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Assessment of Heavy Metals pollution in the soil of Oilfield West Qurna-1 in Basra City, Iraq.

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Abstract

This study aims to assess the degree of contamination by heavy metals in the topsoil of the oilfield West Qurna-1. After collecting 16 soil samples in October 2023, the results were classified as sandy sludge. The research region has a soil organic matter (OM) concentration of 3.6%, a pH level of 7.8, and a soil salinity of 8%. Soil samples collected from the oilfield WQ-1 contained detectable levels of heavy metals compared with national and world limits They had moderate levels for. Cr=255.6 ppm, Ba=445.3 ppm, Rb=46.3 ppm, and high levels of heavy metals Ni=170.6 ppm, Sr=716.5 ppm, Cu=64.6 ppm, Br=128.8 ppm, and Zn=122.4 ppm. The basis for evaluating heavy metal contamination was using the Contamination Factor (CF), Geoaccumulation Index (I-geo), Pollution Load Index (PLI), and Enrichment Factor (EF), all of which indicated that the samples had a high level of contamination. Bromine was the most severely contaminated element, and copper, strontium, and chromium were moderately contaminated..

Keywords: West Qurna-1(WQ-1) , Heavy Metals (HMs) , Contamination Factor (CF), XRD, XRF, Pollution Load Index (PLI), Geo-accumulation Index (I-geo).

تقييم تلوث المعادن الثقيلة في تربة حقل غرب القرنة-1 النفطي في مدينة البصرة، العراق

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الخلاصة

تهدف هذه الدراسة الى تقييم درجة التلوث بالعناصر الثقيلة في التربة السطحية لحقل غرب القرنه-1 النفطي. وبعد جمع 16 عينة تربة في اكتوبر 2023 , تم تصنيف التربة على انها طينية طمية . تحتوي منطقة الدراسة على تركيز المادة العضوية فب التربة بنسبة 3.6% ومستوى الرقم الهيدروجيني 7.8 وملوحة التربة بنسبة 8% . تحتوي عينة التربة التي تم جمعها من حقل غرب القرنه-1 النفطي على مستويات قابله للكشف عن المعادن الثقيلة بالمقارنه مع الحد الوطني والعالمي وكانت المستويات معتدلة في , الكروم (255.6جزء في المليون) و الباريوم (445.3 جزء في المليون) و الربيديوم (46.3 جزء في المليون) ومستويات عاليه من العناصر الثقيله النيكل (170.6 جزء في المليون) و السترونشيوم (716.5 جزء في المليون) والنحاس (46.3 جزء في المليون) و البروم (128.8 جزء في المليون) و النيكل (122.4 جزء في المليون).وكان الاساس لتقييم تلوث العناصر الثقيلة هو استخدام عامل التلوث ومؤشر التراكم الجيولوجي ومؤشر حمل التلوث وعامل الاثراء,

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اشارت جميعها الى ان العينات كانت تحتوي على مستوى عالي من التلوث . كان البروم هو العنصر الاكثر تلوثا , وكان النحاس والسترونشيوم والكروم عناصر ملوثه بشكل معتدل.

1. Introduction:

Heavy metal (HM) pollution of soils is a significant global environmental issue[1]. In recent decades, the proliferation of diverse industrial activities and processes, coupled with the extensive production of materials and compounds, particularly in industrial towns, has resulted in significant environmental pollution from industrial effluents. Consequently, identifying environmental toxins resulting from industrial operations, particularly in water and soil resources, is imperative. Consequently, pinpointing the origins and determinants of water and soil pollution helps enhance the management of these resources. Furthermore, essential actions can be implemented by establishing a monitoring network to mitigate and regulate diverse pollutants in industrial municipalities,. Pollution arises when the concentration of a pollutant element or compound surpasses the threshold level, hence interfering with the activities of organisms[2]. Determining the origin of metal contaminants infiltrating the soil can facilitate the management of soil pollution, avert the dissemination of pollutants to other biospheric components, and ultimately to the human food chain, in addition to formulating strategies for the remediation of polluted soils. Consequently, numerous recent studies have concentrated on chromium, barium, nickel, copper, zinc, bromine, chromium, rubidium, and strontium[3]. To ascertain the potential sources of escalating metal contaminants in the soil, it is vital to examine the statistical properties of the data distribution and employ multivariate statistical methodologies in various research; Nonetheless, examining the ratio of heavy metals attributable to anthropogenic activities versus those originating from natural sources, through metrics such as contamination factor, I-geo accumulation, enrichment factor, pollution load index, and contamination degree[4], is a prevalent approach employed by researchers. The ongoing spatial alterations of soil parent materials, coupled with the concentration of environmentally detrimental human activities in specific locales, undoubtedly result in significant variations in the ratio of natural to anthropogenic factors affecting the concentration of heavy metals in the soil across different spatial dimensions. Simultaneously, accurate data regarding the spatial variations in the concentration of heavy metals in the soil is essential for formulating pollution control strategies. Consequently, mapping the trends of spatial variability in metal pollution can yield valuable insights for identifying regions contaminated by natural or anthropogenic factors[5]. Climatic circumstances considerably impact the dispersion of hazardous materials (HMs) in the air, affecting the ground in the direction of the prevailing wind. The user's text is enclosed in tags [6]. The liquidity and accessibility of HMs vary based on their source. Metals that undergo diagenesis have a reduced ability to move around since they are closely associated with parent minerals. In contrast, heavy metals caused by human activity are more easily transported [7]. [8].

2. Study area.

West Qurna-1 (WQ-1) is located in the southeastern region of the Republic of Iraq. The WQI [9] is located approximately 70 kilometers northwest of Basra City. The field has an area of 500 square kilometers. The Zagros Fold Belt is situated in southern Iraq, on the eastern periphery of the Arabian Platform, south of the Mesopotamian Basin. It has a northern boundary adjacent to the West Qurna-1 Oilfield [10]. The study region is placed between longitudes (47º 19′ 12″ E) and (47º 19′ 53″) E, and latitudes (30º 45′ 35″ N) and (30º 52′ 54″ N). The sample sites were accurately determined using GPS, as shown in (Figure 1).The wind is blowing from the northwest and southeast.

