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Distribution and Evaluation of Lead and Cadmium in Some Soils Surrounding East Baghdad Oil Field

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Abstract
Soil acts as a last sink for elements that people release into the environment through a range of activities due to its physiochemical characteristics. These substances, whether are organic or mineral pollutants, accumulate in the soil and constitute a significant risk to the ecosystem in general because they mess with the chemical and physical equilibrium of the soil, get into the food chain, and eventually get to people. When pollutant concentrations during the bioaccumulated process exceed the global standards for what is regarded as a contaminant in water, air, and soil. Nine soil samples were collected from different sites and two samples from each site at two depths (0-20 and 20-40 cm) to determine if there were any differences in element concentrations at each depth near the East Baghdad oil field in Iraq in February 2022 and analyzed to determine the impacts of industrialization and pollutants related to urbanization. When the grain sizes of the soil samples were analysed, the predominated size fractions were Loam + Clay Loam. The trace elements analysis using atomic absorption spectrometry for the examined soil samples showed levels of Pb and Cd within the global average. The physicochemical characteristic of soil samples was examined. The pH of soil samples from the study area ranged from 7.24 to 7.87, with a mean value of 7.631, indicating that the soil is slightly alkaline.

Keywords: Lead; Cadmium; East Baghdad oil field; Contamination; Spatial distribution

توزيع وتقييم تراكم الرصاص والكادميوم في بعض الترب المحيطة بحقل نفط شرق بغداد

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الخلاصة
تعمل التربة كحوض أخير للعناصر التي يطلقها الناس في البيئة من خلال مجموعة من الأنشطة بسبب خصائصها الفيزيائية والكيميائية. تتراكم هذه المواد سواء كانت ملوثات عضوية أو معدنية ، في التربة وتشكل خطرًا كبيرًا على النظام البيئي بشكل عام لأنها تعبث بالتوازن الكيميائي والفيزيائي للتربة ، وتدخل في السلسلة الغذائية ، وتصل في النهاية إلى الناس. عندما تتجاوز تركيزات الملوثات أثناء عملية التراكم الأحيائي معايير ما يعتبر ملوثًا في الماء والهواء والتربة .جرى جمع تسع عينات تربة من مواقع مختلفة ومن كل موقع تم اخذ عينتين من كل عمق (0–20 و20–40 سم) وذلك لتحديد ماذا كان هناك اختلاف في تراكيز العناصر عند كل عمق

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بالقرب من حقل نفط شرق بغداد في العراق في شباط 2022 وتحليلها لتحديد آثار التصنيع والملوثات المتعلقة بالتحضر. عندما تم تحليل أحجام الحب الحبيبات لعينات التربة ، وجد أن الحجم الحبيبي (Loam + Clay Loam) هي السائدة. باستثناء الرصاص في العينة 10 بسبب انسكاب الزيت بالقرب من موقع الخزان ، فإن تحليل العناصر النزرة باستخدام مطياف الامتصاص الذري (AAS) لعينات التربة التي تم فحصها يوضح مستويات الرصاص والكادميوم ضمن المتوسط العالمي. جرى فحص الخصائص الفيزيائية والكيميائية لعينات التربة. يتراوح الرقم الهيدروجيني لعينات التربة في منطقة الدراسة من 7.24 إلى 7.87 بمتوسط قيمة 7.631 مما يشير إلى أن التربة هناك قلوية قليلاً حسب.

