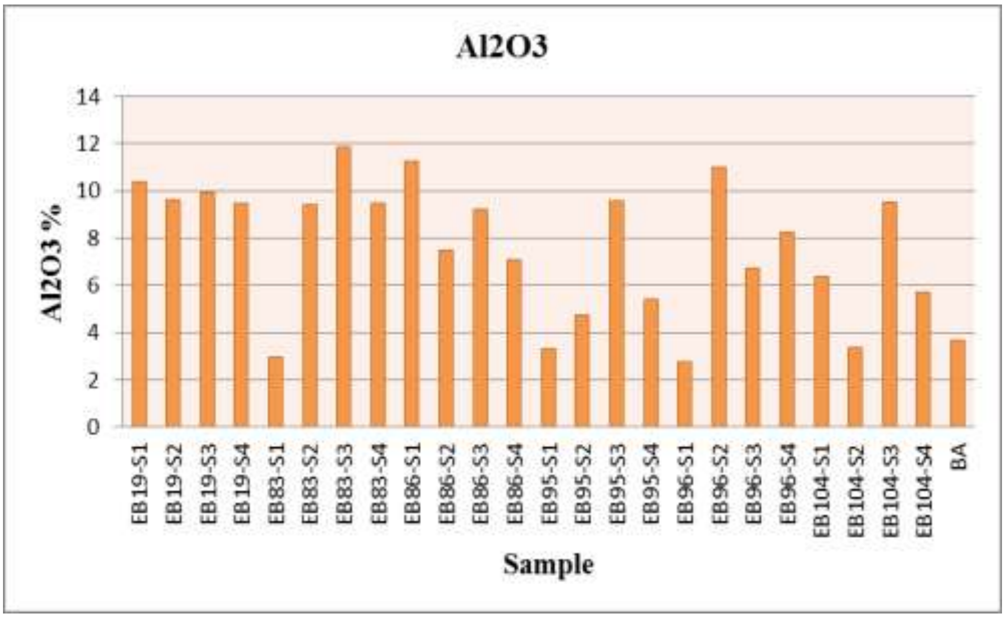

Figure 3: The distribution of Al_2O_3 in the study area

3.2.3 Iron oxide (Fe_2O_3):

Iron oxide (Fe_2O_3) exists in soil as a cementing material or coating for mineral granules within the soil; Fe_2O_3 is associated degree of weathering, parent materials, and pedogenic accumulation or depletion processes [20]. The concentration of iron oxide in the studied area ranges from (1.78 at EB96-S1 - 7.77 at EB86-S1 %) with an average of 5.56% (Table 2), (Figure 4). There is a positive correlation of Fe_2O_3 with SiO_2 (0.473) and a strong positive correlation with MgO (0.608), Al_2O_3 (0.651), K_2O (0.910), and TiO_2 (0.765), Table-3, which indicates entry within the structure crystalline of Montmorillonite and Illite. It has a strong negative correlation with CaO (-0.812) (Table 3). Its negative correlation with L.O.I (-0.573) is attributed to the high content of calcite in clay minerals [17].

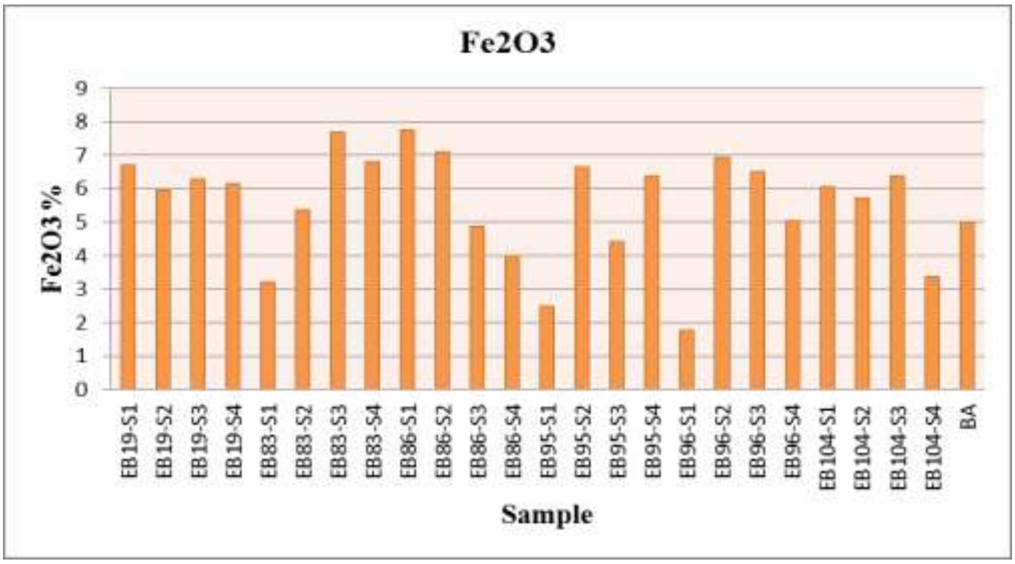

Figure 4: The distribution of Fe_2O_3 in the study area

3.2.4 Calcium oxide (CaO):

The concentration of CaO in the studied area ranges from (14.74 at EB104-S2 - 61.38 at EB95-S1 %) with an average of 23.74% (Table 2), and its concentration in BA sample was 21.21% (Figure 5). High concentration of CaO in soil samples (EB95-S1, EB96_S1) due to the increase of calcite mineral (Table 8).

The negative correlation of calcium oxide with magnesium oxide (-0.430) is due to their low presence in the form of dolomite mineral [17]. It has a negative correlation with SiO_2 (-0.430), Al_2O_3 (- 0.440) and a strong negative with K_2O (- 0.773) (Table 3). This reverses an increased carbonate mineral that replaces SiO_2 [10]. CaO makes a weak negative correlation with Na_2O (-0.384), which suggest low clay minerals with increased carbonate minerals, also have a positive relationship with L.O.I (0.669) because of high content of carbonate [21].