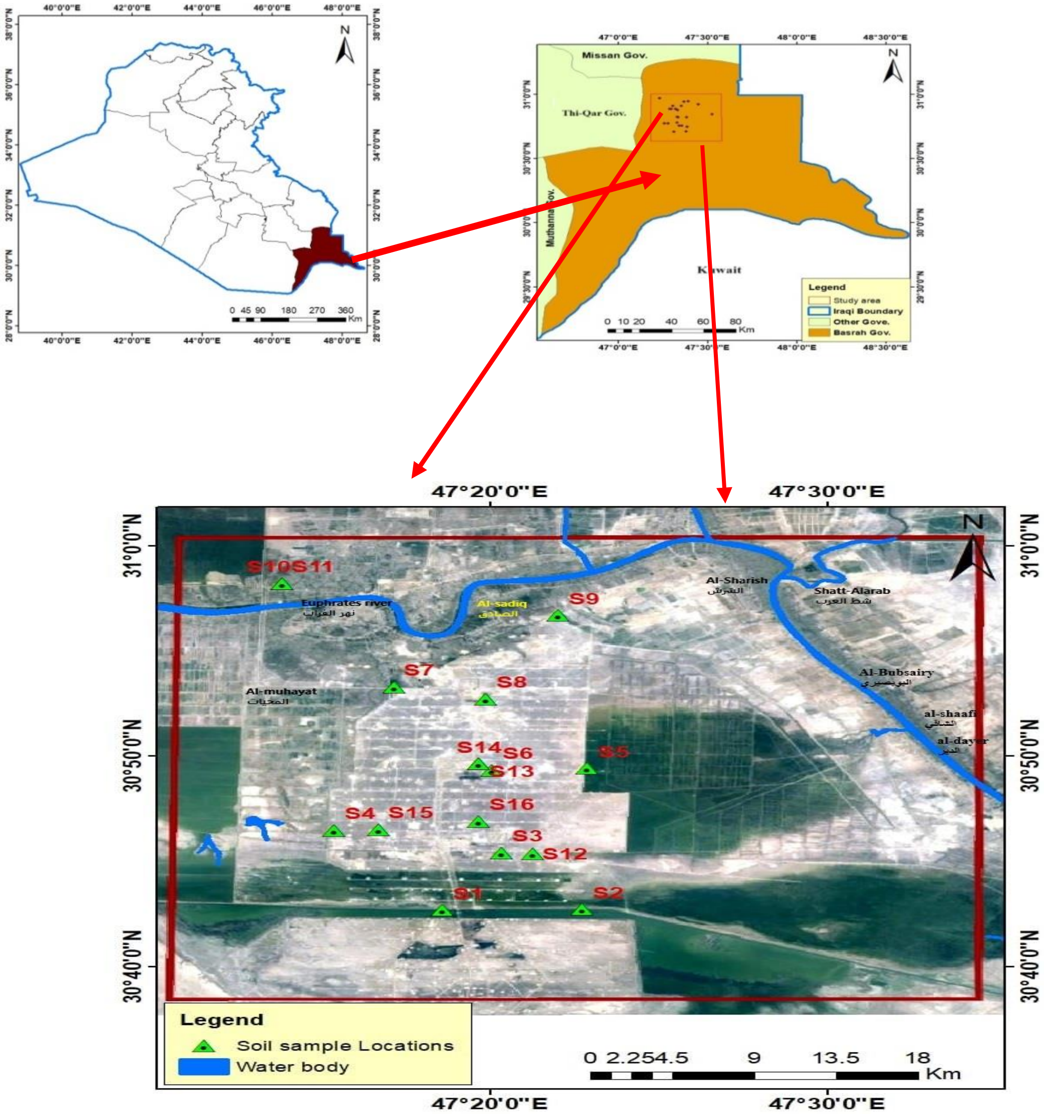


Figure 1: Location map of the studied area (West Qurna-1 oilfield) showing sampling stations.

3. Material and methods

3.1 Sample collection. A total of 16 soil samples were collected from the study area in the field at a distance of km. The samples were taken at three distinct depths: (0 cm, 30 cm, and 50 cm, as shown in Table 1 and Figure 1). The soil samples, weighing one kilogram, were collected manually. Afterwards, the materials were brought to the laboratory and kept at room temperature until fully dehydrated. The samples were further filtered through a two-millimeter sieve to remove any sizable stones, Subsequently, the specimens were enclosed in polyethylene bags and subjected to crushing by applying a mixture of nitric and hydrochloric acids. XRF laboratory of the Geology Department, Faculty of Sciences, Tarbiat Modarres University in Tehran, Iran Islamic.

Table 1: Geographic coordinates of the sampling stations.

Sample. No	longitiude	latitude	Sample. No	Longitiude	latitude
S_1	47° 18′ 34″	30° 42′ 41″	**S_9**	47°21′ 59″	30°56′ 43″
S_2	47° 22′ 42″	30°42′ 43″	**S_10 30cm**	47°13′ 47″	30°58′ 14″
S_3	47°20′ 19″	30°45′ 25″	**S_11 50cm**	47°13′ 47″	30°58′ 14″
S_4	47°15′ 21″	30°46′ 29″	**S_12 30cm**	47°21′ 14″	30°45′ 22″
S_5	47°22′ 51″	30°49′ 26″	**S_13 50cm**	47°19′ 38″	30°49′ 39″
S_6	47°20′ 2″	30°49′ 20″	**S_14**	47°19′ 38″	30°49′ 39″
S_7	47°17 ′6″	30°53′ 18″	**S_15**	47°16′ 39″	30°46′ 31″
S_8	47°19′ 50″	30°52′ 44″	**S_16**	47°19′ 38″	30°46′55″

3.2 Heavy metals pollution assessment

An effective method for analyzing heavy metal contamination is using the pollution load Index. This index allows for a thorough evaluation of soil quality and the buildup of HMs resulting from both natural and human activities. To assess the extent of soil contamination, this index can be integrated with other indicators such as the geoaccumulation index (I-geo), Contamination Factor (CF), and pollution Load Index (PLI) [11]. The approaches proposed by [12] are consistent with this approach.

3.2.1 The Contamination Factor (CF)

The CF is a quantitative measure utilized to assess the impact of human activities on soil contaminants, as highlighted by reference [13]. The Contamination Factor can be calculated using the following formula:

$$CF = Cn/Cb \tag{1}$$

Table 2 is an effective tool for assessing the extent of heavy metal contamination in soil. In this context, "Cb" represents the initial metal concentration, while "Cs" indicates the current metal concentration in the soil. This methodology, as explained by [14], is essential for evaluating the magnitude of soil contamination.