1. Introduction

Oil and gas well drilling produce hazardous compounds that could have an adverse environmental impact [1]. In addition to serving as a geochemical sink for contaminants, soil also functions as a natural buffer, regulating the transport of chemical elements and substances to the atmosphere, hydrosphere, and biota. This makes the soil a very unique component of the biosphere. However, the most important role of soil is its productivity, which is basic for the survival of humans [2]. Heavy metals are particularly of environmental concern because of their potential toxicity and their importance as an essential nutrient background concentrations of heavy metals in soils are, therefore, important due to the recent interest in contamination potential and toxic effects of these elements on humans and the environment [3]. One of the beneficial but poisonous trace elements is lead (Pb), which is also one of the most prevalent and extensively dispersed environmental metal toxins [4]. Since 1920, lead alkyls have been added to gasoline as anti-knocking additives, which has led to an increase in the concentration of lead in the air, surface water, and soil [5]. As well as the few maxima discovered are crucial numbers since cadmium (Cd) is thought to be the most hazardous heavy metal [6]. Significant effects on terrestrial ecosystems, agricultural productivity, and health impacts are caused by Cd-contaminated soils [7].

The purpose of this research is to identify the soil's Pb and Cd concentrations, local distributions, and accumulation locations in some soils surrounding the East Baghdad oil field and compare them to global ratios.

1.1 Location and Geological Setting of the study area

The East Baghdad oil field is situated between latitudes 44.31877 and 44.3504 and longitudes 33.50312 and 33.48871 Figure1. The East Baghdad field may extend over 100 km from north to south, with a maximum width of more than 10 km. The field has a complex structure that links to an oil-trapping transverse fault and a central fault that traverses the length of the field [8]. An entire depiction of a flood plain made up of Quaternary deposits may be seen in the study area. Pleistocene and Holocene deposits might be more than 250 meters thick [9]. Most of the Mesopotamian plain is covered by the Holocene strata, which are composed of a complex as well as the alternate sequence of sand, clay, silt, and gravel. The province of Baghdad is mostly situated on the Unstable Shelf of the Arabian Plate in the Tigris Subzone of the Mesopotamian Zone [10].