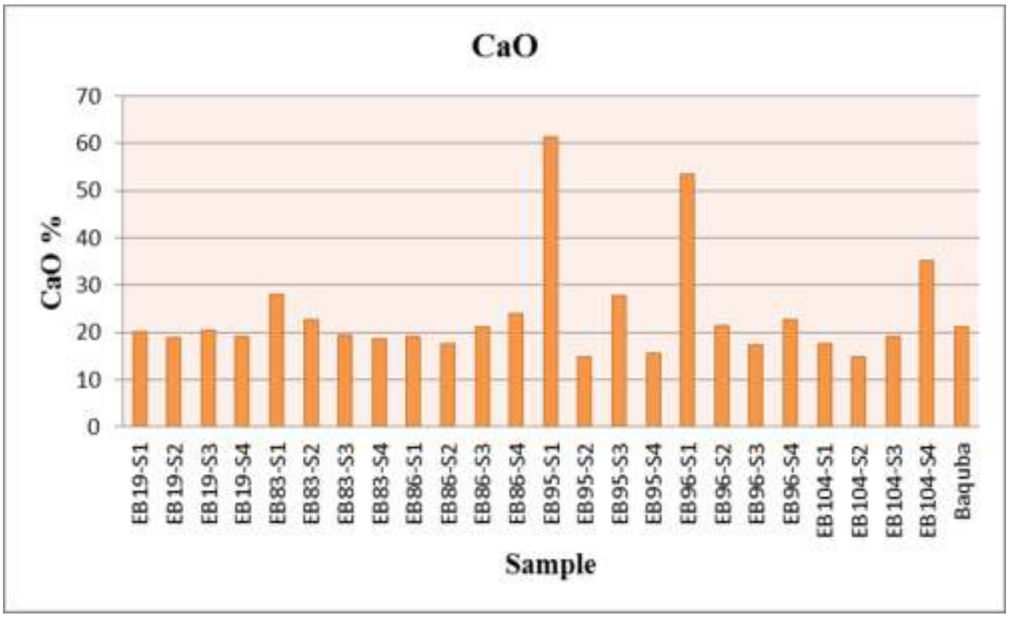

Figure 5: The distribution of CaO in the study area

Table 2: Concentrations of major oxides (%) in soil East-Baghdad oil field

Major Elements									
Sample	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2	L.O.I
EB19-S1	44.12	10.37	6.7	20.24	7.07	2.37	1.72	0.89	13.69
EB19-S2	39.77	9.6	5.97	18.84	6.8	8.42	1.57	0.81	8.77
EB19-S3	43.33	9.94	6.27	20.51	6.62	3.9	1.59	0.92	9.35
EB19-S4	41.88	9.47	6.15	19.05	6.32	6.84	1.57	0.91	10.54
EB83-S1	20.45	2.98	3.22	28.12	4.4	4.69	0.61	0.74	9.08
EB83-S2	44.69	9.4	5.37	22.72	5.29	2.86	1.45	0.8	18.96
EB83-S3	47.77	11.85	7.68	19.5	6.35	1.52	1.79	0.9	14.67
EB83-S4	39.78	9.46	6.82	18.51	5.51	9.63	1.68	0.77	11.25
EB86-S1	44.4	11.26	7.77	19.1	6.53	3.3	1.84	0.95	15.96
EB86-S2	32.25	7.49	7.09	17.59	4.61	17.39	1.68	0.84	12.95
EB86-S3	46.26	9.22	4.89	21.07	5	2.68	1.37	0.81	15.18
EB86-S4	44.39	7.07	3.99	23.86	4.9	3.06	1.16	0.65	20.22
EB95-S1	14.18	3.34	2.49	61.36	3.42	5.37	0.81	0.15	27.83

EB95-S2	23.32	4.74	6.63	14.76	3.93	26.38	1.69	0.76	7.3
EB95-S3	50.65	9.55	4.42	27.74	3.08	1.18	1.12	0.71	24.67
EB95-S4	25.15	5.41	6.38	15.45	4.6	23.94	1.63	0.75	8.35
EB96-S1	11.91	2.74	1.78	53.47	2.64	3.23	0.86	0.63	17.88
EB96-S2	48.16	10.98	6.94	21.37	6.05	1.63	1.69	0.92	12.28
EB96-S3	31.75	6.73	6.5	17.23	4.42	19.69	1.63	0.88	12.12
EB96-S4	40.4	8.27	5.04	22.75	4.36	9.05	1.46	0.73	17.5
EB104-S1	29.84	6.36	6.06	17.61	4.75	19.26	1.77	0.76	12.86
EB104-S2	18.61	3.38	5.72	14.74	3.49	30.68	1.89	0.69	12.05
EB104-S3	41.67	9.54	6.37	19.24	6.56	6.67	1.64	0.83	8.58
EB104-S4	38.22	5.69	3.39	35.04	5.25	4.37	1.22	0.46	28.81
BA	21.08	3.66	5.01	21.21	3.01	26.54	1.45	0.7	9.73
Average	35.36	7.54	5.54	23.64	4.99	9.78	1.47	0.75	14.42

3.2.5 Magnesium oxide (MgO):

Magnesium oxide concentration in soil samples ranged from (2.64 at EB96-S1 - 7.07 at EB19-S1 %) with an average of 5.08%. Its concentration in BA sample was 3.01% (Table 2). The low concentration of magnesium oxide 2.64% in the sample (EB96-S1), is attributed not to having clay minerals that contain magnesium in the chemical composition, while the highest concentration is 7.07% in the sample (EB19-S1) due to the existence of clay minerals (Table 8). The positive correlation between MgO and each of Al_2O_3 (0.787), Fe_2O_3 (0.608), and K_2O (0.488) is a result of its entry within the structure of clay minerals (Table 3) (Figure 6).

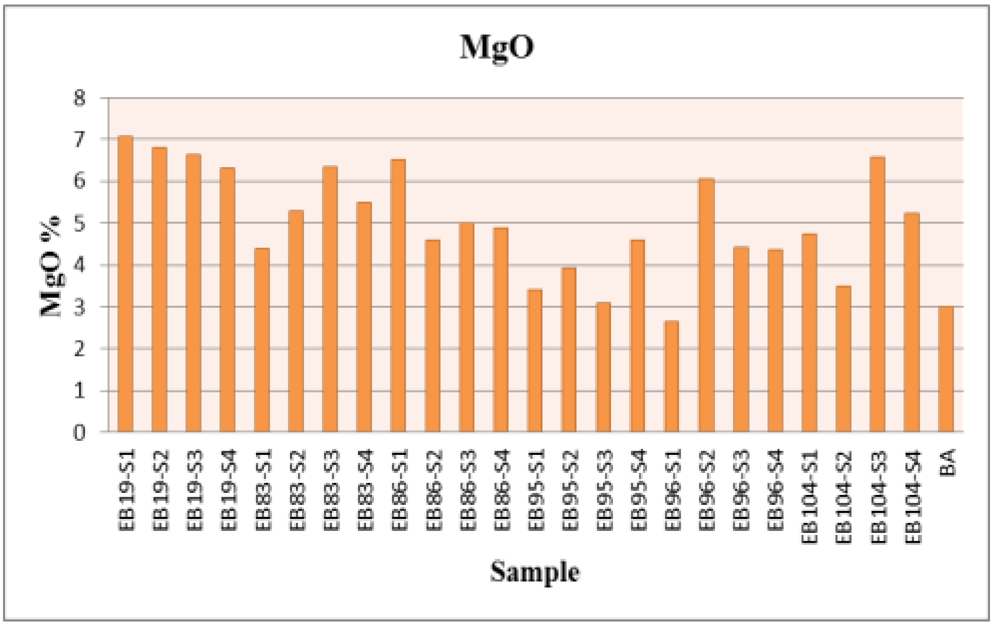

Figure 6: The distribution of MgO in the study area.

3.2.6 Sodium oxide (Na_2O):

Sodium oxide concentration in the studied area ranges between (1.18 at EB95-S3 - 30.68 at EB104-S2 %) with an average of 9.08% (Table 2), and its concentration in BA sample was 26.54%. The high concentration of sodium oxide content in the soil is due to its association with clay minerals, especially albite and montmorillonite [22]. There is a negative correlation between Na_2O with CaO (-0.384) and LOI (-0.455) (Table 3), which indicates the increase in calcite and gypsum minerals [21], (Figure 7).

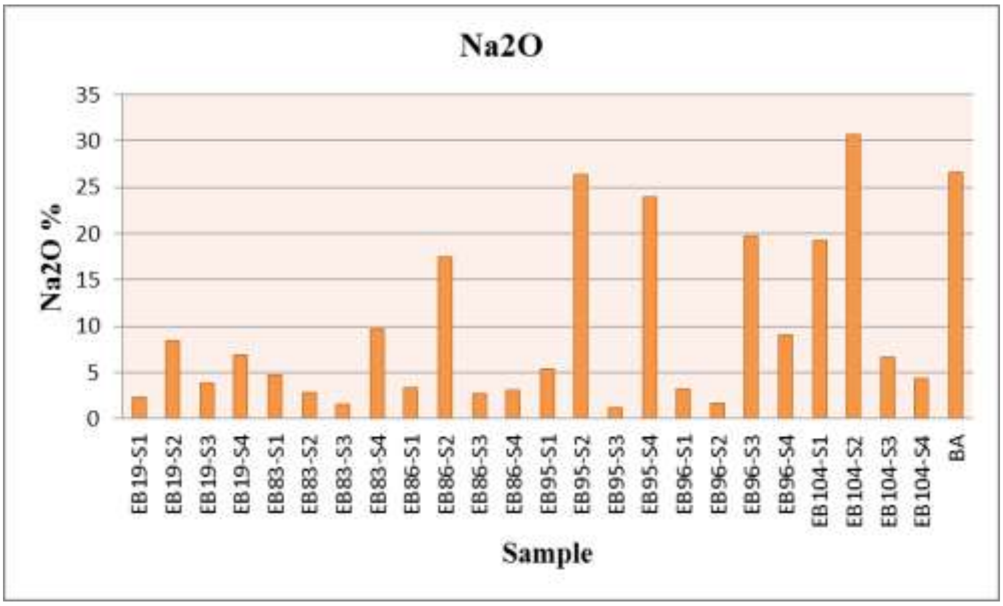

Figure 7: The distribution of Na_2O in the study area.