Table 2: Shows the Contamination Factor (CF) Category [14] was used in the present study.

Value	CF Category
CF<1	Mildly pollution
1<CF>3	Medium pollution
3<CF<6	High pollution
6<CF	Extreme pollution

3.2.2 Geo-accumulation Index (I-geo)

The primary application of this method was to evaluate the magnitude of soil contamination by heavy metals (HMs), as proven by [15]. The method uses the coefficient (I-geo) and a precise formula to ascertain the extent of heavy metal buildup in the soil:

$$I\text{-}geo = \log 2\ Cn/\ Bn*1.5 \tag{2}$$

During the analysis of the samples, the measurement of heavy metals (HMs) is denoted as Cn. In contrast the usual measurement of the earth's crust is denoted as Bn, as indicated by the investigation carried out by [16]. To mitigate potential variations in heavy metal concentrations resulting from human activities and natural events, a constant value of 1.5 was utilized, as recommended by [15] and supported by [17]. The data is presented in Table 3.

Table 3: The Geo-accumulation Index (I-geo) classes [15] were used in the present study.

Degree	Soil Composition
0≥ I-geo	Non-pollution
0<I-geo<1	Non -Medium pollution
1<I-geo<2	Medium pollution
2<I-geo<3	Medium -high pollution
3<I-geo<4	Severe pollution
4<I-geo<5	High –severe pollution

3.2.3 Pollution Load Index (PLI).

The PLI is a quantitative measure employed to assess the extent of metal pollution at a particular site. The PLI is determined by taking the nth root of the n-CF values obtained for each metal. The Pollution Load Index for a specific location is calculated by multiplying the contamination factors (CF values) by the nth source. This indicator helps evaluate the degree of metal pollution and suggests suitable repair measures. The study conducted by [18] found that a PLI (Pollution Load Index) value more than one indicates the presence of pollution, whilst a value less than one indicates the lack of pollution. The PLI considers the levels of trace elements originating from both natural and human activities. Additionally, it is employed to analyze and make sense of data about geochemistry. The classification of PLI values is governed by the contamination factor CF. The formula for PLI, which calculates the average of the products of CF1, CF2, CF3, and so on up to CFn, is represented as: PLI= CFn1*CFn2*CFn3…..CFn ⅟n (3)

3.2.4 Enrichment Factor (EF).

The EF can be utilized as an indicator to assess the concentration of HMs in the soil relative to the source rock. Distinguishing between events caused by human or industrial activities and natural ones is crucial [19] [20]. [21] and [22] utilized the subsequent equation to calculate EF:

$$EF = Cn/Fe\ sample / Cb/Fe\ background \tag{4}$$

The expression (Cn/Fe) sample in the soil samples obtained at the research site represents the iron to HM concentration ratio. The background (Bn/Fe) concentration represents the ratio of heavy metal concentration to the iron content in the background rock. Common geochemical elements in the earth's crust include iron, scandium, manganese, aluminium, titanium, and iron [22]. It serves as a benchmark for comparison. According to [18][23] [24], HMs are believed to originate from industrial or human activities when the EF value exceeds 1.If the enrichment factor (EF) value is less than 1, heavy metals are believed to come from source rocks or naturally occurring weathering processes. The authors [25][21] have identified and classified five types of fortifications, as presented in Table 4.

Table 4: The Enrichment Factor (EF) Category [25] [21], which was used in the present study.

Degree	**EF of Category**
EF<2	Decreases to minimal EF
2<EF<5	Moderate EF
5<EF<20	High EF
20<EF<40	Very high EF
40<EF	Extremely EF

3.2.5 Contamination Degree (CD).

The CD is calculated by summing the contamination factors (CF) of all the heavy metals that have been analyzed [26] [27]. According to [12], the CD can be classified into four groups based on their values, ranging from (6 to 24). These categories are as follows: low (CD < 6), Medium (6 ≤ CD < 12), High (12 ≤ CD < 24), and Extremely (CD ≥ 24).

The equation CD= ΣCF expresses the correlation between CD and ΣCF, where ΣCF denotes the cumulative contamination factors for all metals. This equation is further elaborated upon in the findings and discussion section.

4 Result and Discussion.

4.1 Analysis of Grain Size.

The qualities of soil substantially influence its capacity to retain and interchange components present in soil solutions. Soil contamination is mostly affected by the texture category, where fine particles have a higher ability to absorb cations than coarse particles [28]. Soil floors exhibit variations in both size and shape, and they are classified according to their dimensions. The composition of these intervals determines the distribution of particle sizes in the soil. Hydrometer techniques estimate smaller fractions, while sieving determines greater intervals [29]. These parameters influence erosion factors such as the mechanical characteristics of sediments, and the material's history [30]. The soil samples tested in this study were classified as loam and sandy loam based on their silt content of approximately 50.4%, clay content of 28%, and sand content of 21.6% (Table 5) (Figure 2).

Table 5: Grain size analysis values for the soil sample collected from the West Qurna oilfield.

Sample No.	Percentage of Sand %	Percentage of Silt %	Percentage of Clay %	Soil Texture
S-1	8.8	52.6	38. 6	Mud.
S-2	11.7	48.8	39.5	Sandy mud.
S-3	12.2	47.5	40.3	Sandy mud.
S-4	7.9	47.6	44.5	Mud.
S-5	8.4	53.9	37.7	Mud.
S-6	9.5	51.7	38. 8	Mud.
S-7	13.1	52.4	34.5	Sandy mud.
S-8	9.7	58.9	31.4	Sandy mud.
S-9	8.4	42.5	49.1	Mud.
S-10.30cm	7.6	47.8	44.7	Mud.
S-11,50cm	8.5	53.6	37.9	Sandy mud.
S-12,30cm	10.7	35.9	53. 4	Sandy mud.
S-13,50cm	8.8	48.7	42.5	Sandy mud.
S-14	14.9	49.5	35. 6	Sandy mud.
S-15	11.4	47.2	41.4	Sandy mud.
S-16	12.6	59.9	27.5	Sandy mud.