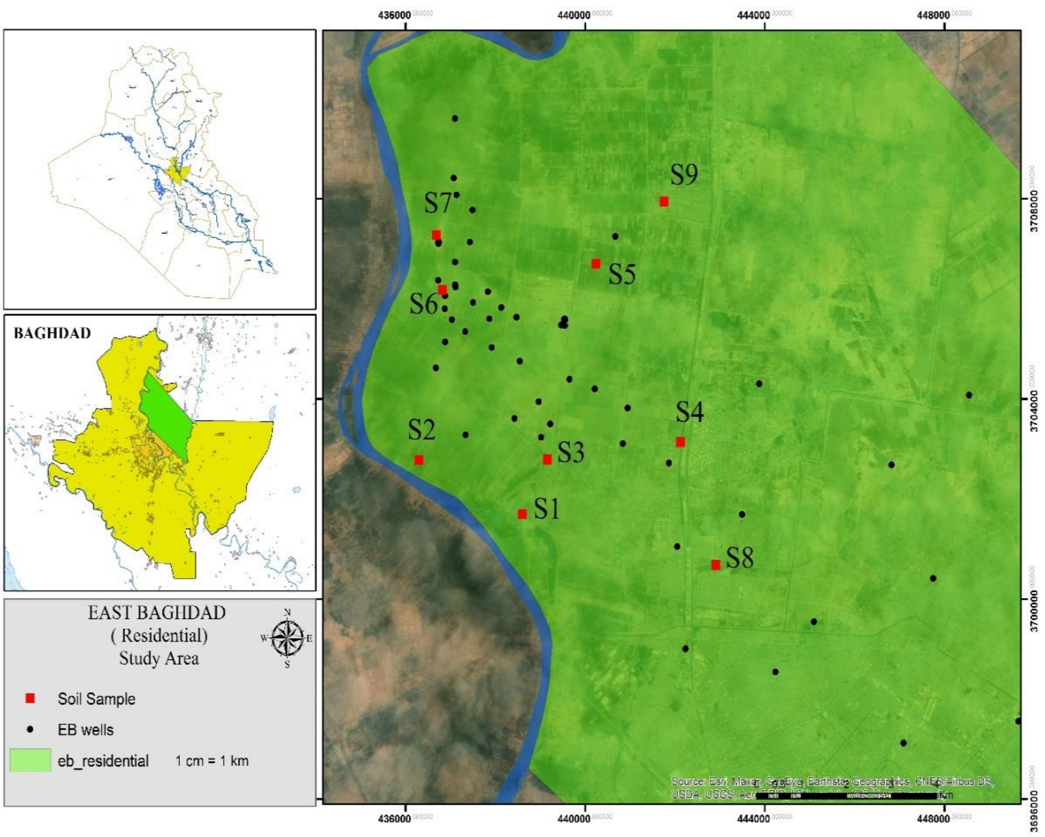

Figure 1: Map of the study area shows the location of soil samples.

2. Materials and Methods

2.1. Sampling and analysis

Eighty soil samples were taken as part of the research that was carried out on 12/2/2022. Each site had two depths of soil analyzed. Each sample comprises a depth component (0–20 cm for sample A and 20–40 cm for sample B). Some samples are situated approximately 5 km to the east of the Baghdad oil field, while other samples are located within the oil field. All samples were kept in sealed Ziploc bags with labels for further inspection, and indeed, the precise location was determined using GPS data, as shown in Table 1.

Table 1: The coordinate of the soil sampling sites

Soil site symbols		location	Coordination	
			Longitude	latitude
S1	A1	Near the water liquefaction station	33.452929	44.339363
	B1			
S2	A2	3 km away from S1	33.462535	44.314518
	B2			
S3	A3	Near the residential area south of the field (qumira)	33.462797	44.345319
	B3			
S4	A4	Near the puncture site, June 1st, facing Bob Al-Sham	33.0466106	44.0377149
	B4			
S5	A5	Near Al Quds Electricity Station	33.498168	44.356684
	B5			
S6	A6		33.493224	44.319885

	B6	Abu Dali village near the drilling company		
S7	A7	1 km away from smart option store	33.477385	44.350144
	B7			
S8	A8	Near Mrs. Narjs Mosque	33.477385	44.350144
	B98			
S9	A9	Near Al-Entisar clinic	33.469615	44.345880
	B9			

Each sample was then processed in a lab so that it could be used for the required analysis. The humid samples were set apart sufficiently enough to dry completely overnight and dry the soil at 110°± 5° C. after which they were sieved using a 2 mm sieve to remove big debris, stone, gravel, plant matter, and other contaminants. In the laboratory of the Directorate of Environmental and Water Research and Technology, Ministry of Science and Technology, all soil samples were tested for geochemical characteristics such as pH, electrical conductivity (EC), organic matter (OM%), and grain size analyses, while Atomic Absorption Spectrometry (AAS) were analyzed in University of Baghdad, College of sciences Department of Biology.

3. Results and Discussion

3.1 Pb and Cd abundance

The result of AAS for Pb and Cd are shown in Table 2. They indicated that Pb concentration varied from 7.2 ppm in S9B to 19.5 ppm in S9A, with a mean of 12.777 ppm. While the concentration of Cd ranged from 0.84 ppm in S3B to 1.37 ppm in S (A3 and B7), with a mean of 1.087 ppm

Table 2: concentration of Pb and Cd in study area

Sample		Pb	Cd
S1	**A1**	15.6	1.19
	B1	12.8	0.93
S2	**A2**	11.7	1.24
	B2	12.8	0.93
S3	**A3**	14.5	1.37
	B3	10.0	0.84
S4	**A4**	18.4	1.1
	B4	13.9	0.93
S5	**A5**	10.6	1.0
	B5	13.9	0.97
S6	**A6**	10.6	1.05
	B6	10.6	0.93
S7	**A7**	12.8	1.19
	B7	13.9	1.37
S8	**A8**	12.3	1.1
	B8	8.9	1.32
S9	**A9**	19.5	1.1
	B9	7.2	1.02
Range		7.2 to 19.5	0.84 to 1.37
Average		12.777	1.087

The WHO, 2003 [11] for Pb and Cd proposed soil quality standard was used to compare the chemical contamination in the soil, Table 3 displays these requirements.