3.2.7 Potassium oxide (K_2O):

Potassium oxide (K_2O) concentration in the study area ranged from (0.61 at EB83-S1- 1.89 at EB86-S1 %) with a mean of 1.47%. Its concentration in BA sample was 1.45% (Table 2), (Figure 8). Potassium is related to the occurrence of illite minerals. Also, potassium is found in clay minerals as one of the exchangeable ions or can be present on the layers surface of clay minerals [23]. There is a positive correlation of K_2O with Fe_2O_3 (0.910), Al_2O_3 (0.513), and MgO (0.488), indicating its entry into the crystal structure of clay minerals such as illite and mica [19]. It negatively correlates with L.O.I (-0.488) due to low potassium content in carbonate minerals (Table 3).

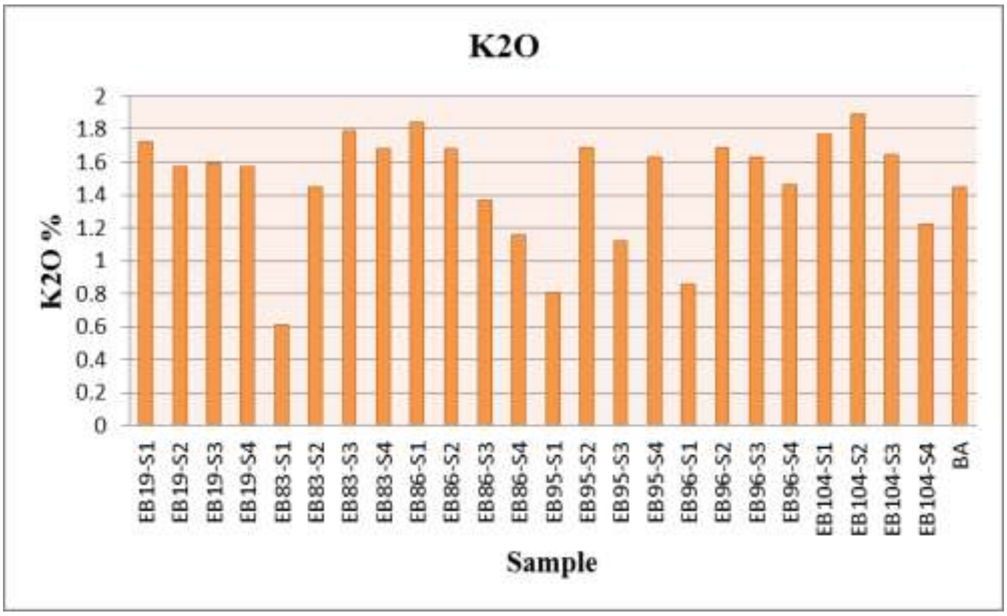

Figure 8: The distribution of K_2O in the study area.

3.2.8 Titanium oxide (TiO_2):

Titanium is most resistant during weathering processes and the less mobile [24]. TiO_2 concentration in the soil ranged from (0.15 at EB95-S1 - 0.95 at EB96-S2 %) with a mean of 0.76%. Its concentration in BA sample was 0.7% (Table 2) (Figure 9). There is a positive correlation of TiO_2 with Al_2O_3 (0.650), Fe_2O_3 (0.765), and K_2O (0.634), Table- 2. This indicates their presence within the clay minerals [18]. TiO_2 has a strong negative correlation between CaO (-0.779) and L.O.I (-0.664) (Table 3).

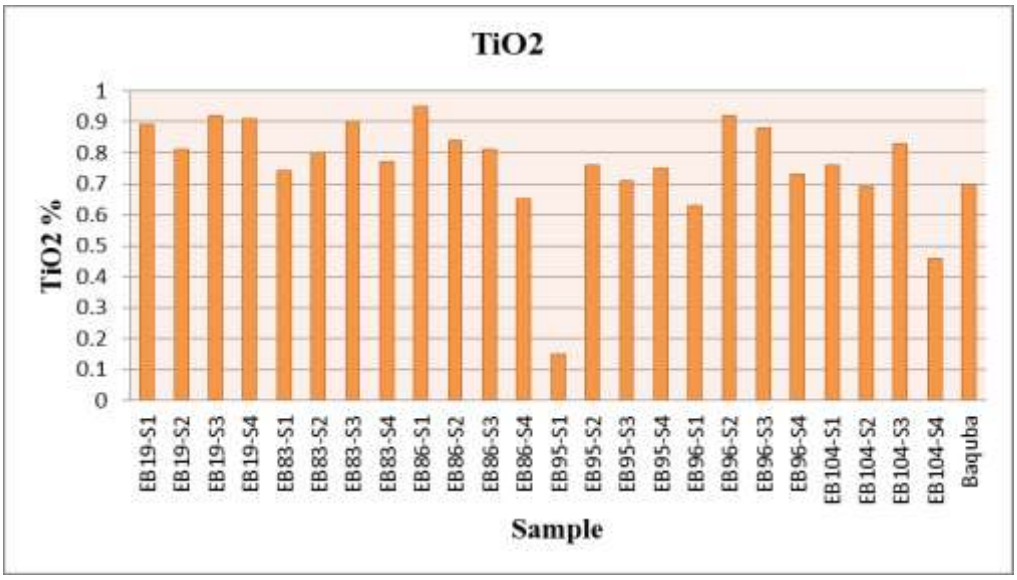

Figure 9: The distribution of TiO_2 in the study area.

3.2.9 Loss on ignition (LOI):

Loss on ignition is restricted between (7.3 at EB95-S2 - 28.81 at EB104-S4 %) with an average of 14.61% (Table 2), its concentration in the BA sample was 9.73% (Figure 10). Loss on ignition is attributed to several reasons, the most important evaporation of molecular water (H_2O^+, OH^-) inside the crystalline structure of clay minerals and the adsorbed water on its surfaces. This is accompanied by the breakdown of carbonate minerals structure and release of carbon dioxide [25], (Table 3).

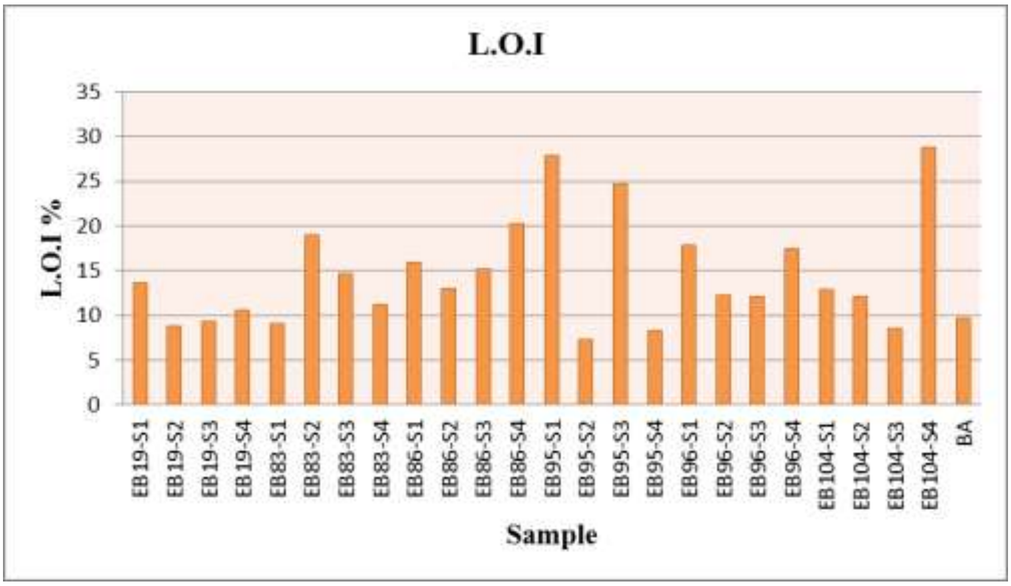

Figure 10: The distribution of LOI in study area

Table 3: Correlation coefficient of major oxides

	SiO2	**Al2O3**	**Fe2O3**	**CaO**	**MgO**	**Na2O**	**K2O**	**TiO2**	**L.O.I**
SiO2	1								
Al2O3	0.927	1							
Fe2O3	0.473	0.651	1						
CaO	-0.430	-0.440	-0.812	1					
MgO	0.681	0.787	0.608	-0.430	1				
Na2O	-0.581	-0.537	0.219	-0.384	-0.433	1			
K2O	0.357	0.513	0.910	-0.773	0.488	0.382	1		
TiO2	0.543	0.650	0.765	-0.779	0.579	-0.034	0.634	1	
L.O.I	0.089	-0.079	-0.573	0.669	-0.288	-0.455	-0.488	-0.664	1

3.3 Trace elements:

One hazardous chemical compound that can form in the soil is trace elements pollution. The content of some trace elements has been analysed (Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sr, V, Zn) in the soil of the East-Baghdad oil field (Table 4). Trace elements contamination can spread in soil via wind, water, and plant absorption [26].