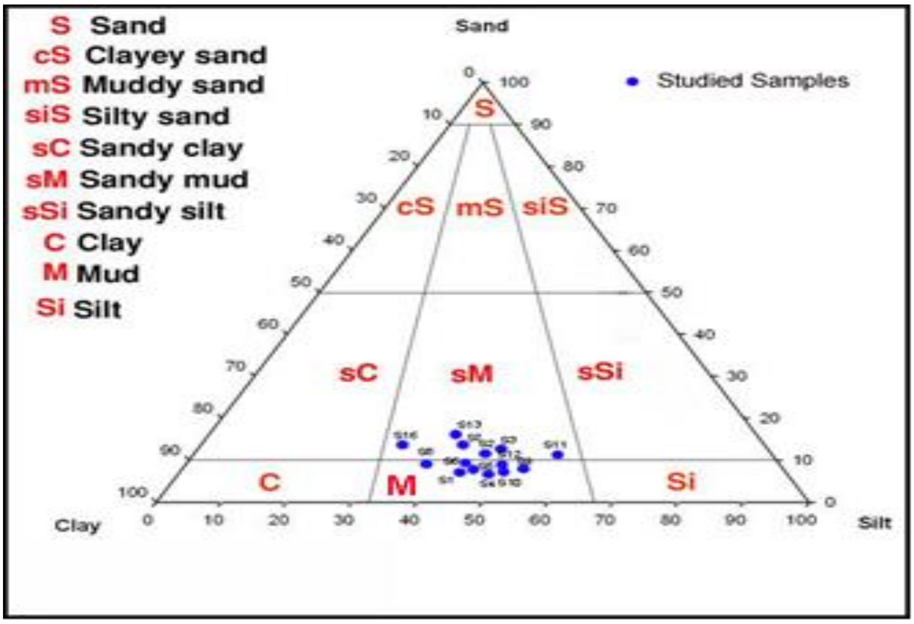


Figure 2: Ternary soil classification based on grain size for the studied soil samples according to [31]

4.2 Hydrogen number (pH)

To ascertain the acidity or alkalinity of 16 soil samples in the research region, a pH meter that had been calibrated was employed. The gadget sensor underwent calibration by submerging it in a solution with a temperature set at 25 °C and activating the CAL button. From the acquired pH values, it was noted that all the soil samples examined displayed alkaline characteristics. The high alkalinity of the soil can be due to the increased concentrations of calcium carbonate and magnesium carbonate. The mean pH value for the entire research area was 7.30 Table 6.

4.3 Organic Matter (OM%).

Soil organic matter (OM) is composed of plant or animal tissue in different phases of decomposition [32]. Soil OM acts as a highly efficient absorber of HMs, effectively trapping them and causing their concentration to increase in tissues [33]. Consequently, soil heavy metal contamination might potentially modify the soil organic matter mineralization rate and affect its distribution and accumulation. The observed OM values in this study ranged from 0.86% to 3.6%, with an average value of 1.9% (Table 6).

Table 6: OM and pH results of soil samples collected from the West Qurna oilfield.

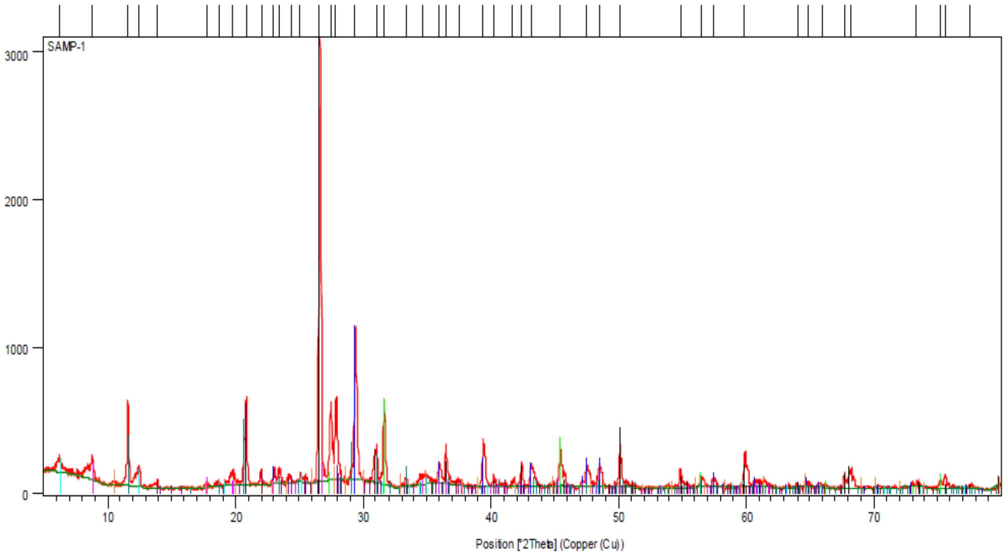
Sample No.	Ratio of OM	pH
S 1	0.8	7.35
S 2	1.1	7
S 3	1.2	7.2
S 4	1.9	7.81
S 5	1.0	7.23
S 6	0.9	7.02
S 7	1.1	7.52
S 8	1.7	7
9	1.4	7.7
S10,30cm	3.6	7.3
S 11,50cm	3.5	7.42
S 12,30cm	1.7	7
S 13,50cm	1.8	7.3
S 14*	1.9	7.45
S 15*	3.4	7.25
S 16*	3.2	7.3

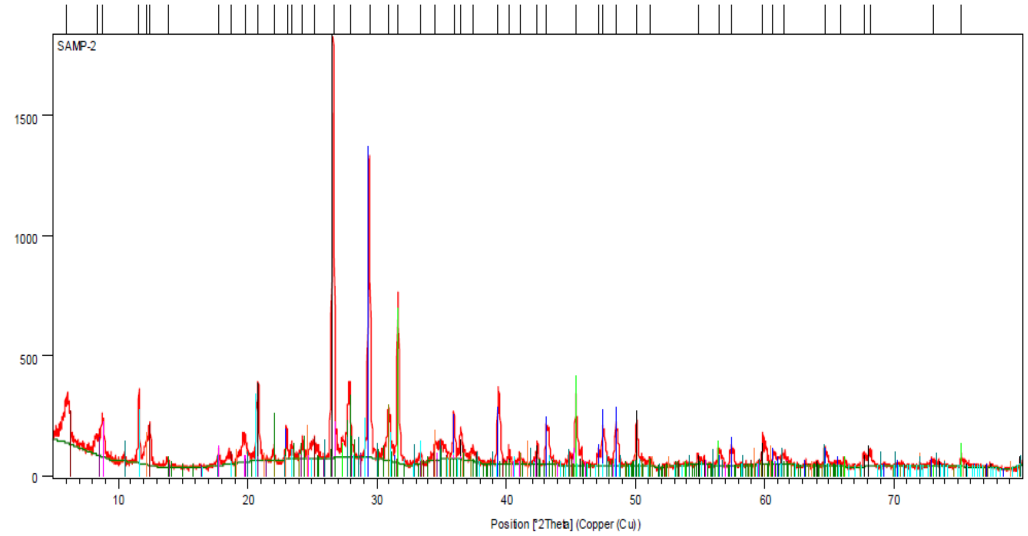
4.4 X-ray diffraction (XRD)