Table 3: The WHO, 2003 for Cd and Pb, a guideline for soil in ppm

Element	*WHO, 2003*	*Mean of Present Study*
Pb	100	12.777
Cd	3	1.087

The effects of industrial emissions and leaded gasoline are thought to provide the greatest environmental concern among the different anthropogenic and natural sources of Pb contamination. According to estimates made by [12], the rate of Pb concentration in soil is at least 20 times higher than the rate of natural clearance.

The top 15 cm of soil still contains up to 90% of Cd pollution from various sources. Industrial Cd wastes are a well-known significant cause of illness in farmlands of many different countries [13]. As a Comparison with worldwide soil studies [11] for Pb 100 ppm and Cd 3 ppm. According to the WHO, lead concentrations were all within permissible values, indicating that they are beyond the normal range. The acceptable limit of Cd is because there is no increased amount of Cd in the soil at any of the locations that have been analysed [14].

3.2 Spatial distribution of heavy metals

Any estimate of the environmental effect of heavy metals must take into account the geographical distribution of heavy metals in soils. The GIS method creates a map to estimate the spatial distribution of Cd contents in the soil of study area using the spatial analyst extension in Arc Map [15]. As shown in Figures 2, 3, 4, and 5.

The map showed that the concentrations of Pb increased in site 9A and Cd increased in site 7B.