3.3.1 Cadmium:

The cadmium bioavailability is governed by many factors such as soil texture, pH, clay content, type and quantity of organic matter and moisture content [27]. Cadmium contamination in soil is produced from natural sources (weathering of minerals) and anthropogenic activities such as human industrial and agricultural activities [28], [29]. The concentration of cadmium range from (2- 3 ppm) with a mean of 2.12 ppm in the surface soil, its concentration in the BA sample was 2 ppm, exceeding the average value of Cd in Baghdad soil, the international limits natural in soil (Table 5). Cd increase comes from combustion products increasing the concentration of Cadmium in the atmosphere and accumulating in the soil [3] (Figure 11).

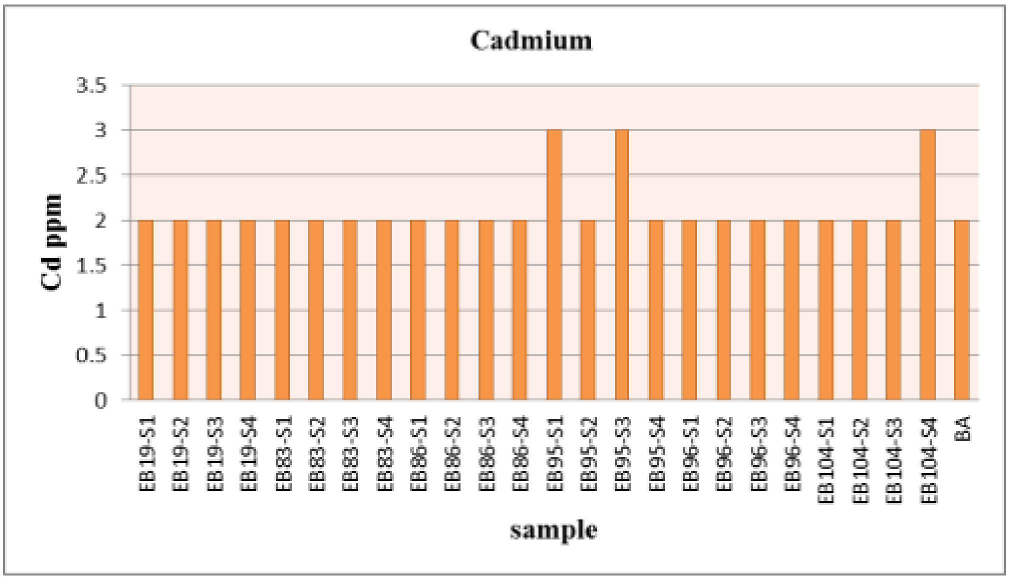

Figure 11: The distribution of Cd in study area

3.3.2 Cobalt:

Cobalt is released into the environment from burning oil and industrial processes [30]. The concentration of Co in the studied area ranges from (3 at EB86-S4 – 29 EB83-S3 ppm) with an average of 13.9 ppm. Its concentration in the BA sample was 7 ppm. The average cobalt value exceeded Baghdad soil's international limits for soil (Table 5). Higher cobalt content in the soil is due to different factors such as the origin of the soil, anthropogenic activities, weathering processes, and sewage water [31] (Figure 12). Cobalt has a strong positive correlation coefficient with Fe_2O_3 (0.839), MgO (0.544), and TiO_2 (0.619) (Table 6); Cobalt may replace Iron or adsorb on the surfaces of its oxides [17]. There is a strong positive correlation with Cu (0.861), Ni (0.844), and V (0.604) (Table 7).

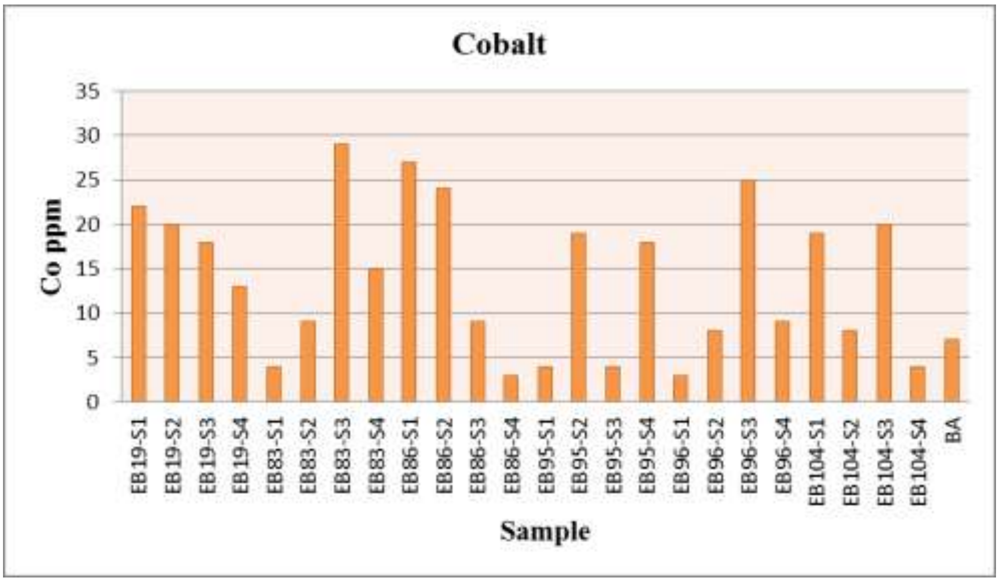

Figure 12: The distribution of Co in the study area

3.3.3 Chromium:

The concentration of Cr ranges from 12 at EB96-S1 to 592 EB86-S3 ppm with a mean of 265.7 ppm. Its concentration in the BA sample was 125 ppm (Figure 13). Cr average value exceeded the international limits for soil in the current study (Table 5). The concentration of Cr in the EB86-S3 sample increases exponentially due to oil spills near the well. There is a positive correlation coefficient between chromium and the major oxides represented by Al_2O_3 (0.509), Fe_2O_3 (0.361), MgO (0.405), and K_2O (0.381), which indicates chromium exists in clay minerals (Table 6).