X-ray diffraction is employed to study individual soil samples to differentiate between clay and non-clay minerals found in surface soils. The XRD soil pictures of the West Qurna1 field exhibit substantial quantities of quartz and calcite, and several non-clay minerals such as halite, dolomite, gypsum, actinolite, and albite. The clay minerals that have been identified include muscovite, palygorskite, phyllite, serpentine, and slashite [34]. Clay minerals exhibit numerous characteristics that are advantageous in environmental studies. When exposed to moisture, many clay minerals can undergo a small amount of swelling and expand in thickness by a factor of up to four. Additionally, can assimilate positively charged ions from liquid solutions and subsequently discharge these ions. Furthermore, clay minerals are transported into the soil as detrital detritus from the surrounding environment [35]. This technique has been extensively scrutinized for its effectiveness in identifying minerals in large soil samples. The minerals commonly found in soil include quartz, calcite, albite, dolomite, feldspar, mica, and clay. Among these options, quartz is the most abundant, constituting 32.7% of the total composition (Figure 3). Calcite accounts for 29.2% of the total, while mica, dolomite, and albite comprise only 6.6%, 6.8%, and 10.7%, respectively. The clay minerals comprise 9.3% chlorite and 4.7% kaolinite (Table 7).

Table 7: X-ray diffraction results and identification for collecting soil samples in the study area.

Sample No.	**XRD**	
	Clay	**Non clay**
S1	Clinochlore, Muscovite,	Quartz, Calcite, Albite high, Dolomite, Gypsum, Actinolite, Halite,
S2	Clinochlore ,Muscovite, Palygorskite ,Antigorite	Quartz, Calcite, Albite high, Halite, Actinolite, Dolomite,
S3	Muscovite, Clinochlore	Quartz, Calcite, Albite high, Gypsum, Halite,
S4	Muscovite, Clinochlore	Quartz, Calcite, Albite high, Gypsum, Halite,
S5	Muscovite, Clinochlore	Quartz, Calcite, Albite high, Gypsum, Halite, Dolomite,

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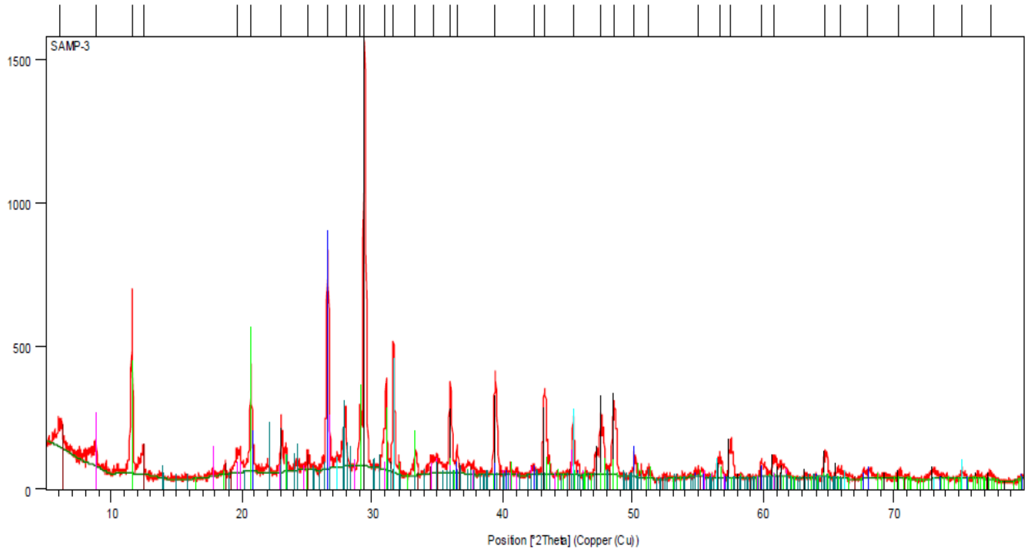
Position [°2Theta] (Copper (Cu))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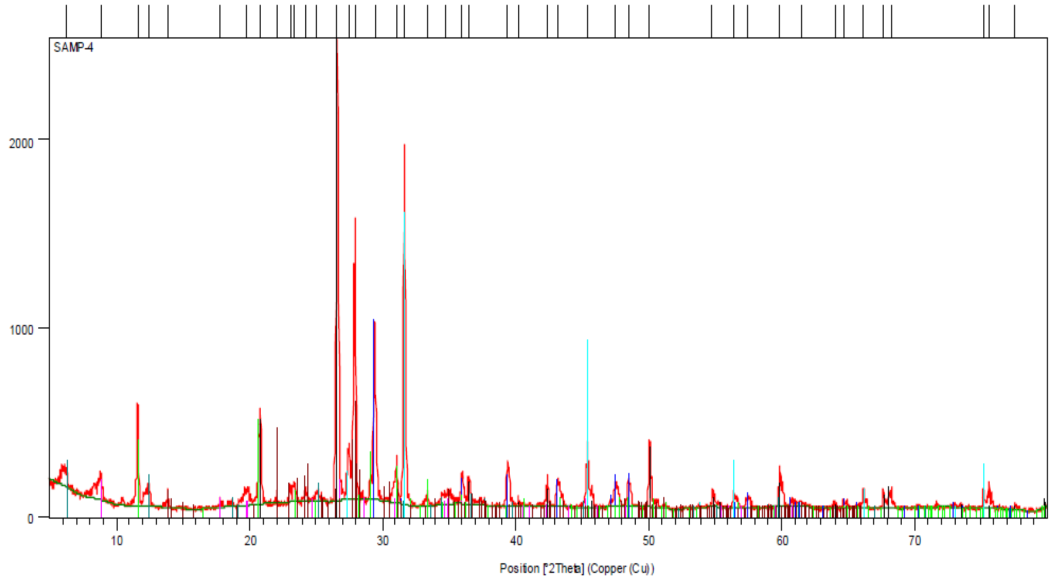
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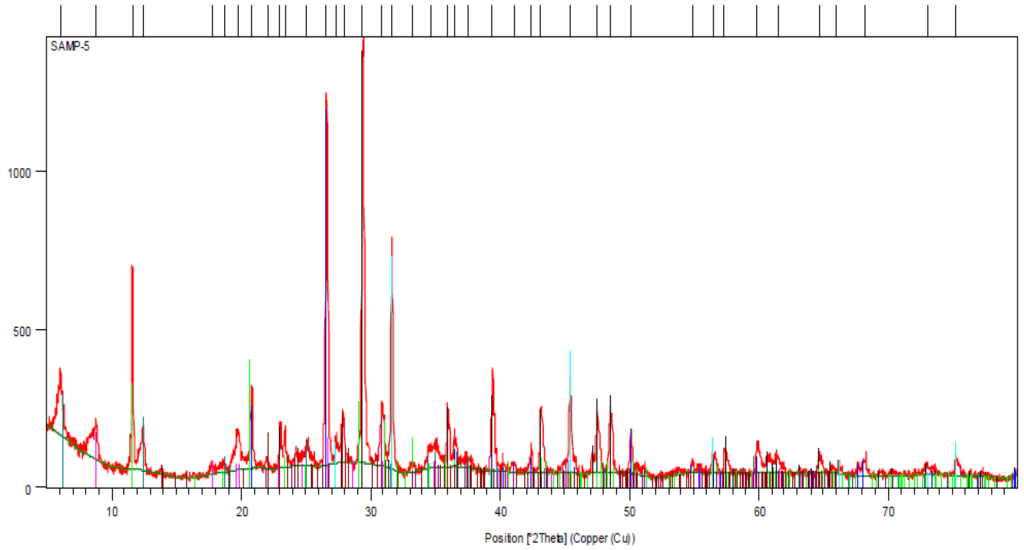