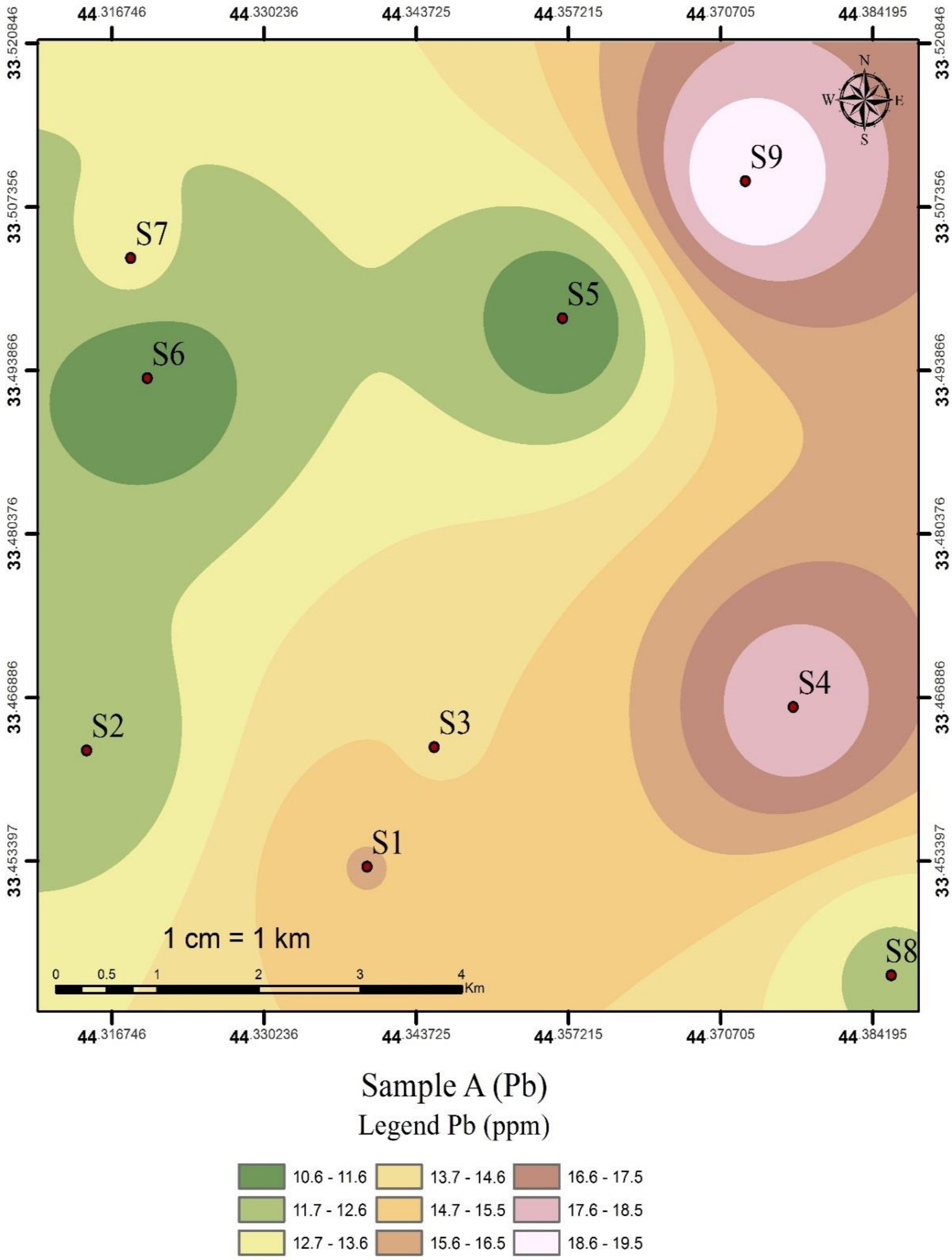

Figure 2: The spatial distribution map of Pb in the soil of the study area for sample (A).