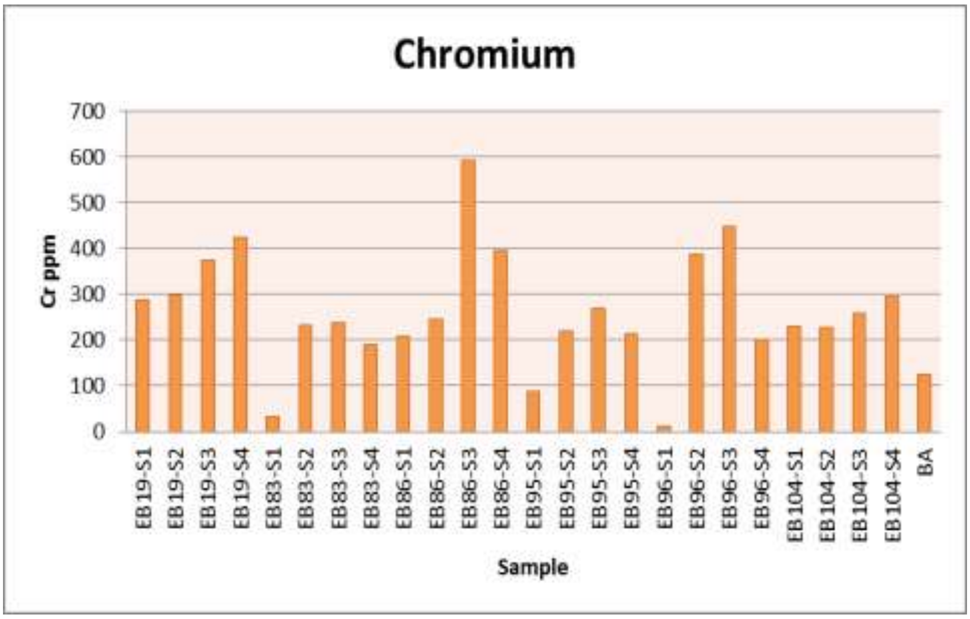

Figure 13: The distribution of Cr in the study area

3.3.4 Copper:

Copper is an essential element but can be toxic in soil when its concentration exceeds natural limits [32]. The concentration of Cu ranged from (19 at EB96-S1 – 61 at EB86-S1, EB86-S2 ppm) with a mean of 40.7 ppm in surface soil. Its concentration in the BA sample was 26 ppm. Cu average value exceeded Baghdad soils international limits (Table 5). The increased concentration of Cu in the study soil might be due to engine wear cars and subtracting these elements from vehicle emissions [33] (Figure 14). There are a strong positive correlation coefficient between Cu with Fe_2O (0.917), K_2O (0.808), TiO_2 (0.674), and positive with Al_2O_3 (0.541), SiO_2 (0.306), which means Cu is absorbed on the surface of the clay minerals [14]. It negatively correlates with CaO (-0.661) (Table 6), indicating a small amount of Cu in calcite. The positive correlation of Co (0.861), Ni (0.911), and V (0.672), suggests that these elements are related to the parent materials and indicate similar geochemical behaviors during weathering [18] (Table 7).

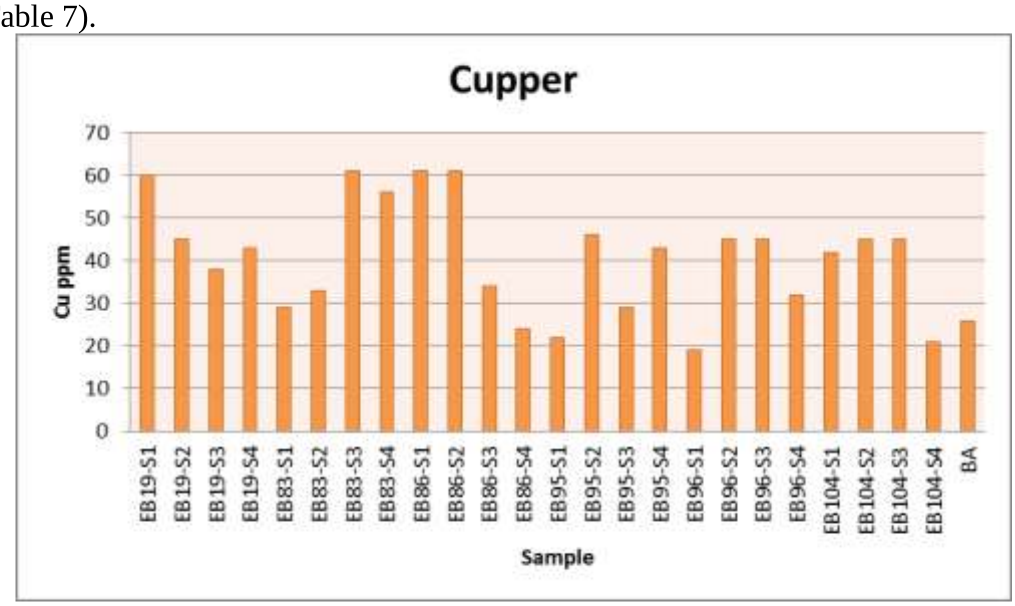

Figure 14: The distribution of Cu in the study area

3.3.5 Iron:

Iron is a commonly occurring metallic element, comprising 4.4% of sedimentary rocks and 4.6% of igneous rocks [34]. Clayey soils have the highest Fe content due to the adsorption processes on clay minerals, while sandy soils have the lowest Fe content [35]. The concentration of Fe in the soil of the study area ranges from (12486 at EB96-S1 - 54380 at EB86-S1 ppm) with an average of 38980 ppm in the soil surface (Table 5). Its concentration in the BA sample was 35091 ppm. The average value of Fe in the current study within the international limits soil according to (Table 5). The existence of Fe in the soil depends on Fe concentration in the parent rocks [36], (Figure 15).

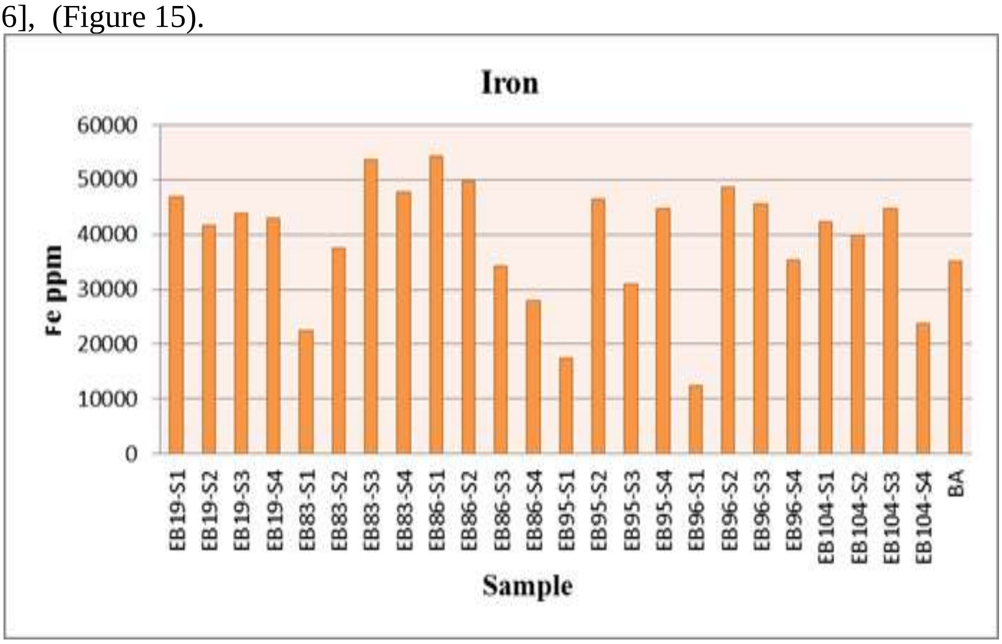

Figure 15: The distribution of Fe in the study area

3.3.6 Manganese:

Manganese is commonly ranges in rocks from 350- 2000 ppm [32]. The most common form of Manganese in soil solution is Mn^{+2}, which is often complexed by organic compounds [32]. The concentration of Mn in the current study range (347 at EB95-S1 – 1087 EB83-S3 ppm) with a mean of 798.2 ppm, and its concentration in the BA sample was 729 ppm. The average concentration of Mn in surface soil exceeded the average value of Mn in international soils (Table 5), (Figure 16). The increase of Mn in the soil is due to a strong association of Mn with Fe [39]. There is a strong negative correlation coefficient of Mn with CaO (-0.7650) (Table 6), indicating the substitution of Ca^{+2} by Mn^{+2} in calcite and the adsorption of Mn on the clay mineral surface [14].