Figure 3: XRD analysis charts for collect soil samples from the West Qurna-1 oilfield.

4.5 XRF

This study utilized X-ray fluorescence (XRF) analysis to evaluate the levels of heavy metals (HMs) in the soil geochemistry of the West Qurna-1 Oilfield. The aim was to assess the concentrations and migration of toxic metals in soil samples. A study was conducted at the XRF Laboratory, located under the Department of Geology at the Faculty of Science, Tarbiat Modares University in Tehran, Iran, to examine the occurrence of HMs (heavy metals) and important oxides. To prepare the samples, they underwent homogenization, were dried at 40°C, and were filtered through a 2 mm sieve to remove pebbles, stones, and plant debris. Before pulverization, a mixture was created by combining 8 grams of the specimen and 2 grams of binder (boric acid). The mixture was then ground into a powder with a particle size of 0.063 µm using an agate mortar for 10 minutes. The compressed soil samples were placed under a 4 cm diameter press, exerting a force of 25 tons for 15 minutes. Afterwards, the samples were put into the XRF equipment (PW2404), and the elemental composition was determined using the measurement software. The recognition of heavy metal poisoning as an environmental hazard has increased significantly due to its detrimental impact on the environment and its association with human health. Heavy metals possess non-biodegradable and thermally resistant properties, enabling them to last in the environment for long periods and eventually accumulate in dangerous amounts.

4.5.1 Heavy Metals (HMs)

Human activities have caused the discharge of toxins into the environment, resulting in a pressing issue of soil contamination by heavy metals. Precisely measuring the magnitude of this pollution is crucial, as it presents a substantial risk to both human well-being and agricultural products. The concentration of heavy metals in surface soil is influenced by several parameters, including particle sedimentation, deposition rate of heavy metals, particle size, and soil organic matter. Under situations of lower reactivity, metallic elements such as Nickel (Ni), Zinc (Zn), Copper (Cu), Chromium (Cr), Bromine (Br), Rubidium (Rb), Strontium (Sr), and Barium (Ba) can establish chemical connections with carbonates and go from a liquid solution into the soil. For instance, the soil at West Qurna-1 contains different concentrations of several metallic elements. (Table 7). Human-induced pollution, such as air pollution, wastewater, waste decomposition, and combustion processes, is the primary source of heavy metal contamination. Sr is assimilated into the mineral calcite in the studied area, making up 29.2% of its composition. In addition, Sr is frequently present in the clay fraction due to the replacement of Ca in the $CaCO_3$ derivatives of the rock [36] [37] [38]. The increased nickel concentrations in the soil can be linked to carbonates and clay minerals. Fertilizers containing high levels of zinc, as well as other heavy metals such as copper, contribute to the generation of certain pollutants. The rise in these pollutants can be attributed to the industrial discharge resulting from fuel combustion and the release of gases from isolation stations. Pollutants in bottom sediments can originate from both natural and anthropogenic sources, including fertilizer waste and petroleum extraction [39].

Table 7: Heavy metals concentration for collecting soil samples in the study area using the XRF technique recommended by World Soil [38].

Samlpe Number	Ni	Zn	Cu	Cr	Br	Rb	Sr	Ba
S1	120	110	120	400	70	50	540	390
S2	170	100	110	300	130	40	380	350
S3	130	70	100	230	120	50	1180	440
S4	130	60	60	200	120	50	450	370
S5	170	70	50	300	100	60	470	400
S6	180	70	50	240	170	30	790	400
S7	130	110	60	270	70	60	500	520
S8	190	440	70	260	100	40	800	520
S9	130	190	40	260	60	60	570	510
S10 -30cm	170	200	50	250	30	60	520	370
S11 -50cm	200	80	70	270	40	50	590	360
S12 30cm	160	150	70	230	140	40	810	520
S13, 50cm	240	100	50	310	80	50	440	400
S14	190	80	60	180	140	30	1270	600
S15	210	60	60	170	520	40	820	330
S16	200	110	50	250	180	40	800	700
Minimum	120	60	50	170	30	30	380	330
Maximum	240	440	120	400	520	60	1270	700
Average	170.6	122.4	64.6	255.6	128.8	46.3	716.5	445.3
Basra city.	131.4	71.96	47.22	488.18	--	--	---	--
World soil.	29	70	38.9	59.5	10	68	175	460

4.6 Geo-accumulation Index (I-geo)

The assessment of soil contamination is determined through the application of the seven levels of geoaccumulation criteria, which span from "severely contaminated" to "not at all contaminated" [40]. If the values of the total trace elements pollution index (I-geo, CF, and PLI) for HMs match the results, the analyzed samples in their respective sites may be damaged by the same species, as stated by [41]. Surface soils have been contaminated with nickel due to industrial and agricultural operations, as well as other human activities, as shown by the pollution index values [42]. The I-geo accumulation results in the research area indicate different degrees of contamination in the soil samples, ranging from non-contaminated to moderate. Copper, zinc, bromine, strontium, chromium, and nickel demonstrate varying degrees of contamination, ranging from negligible to moderate amounts (Table 9). The metals discovered in the soil (Figure 4) are free from Ba and Rb pollution.