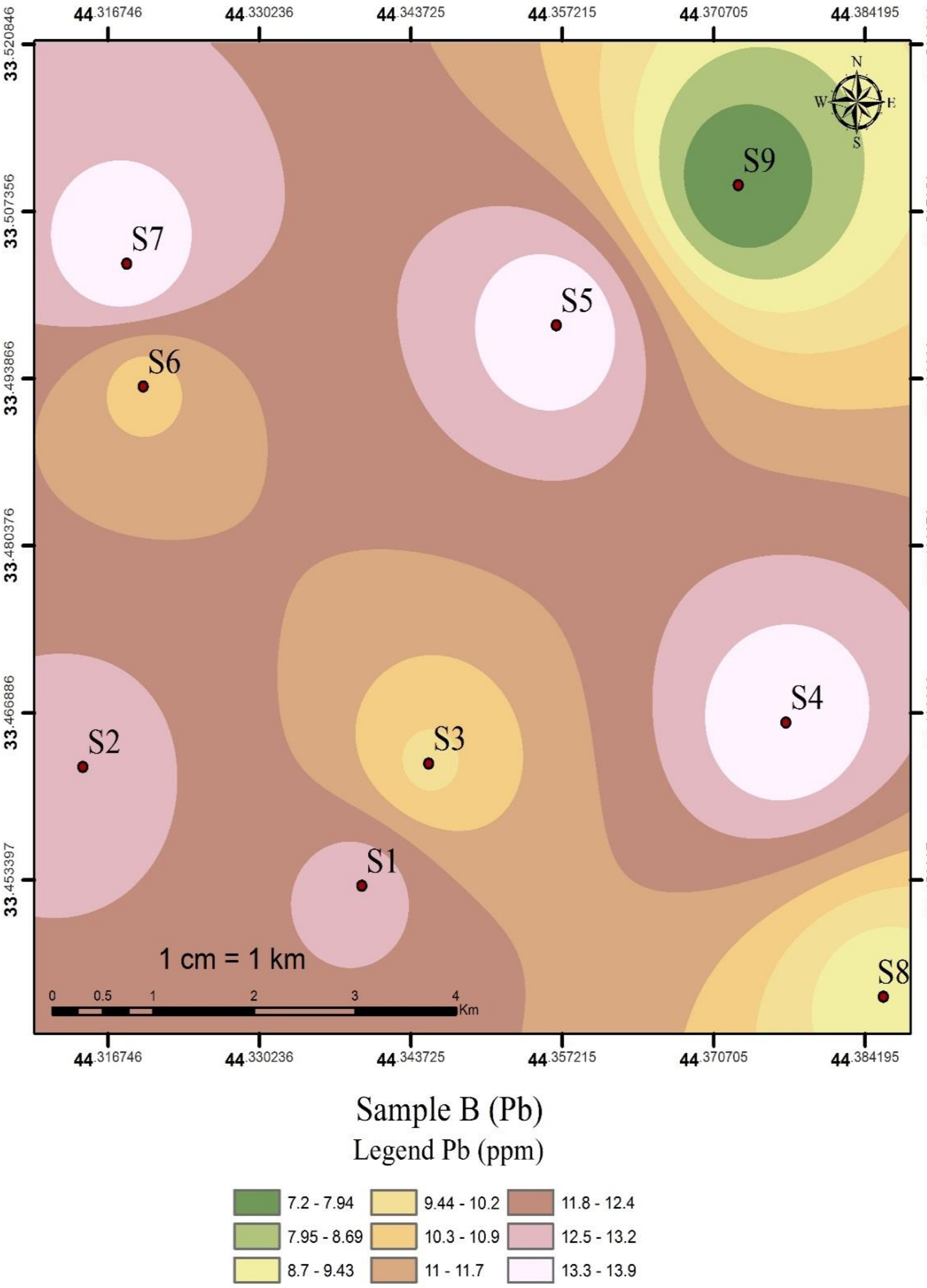

Figure 3: The spatial distribution map of Pb in the soil of the study area for sample (B).