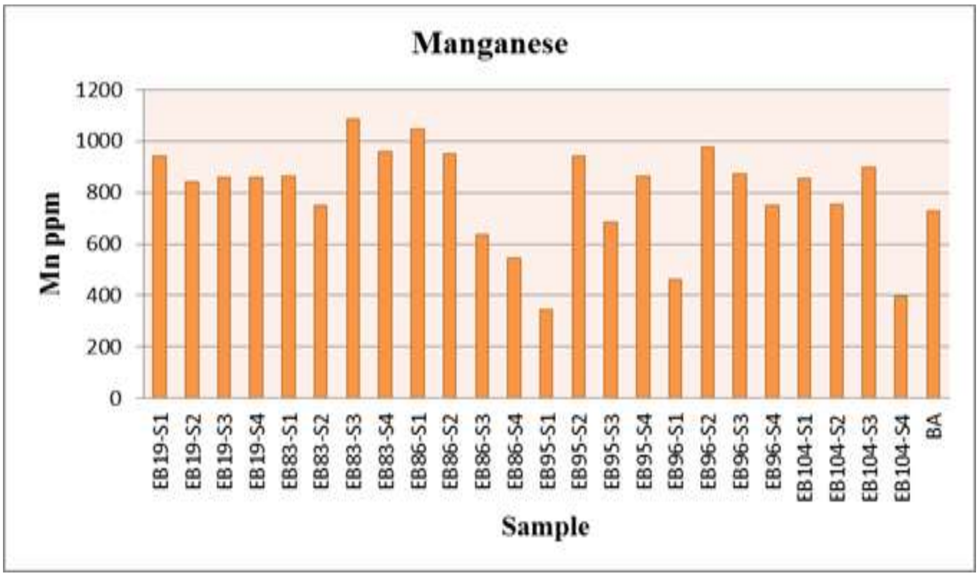

Figure 16: The distribution of Mn in the study area

Table 4: Concentration of Trace elements in the study area (ppm).

Sample No.	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	Mn ppm	Ni ppm	Pb ppm	Sr ppm	V ppm	Zn ppm
EB19-S1	2	22	288	60	46880	943	228	26	434	96	144
EB19-S2	2	20	299	45	41775	842	209	39	391	83	102
EB19-S3	2	18	374	38	43879	860	211	37	414	104	83
EB19-S4	2	13	425	43	43071	861	204	79	471	2	117
EB83-S1	2	4	34	29	22570	864	48	149	564	101	81
EB83-S2	2	9	233	33	37569	749	156	82	723	60	73
EB83-S3	2	29	237	61	53754	1087	259	67	353	131	114
EB83-S4	2	15	191	56	47726	959	230	374	501	130	104
EB86-S1	2	27	210	61	54380	1046	257	362	454	97	119
EB86-S2	2	24	247	61	49631	952	243	36	351	117	103
EB86-S3	2	9	592	34	34254	638	141	428	597	59	82
EB86-S4	2	3	395	24	27975	547	105	58	644	86	52
EB95-S1	3	4	89	22	17425	347	75	95	1069	1.3	77
EB95-S2	2	19	220	46	46394	944	230	42	374	119	100
EB95-S3	3	4	270	29	30928	685	89	28	381	89	70
EB95-S4	2	18	215	43	44690	863	219	113	395	106	98
EB96-S1	2	3	12	19	12486	461	27	82	775	1.2	50
EB96-S2	2	8	388	45	48566	979	236	21	354	88	95
EB96-S3	2	25	448	45	45493	871	213	46	343	115	92
EB96-S4	2	9	200	32	35276	752	138	60	451	59	73
EB104-S1	2	19	231	42	42428	857	207	24	445	98	92
EB104-S2	2	8	227	45	40025	756	205	61	448	107	88
EB104-S3	2	20	258	45	44619	897	217	40	408	117	94
EB104-S4	3	4	296	21	23727	399	64	390	509	1.4	238
BA	2	7	125	26	35091	729	56	22	243	89	43

Table 5: Range and average of trace element concentrations in surface soil samples for the study area and elements distribution limits in world soil according to [30], [37], and Baghdad soil according [38]..

Trace element	Present Study		[38]	[37]	[30]
	Range	Mean			
Cd	2-3	2.1	0.472	0.06	1.1
Co	3-29	13.9	16.63	8	6.9
Cr	12-592	265.7	90.25	100	42
Cu	19-61	40.7	32.5	30	14
Fe	12486-54380	38980	-	38000	
Mn	347- 1087	798.2	567.6	600	418
Ni	27-259	175.4	142.525	40	18
Pb	21-428	114.1	31.358	10	25
Sr	343-1069	493.7	415.79	-	147

V	1 -131	81.9	51.416	-	60
Zn	50-238	97.5	169.79	50	62

3.3.7 Nickel:

The nickel acts as a toxic trace element. Ni is introduced chiefly into the soil by anthropogenic activities, such as smelting, mining and sewage sludge. Combustion of oil and coal, burning of diesel, chemical industries, and metal and glass industry are all sources of this element [40]. The concentration of Ni ranged from (27 at EB96-S1- 259 at EB83-S3 ppm) with a mean of 175.4 ppm in surface soil (Table 5), and its concentration in the BA sample was 56 ppm. The average concentration of Ni in surface soil exceeded the average value of Ni in international limits soil (Table 5), (Figure 17). Ni has a strong positive correlation with Fe_2O_3 (0.975), K_2O (0.926), Al_2O_3 (0.680), and TiO_2 (0.688). Table-6 suggests that Ni is associated with chlorite minerals [41].

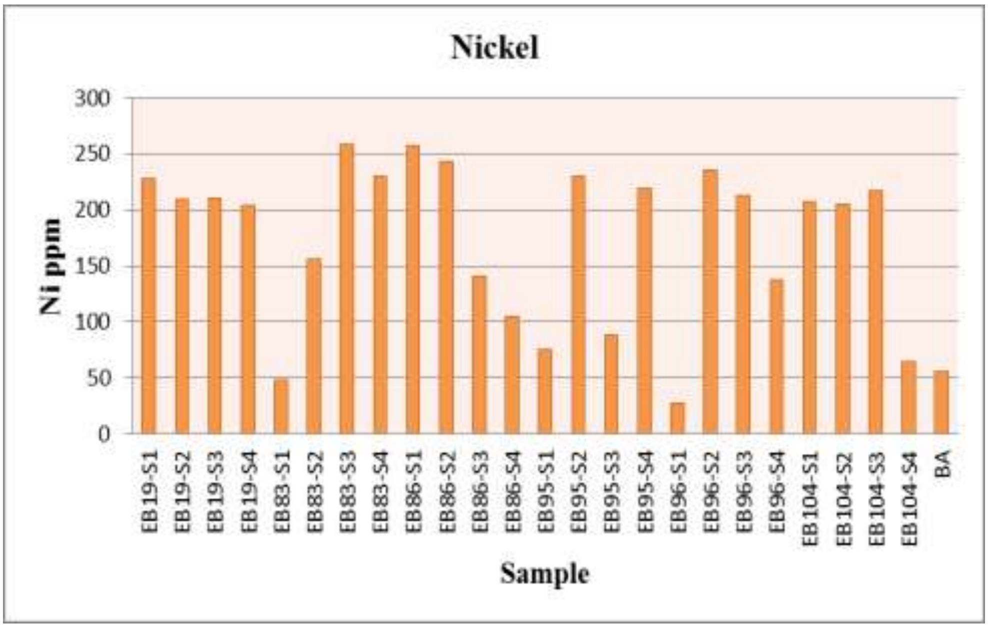

Figure 17: The distribution of Ni in the study area

3.3.8 Lead:

Lead metal is a carcinogenic trace element that takes a long time to degrade [42]. Anthropogenic sources of lead contamination, the influence of previously used leaded petrol, and industrial emissions are considered the most significant environmental risks [43]. Generally, industrial sites have the highest concentrations of Pb than roadside sites and other land-use sites [44]. The concentration of Pb in the current study range from (21 at EB96-S2 – 428 at EB86-S3 ppm) with an average of 114.1 ppm, its concentration in the BA sample was 22 ppm. The average concentration of Pb in surface soil is higher than the average value of Pb in international limits soils (Table 5), (Figure 18). The increase of Pb concentration in soil is due to industrial processes in oil fields that increase the concentration of Pb in the atmosphere and then in the soil [45]. The high Pb concentration in some samples has been attributed to the oil spills during drilling processes.