4.7 Contamination Factor (CF)

The data in (Table 8) and (Figure 5) indicate that the contamination factor (CF) for nickel in the research region varies between 4.14 and 8.28, with an average value of 5.88. Zinc displays a coefficient of friction (CF) range of 0.86 to 6.26, with an average value of 1.75. The coefficient values (CF) for Chromium (Cr) range from 2.86 to 6.72, with an average of 4.30. The element Cu has a range of CF values from 1.29 to 3.08, with an average of 1.66. The coefficient of friction (CF) for bromine (Br) ranges from 3 to 52, with an average CF value of 12.88. The average CF of Rb is 0.68, with a range of 0.44 to 0.88. The Sr has a coefficient of variation (CF) ranging from 2.17 to 7.26, with an average CF value of 4.09. The CF range of Ba is 0.72 to 1.52, with a mean CF of 0.97. The CF values for Ni, Zn, Cu, Cr, Br, Rb, Sr, and Ba in the research region are classified as "moderately polluted-severely polluted".

Table 8: Contamination factor results of heavy metals for collecting soil samples in the present study.

Sample Number	CF							
	Ni	Zn	Cu	Cr	Br	Rb	Sr	Ba
S_1	4.14	1.57	3.08	6.72	7	0.74	3.09	0.85
S_2	5.86	1.43	2.82	5.04	13	0.59	2.17	0.76
S_3	4.48	1	2.57	3.87	12	0.74	6.74	0.96
S_4	4.48	0.86	1.54	3.36	12	0.74	2.57	0.80
S_5	5.86	1	1.26	5.04	10	0.88	2.69	0.87
S_6	6.21	1	1.28	4.03	17	0.44	4.51	0.87
S_7	4.48	1.57	1.54	4.54	7	0.88	2.86	1.13
S_8	6.55	6.29	1.80	4.37	10	0.59	4.57	1.13
S_9	4.48	2.71	1.02	4.37	6	0.88	3.26	1.11
S_10 30cm	5.86	2.86	1.29	4.20	3	0.88	2.97	0.80
S_11, 50cm	6.90	1.14	1.80	4.54	4	0.74	3.37	0.78
S_12,30cm	5.52	2.14	1.80	3.87	14	0.59	4.63	1.13
S_13 50cm	8.28	1.43	1.29	5.21	8	0.74	2.51	0.87
S_14*	6.55	1.14	1.54	3.03	14	0.44	7.26	1.30
S_15*	7.24	0.86	1.54	2.86	52	0.59	4.69	0.72
S_16*	6.90	1.57	1.29	4.20	18	0.59	4.57	1.52
Minimum	4.14	0.86	1.02	2.86	3	0.44	2.17	0.72
Maximum.	8.28	6.26	3.08	6.723	52	0.88	7.26	1.52
Mean.	5.88	1.75	1.71	4.30	12.88	0.68	4.09	0.97

Table 9: Minimum, maximum, and mean values of Contamination (CF) and Geo-accumulation index(I-geo) of heavy metals for collecting soil samples in the study area.

elements	**Present study**							
	CF				**I-geo**			
	Min	**Max**	**Mean**	**grade**	**Min**	**Max**	**Mean**	**grade**
Ni	4.14	8.28	5.88	Considerable contaminated factor	0.46	0.76	0.60	Uncontamination - moderately contamination
Zn	0.86	6.26	1.75	Moderately contaminated factor	-0.2	0.62	0.05	Uncontamination - moderately contamination
Cu	1.02	3.08	1.71	Moderately contaminated factor	-0.16	0.31	0.04	Uncontamination - moderately contamination
Cr	2.86	6.72	4.30	Considerable contaminated factor	0.28	0.65	0.45	Uncontamination - moderately contamination
Br	3	52	12.88	Very highly contaminated factor	-1.3	-0.23	-0.41	Practically uncontamination
Rb	0.44	0.88	0.68	Low contaminated factor	0.3	1.54	0.83	Uncontaminated - moderately contamination
Sr	2.17	7.26	4.09	Considerable contaminated factor	0.16	0.68	0.41	Uncontaminated - moderately contamination

Ba	0.72	1.52	0.97	Low contaminated factor	-0.32	0.01	-0.12	Practically uncontamination

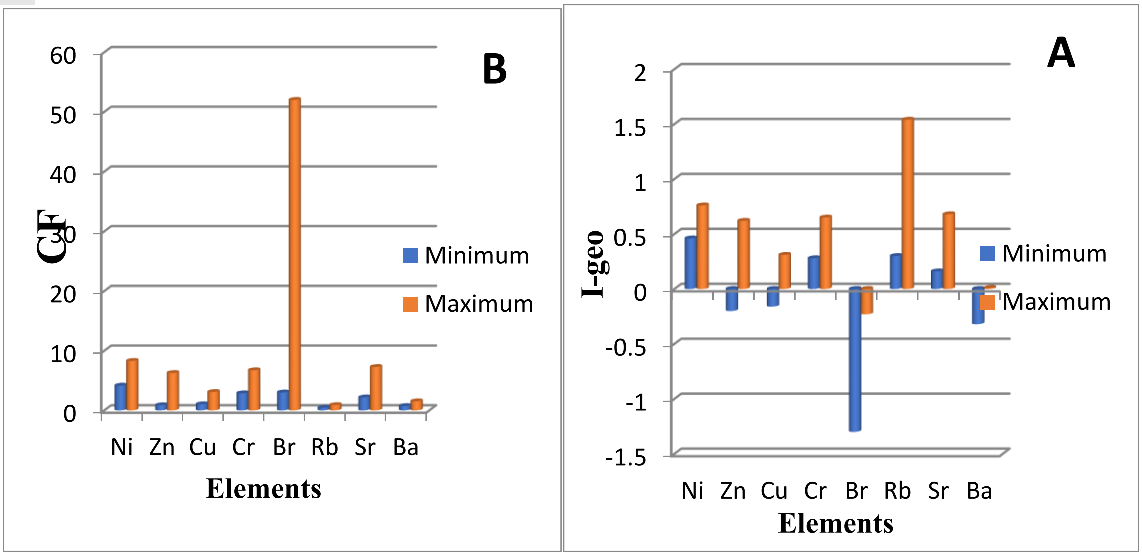

Figure 4: Minimum and Maximum values for heavy metals A- geo-accumulation index B-Contamination Factor.