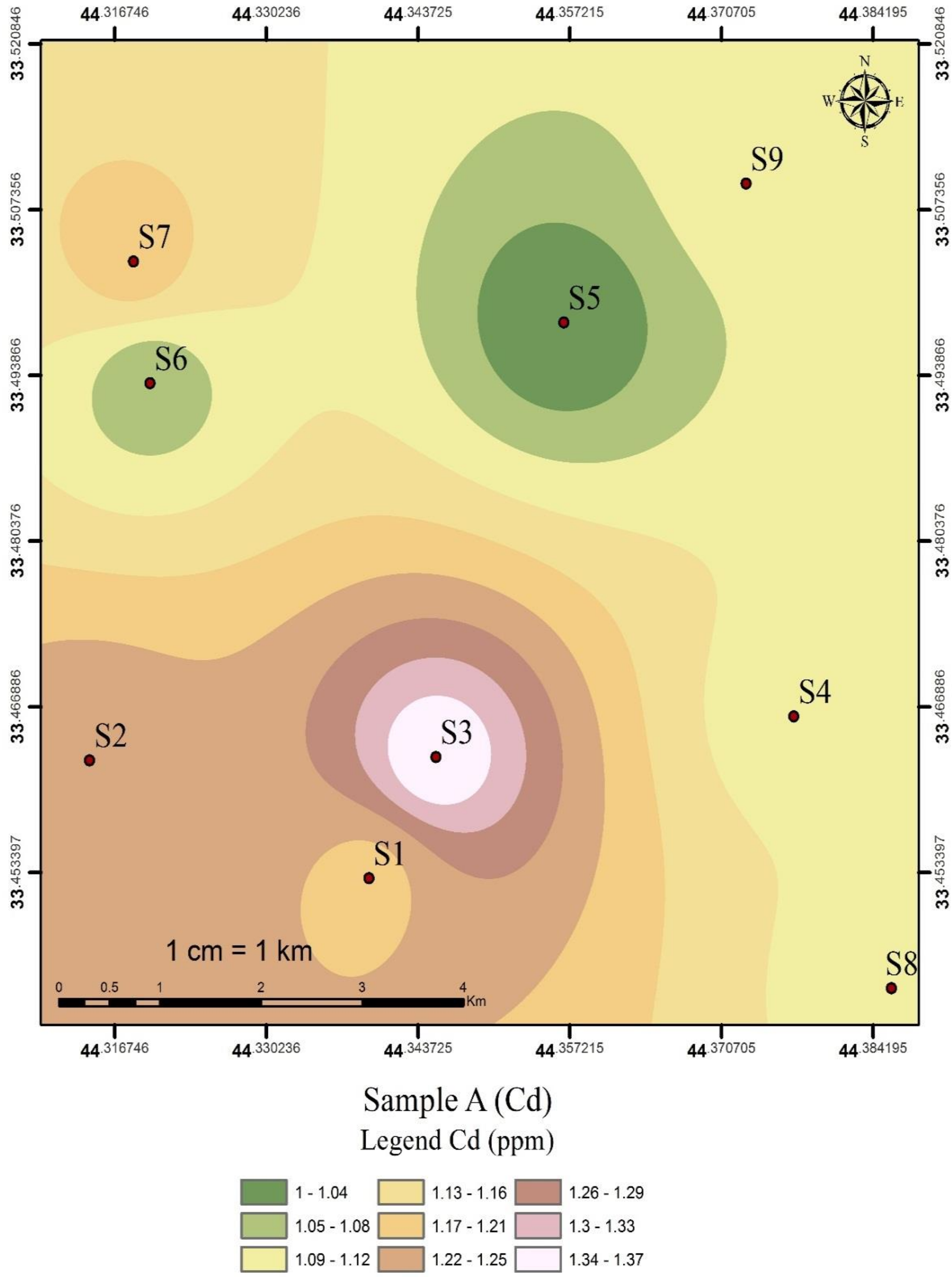

Figure 4: The spatial distribution map of Cd in the soil of the study area for sample (A).