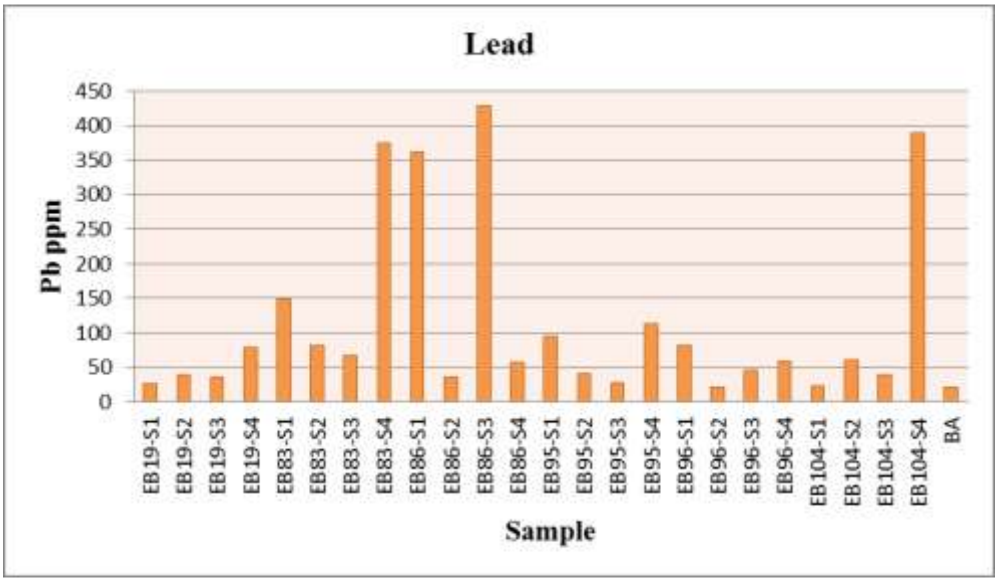

Figure 18: The distribution of Pb in the study area

3.3.9 Strontium:

The main sources of Sr pollution are sulfur mining and coal combustion. Phosphorite Sr may be concentrated up to 2000 ppm, making them a local source of soil pollution because of phosphate fertilisers [32]. The concentration of strontium range from (343 at EB96-S3 -1069 at EB95-S1 ppm) with an average of 493.7 ppm in surface soil. Its concentration in the BA sample was 243 ppm. The average concentration of Sr in surface soil higher the average value of Sr in international limits soils (Table 5), (Figure 19). High concentration of Sr in soil sample (EB95-S1) due to the increase of calcite mineral in a sample, Sr can be found in high concentration in calcite mineral, as Sr^{+2} can replace Ca^{+1} in the acceptance process because the Sr ion radius is similar to the radius of calcium and is related to calcium due to its geochemical affinity, its strong positive correlation with calcium oxide (0.821) enhances its presence in calcite mineral in this study [17]. Sr has a negative correlation coefficient with SiO_2 (-0.423), Al_2O_3 (-0.450), Fe_2O_3 (-0.743), and K_2O (-0.680) (Table 6), which are the chemical composition of clay minerals. It has a strong positive correlation with CaO (0.821) Because the strontium ion radius is similar to the radius of calcium and is related to calcium due to its geochemical affinity.

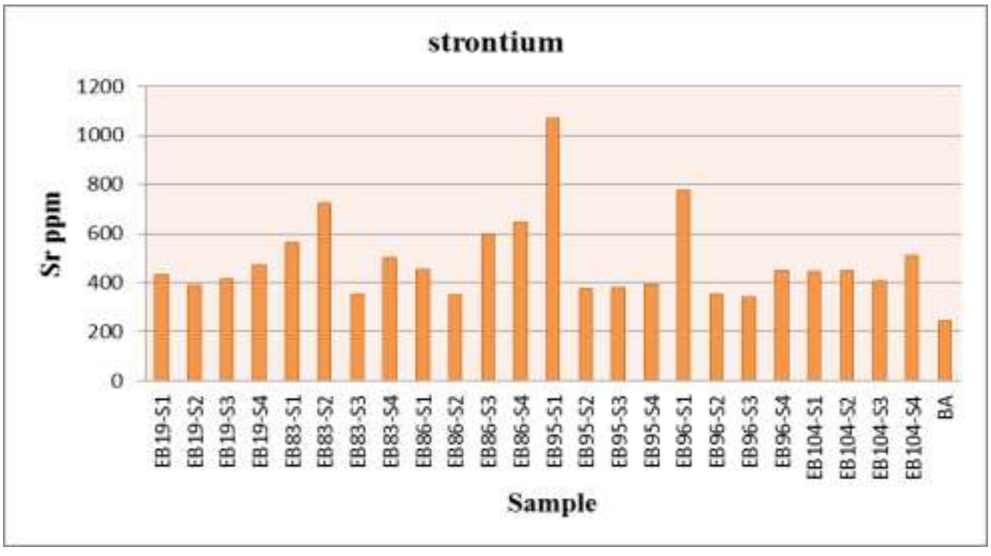

Figure 19: The distribution of Sr in the study area

3.3.10 Vanadium:

Vanadium is a redox-sensitive metal released to soils by weathering, and anthropogenic emissions such as mining, burning fossil fuels, pesticides, and domestic waste recycling can damage the soil. Parent rocks are the main sources of vanadium-contaminated soils [46]. Vanadium concentration in soil samples varies from (1 at EB96-S1 – 131 at EB83-S3 ppm) with an average of 81.9 ppm. Its concentration in BA sample was 89 ppm. Increased vanadium concentrations in the soil are caused by combustion emissions [47], as a high percentage of vanadium remains in oil derivatives even after the refining process and release when the fuel is burning [48]. The mean concentration of V in the studied area is higher than international limits soil (Table 5). The high concentration of V in soil is due to fuel combustion from the East Baghdad oil field [3] (Figure 20).

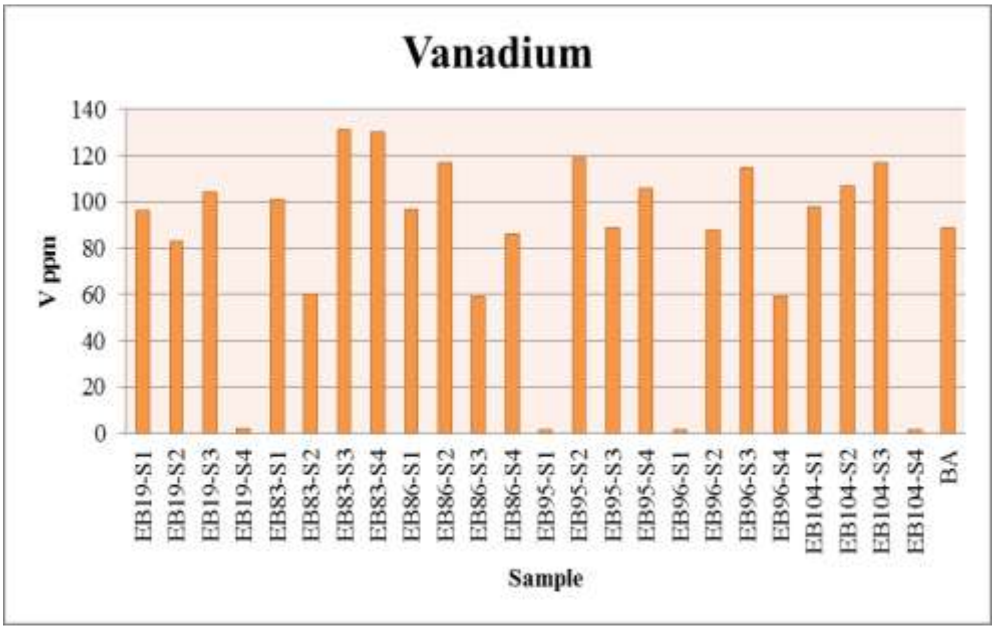

Figure 20: The distribution of V in the study area

3.3.11 Zinc:

The important sources of anthropogenic zinc in the soil are coal, mine tailings, and fertilizers. The content of Zn in the soil is associated with the extent of weathering processes and the chemical composition of the parent rock [32]. The concentration Zn in the soil of the study area ranged from (50 at EB96-S1 - 238 at EB104-S4 ppm) with an average of 97.5 ppm in soil. Its concentration in BA sample was 43 ppm. The average concentration of Zn in the studied area is higher than international limits soil (Table 5) (Figure 21). The relatively high concentration of Zn may be due to the presence of highly concentrated minerals in industrial areas such as Pb [49]. Zinc has a weak negative correlation with SiO_2 (-0.176), Al_2O_3 (-0.254), K_2O (-0.419), and TiO_2 (-0.032). There is also a negative correlation between Zn and Fe_2O_3 (-0.219), indicating no Zn in iron oxides (Table 6). The mean concentration of Cr, Ni, and Zn in the studied area is higher than the international limits soil (Table 5). Cr, Ni, and Zn values are known to come from the fuel combustion products, which increase their concentration in the atmosphere and accumulate in the soil [3].