4.8 Pollution Load Index (PLI)

The grading system can be enhanced by assessing the PLI (Pollution Load Index) and Anthropogenic Contamination Factor. The PLI, or Pollution Load Index, is a technique to evaluate the extent of metal pollution in soil samples. The process entails determining the concentration of each metal and subsequently dividing it by the CF value. The PLI (Pollution Load Index) of a particular site is calculated by extracting the roots derived from the CF (Contamination Factor) values for each metal. The location-specific PLI is derived from the CF values, as illustrated in Table 8. The pollution factors are categorized based on the classification system proposed by [43]. The contamination factor CF values offer methodological support for the PLI values, as indicated by [44]. The contamination factors are presented in (Table 8). The PLI results from Table 10 reveal that pollution was detected in all soil sample locations. A pollutant load index can be utilized to evaluate the danger and variations of pollution along a certain area. This index functions as a convenient tool for comparing pollution levels at various sites,

Table 10: Pollution load index values for collecting soil samples in the study area.

Sample No.	PLI	Decision	Sample No.	PLI	Decision
S_1	900	Pollution	S_9	488.5	Pollution
S_2	622	Pollution	S_10,30 cm	235.3	Pollution
S_3	1210	Pollution	S_11, 50cm	190.4	Pollution
S_4	179	Pollution	S_12, 30cm	1513.6	Pollution
S_5	317	Pollution	S_13, 50cm	357.5	Pollution
S_6	377	Pollution	S_14	791.5	Pollution
S_7	463	Pollution	S_15	1055.9	Pollution
S_8	1325	Pollution	S_16	1648.3	Pollution

4.9 Enrichment Factor (EF)

The analysis revealed that all samples exhibited varying degrees of metal deficiency or little metal enrichment, indicating a significant level of enrichment. Below are the mean EF values for metals in soil samples: The data presented in Table 11 indicates that the elements are arranged in the following order of decreasing reactivity: Bromine (Br), Nickel (Ni), Chromium (Cr), Strontium (Sr), Zinc (Zn), Copper (Cu), Barium (Ba), and Rubidium (Rb).

Table 11: Enrichment factor results for collecting soil samples in the study area.

Sample Number	**EF**							
	Ni	**Zn**	**Cu**	**Cr**	**Br**	**Rb**	**Sr**	**Ba**
S.-1	4.1	1.6	3.1	6.7	7	0.7	3.1	0.8
S.-2	5.9	1.4	2.5	5.0	13	0.6	2.2	0.8
S.-3	4.9	1	2	3.3	12	0.7	6.7	1.0
S.-4	4.9	0.9	1	3	12	0.7	2.6	0.8
S.-5	5.9	1	1.3	5	1	0.9	2.7	0.9
S.-6	6.2	1	1	0.4	17	0.4	4.5	0.9
S.-7	4.9	1.6	1.5	4.5	7	0.9	2.9	1.1
S.-8	6.6	6.3	1.8	4.4	1	0.6	4.6	1.1
S.-9	4.9	2.7	0.5	4.4	6	0.9	3.3	1.1
S.-10, 30cm	5.9	2.9	1.3	4.2	3	0.9	3.0	0.8
S.-11, 50cm	6.9	1.1	1.8	4.5	4	0.7	3.4	0.8
S.-12, 30cm	5.5	2.1	1.8	3.9	14	0.6	4.6	1.1
S.-13, 50cm	8.3	1.4	1.3	5.2	8	0.7	2.5	0.9
S.-14	6.6	1.1	1.5	3.0	14	0.4	7.3	1.3
S.-15	7.2	0.9	1.5	2.9	52	0.6	4.7	0.7
S.-16	6.9	1.6	1.3	4.2	18	0.6	4.6	1.5
Minimum.	4.1	0.9	0.5	0.4	1	0.4	2.2	0.7
Maximum	8.3	6.3	3.1	6.7	52	0.9	7.3	1.5
Mean.	6.0	1.7	1.6	4.0	11.8	0.7	4.1	1.0

5. Conclusion

The identification and quantification of the sources of heavy metals and the final destination of these trace elements are important topics in environmental research. The research results provide important information on the trace element content of soil land use in different areas along the WQ-1 Oilfield. Consequently, we can conclude that soil particle size testing reveals that silt and clay are significant components of various soil types, with silt having a highly relative distribution level. These are particle size classifications for different types of sand and mud. The soil samples from the research region, analyzed using XRD testing, consist of various non-clay minerals such as quartz, calcite, dolomite, rock salt, actinolite, and albite. Additionally, they contain clay minerals like Vermiculite, muscovite, palygorskite, Antigorite, and clinochlor. The surface soil of the West Qurna-1 oil field is often alkaline due to the potent conditioning ability of Iraqi soil. However, the high saline concentrations in samples 1, 4, and 6 can be attributed to the evaporation of mineral deposits, flooding, excessive evaporation, and their vast distance from the main river and sand dunes. The concentration of Heavy Metals in the study area, ranked from highest to lowest, is as follows: Strontium (Sr) > Barium (Ba) > Chromium (Cr) > Nickel (Ni) > Bromine (Br) > Zinc (Zn) > Copper (Cu) > Rubidium (Rb). Based on the Contamination Factor (CF) and Index of Geoaccumulation (I-geo), all samples exhibited significant contamination levels. The soil samples displayed a range of contamination levels, with nickel (Ni) being severely contaminated and copper (Cu), bromine (Br), strontium (Sr), and chromium (Cr) showing moderate contamination levels. The pollution in the research area is likely a result of elevated levels of pollutants generated by human industrial activities, such as the combustion of hydrocarbons and the release of crude oil. Carbonate minerals can absorb naturally occurring heavy minerals, including HMs, found in clays and other heavy minerals in the soil.

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