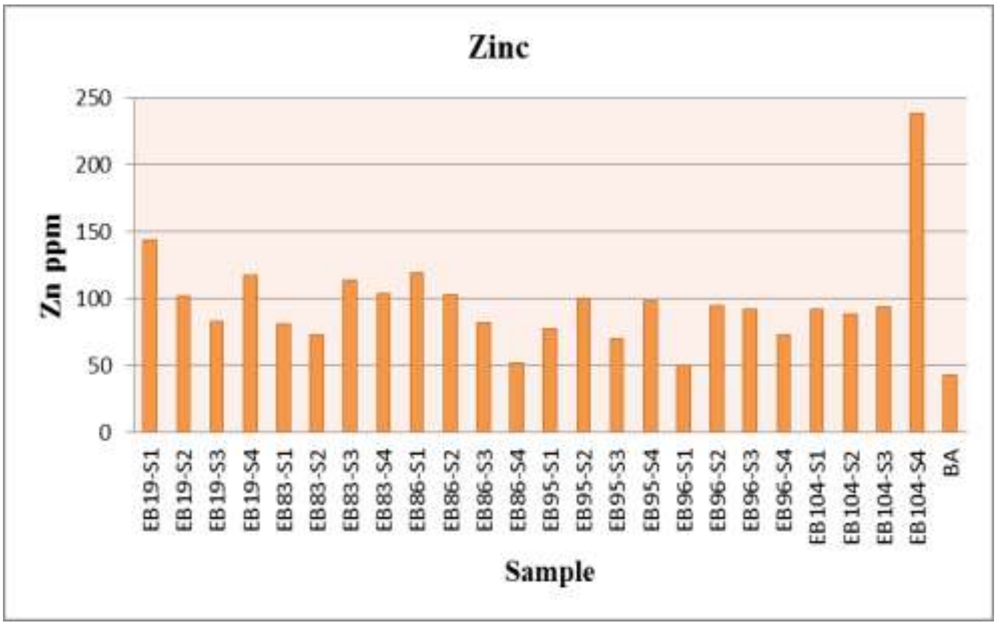

Figure 21: The distribution of Zn in the study area

Table 6: Correlation coefficient of major oxides with trace elements

	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2	L.O.I
Cd	-0.032	-0.213	-0.504	0.559	-0.313	-0.249	-0.477	-0.711	0.804
Co	0.238	0.477	0.839	-0573	0.544	0.210	0.739	0.619	-0.517
Cr	0.620	0.509	0.361	-0.472	0.405	-0.099	0.381	0.418	-0.096
Cu	0.306	0.541	0.917	-0.661	0.548	0.197	0.808	0.674	-0.542
Fe	0.473	0.651	0.999	-0.813	0.608	0.220	0.910	0.765	-0.574
Mn	0.352	0.548	0.896	-0.765	0.544	0.150	0.705	0.838	-0.720
Ni	0.363	0.680	0.975	-0.745	0.599	0.276	0.926	0.688	-0.597
Pb	0.161	0.101	-0.077	0.077	0.133	-0.253	-0.081	-0.108	0.264
Sr	-0.423	-0.450	-0.743	0.821	-0.389	-0.264	-0.680	-0.748	0.550
V	0.191	0.271	0.692	-0.721	0.218	0.346	0.553	0.561	-0.605
Zn	-0.176	-0.254	-0.219	0.040	0.068	-0.132	-0.419	-0.032	-0.103

Table 7: Correlation coefficient of trace elements

	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sr	V	Zn
Cd	1										
Co	-0.447	1									
Cr	-0.136	0.166	1								
Cu	-0.487	0.861	0.145	1							
Fe	-0.504	0.839	0.362	0.917	1						
Mn	-0.621	0.775	0.117	0.880	0.896	1					
Ni	-0.524	0.844	0.332	0.911	0.975	0.846	1				
Pb	0.178	-0.099	0.132	-0.024	-0.077	-0.156	-0.124	1			
Sr	0.357	-0.596	-0.360	-0.629	-0.743	-0.742	-0.662	0.168	1		
V	-0.477	0.604	0.068	0.672	0.693	0.760	0.646	-0.192	-0.652	1	
Zn	0.057	-0.152	-0.307	-0.094	-0.218	0.087	-0.295	0.228	-0.026	0.032	1

4.Minerology

X-ray Diffraction for the same soil samples was achieved to distinguish clay and non-clay minerals. It shows the clay mineral content of selected soil samples (Table 8). The results showed the presence of clay minerals represented by Chlorite and Illite, Kaolinite, Palygorskite, Montmorillonite and mica on-clay minerals represented

Table 8: Semi-quantitative percentage of clay minerals and non-clay minerals

Clay mineral& Non-clay mineral	EB19-S1	EB83-S3	EB86-S1	EB95-S1	EB96-S1	EB104-S4	0.
Albite	4.2	10.1	10.2	-	-	6.6	7.775
Barite	-	-	-	2.7	10.8	-	6.75
Calcite	26,6	40.8	29.5	83	80.5	15.7	46
Dolomite	7.2	-	4.7	4.4	-	15	7.825
Gypsum	7.1	-	3.8	4.1	5.6	-	5.15
Quartz	42.6	18.3	32.4	5.8	-	55.9	31
Sulfur	-	-	-	-	3	-	3
Chlorite	7.6	9	5	-	-	-	7.2
Kaolinite	-	-	5.7	-	-	3.9	4.8
Illite	-	10.3	8.7	-	-	2.8	7.26
Palygorskite	2.7	3.2	-	-	-	-	2.95
Mica	1.6	-	-	-	-	-	1.6
Montmorillonite	0.5	0.3	-	-	-	-	0.4

5. Conclusions

The results of the geochemical analysis of the major oxides showed a high concentration of SiO_2, CaO, and a high percentage of loss on ignition compared to other major oxides Na_2O, Al_2O_3, Fe_2O_3, MgO, K_2O, TiO_2 respectively. The increased Fe_2O^3 concentration is due to soil alkalinity. A positive correlation coefficient between iron oxide with silica, aluminum oxide, potassium oxide, and titanium oxide suggests the presence of iron oxide in clay minerals. It negatively correlates with LOI due to the high calcite content in the clay minerals.

It is apparent through the results obtained from the geochemical analysis showed that the average relative content of the concentration of trace elements in the study soil is in the following ascending order: (Cd<Co<Cu<V<Zn<Pb<Ni<Cr<Sr<Mn<Fe). All concentrations of trace elements are above their normal rates when compared to the world limits except for iron which was within the world limits of soil. East Baghdad oil field soil was heavily contaminated with trace elements. The oil industries, oil drilling and extraction operations, and human activities are among the causes of increasing concentrations of trace elements in the soil of the study area. In addition, the parent rocks and soil type form this soil of trace elements. The results of the mineralogical analysis revealed that chlorite, Palygorskite, Illite, Montmorillonite and kaolinite represent the clay minerals. Quartz and calcite were the most common non-clay minerals, followed by Gypsum, Barite, Dolomite, Albite and Sulfur minerals with lower percentages.

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