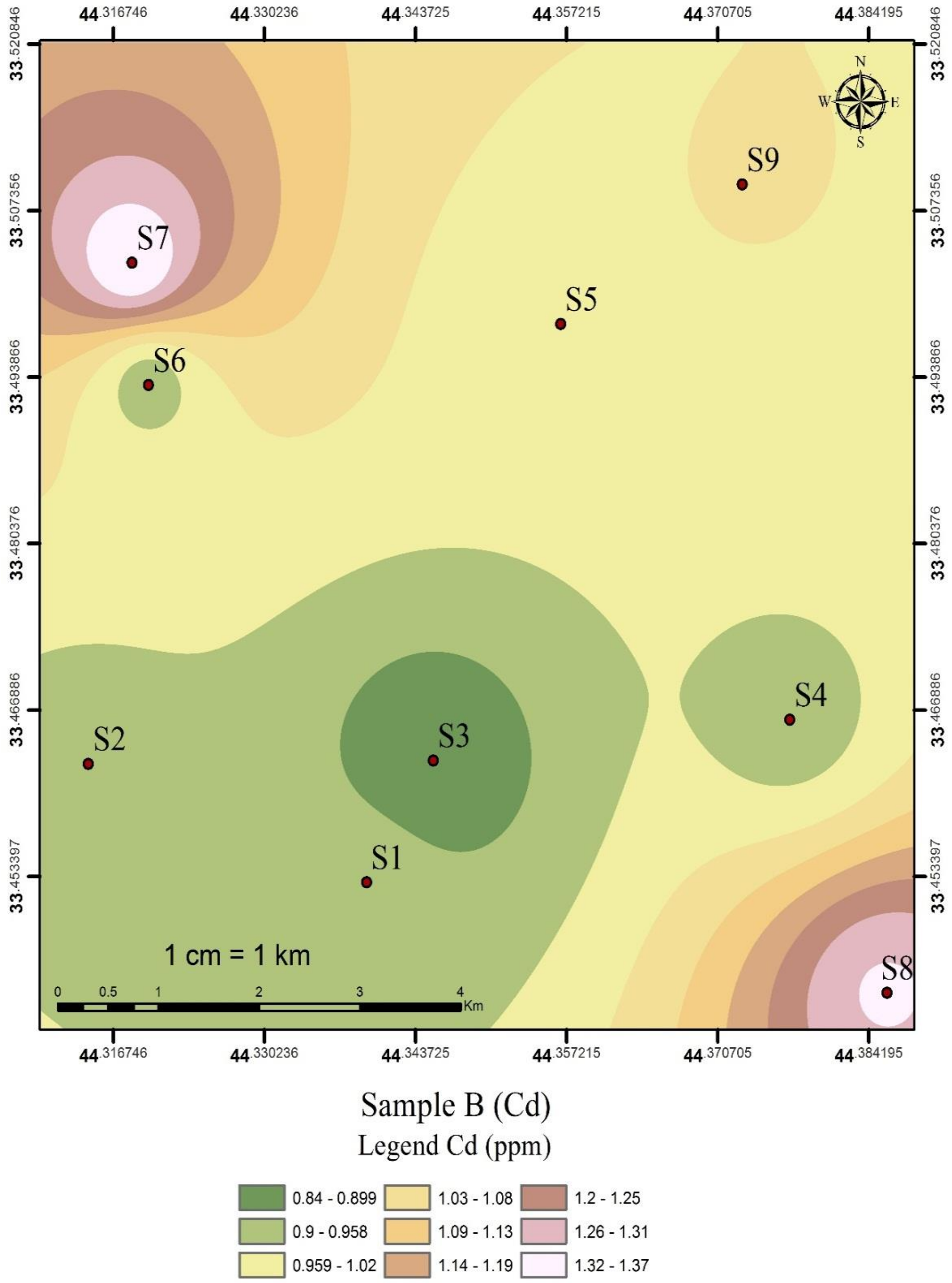

Figure 5: The spatial distribution map of Cd in the soil of the study area for sample (B).

3.3 Soil physio-chemistry

3.3.1 Grain Size Analysis

The physical texture of soil comprises a range of minerals, oxides, and organic compounds as well as a particle size distribution [16]. The soil's texture affects the soil's ability to exchange and retain chemicals introduced into the soil by solutions [17]. Contamination frequently affects the texture class because fine earth, like clay, absorbs more cations than coarse fractions [18].

Table 4: Grain size analysis of the studied samples

Soil samples	*Depth*	*Grain size analysis %*			*Type of soil*
		Sand %	**Silt %**	**Clay %**	
S1	A	19.20	50	30.80	Clay loam
	B	27.4	47.08	25.52	Loam
S2	A	14.64	62.92	22.44	Loam
	B	48.08	29.48	22.44	Loam
S3	A	23	52.8	24.20	Loam
	B	37.52	34.76	27.72	Loam
S4	A	34.88	33.72	26.40	Loam
	B	48.52	25.96	25.52	Loam
S5	A	13.32	61.16	25.52	Loam
	B	29.16	45.32	25.52	Loam
S6	A	13.32	28.6	58.08	Clay
	B	18.16	51.92	29.92	Loam
S7	A	26.52	47.02	26.40	Loam
	B	11.14	59.84	29.04	Loam
S8	A	39.28	37.4	23.32	Loam
	B	21.68	52.36	25.96	Loam
S9	A	43.24	38.72	18.04	Loam
	B	25.64	37.84	36.52	Clay Loam

As shown in Table 4, grain size assessments for eighteen soil samples show that soil samples S1(A) and S7(A, B) are clay loam, where (loam) is a soil that is mostly made of sand (particle size > 63 µ), silt (particle size > 2 µ), and a small amount of clay (particle size 2 µ). Its particle composition is roughly 40-40-20% sand-silt-clay by weight. These proportions, however, can vary to some extent, resulting in a variety of loam soils: Some of the terms used to describe different types of soil are sandy loam, silty loam, clay loam, sandy clay loam, silty clay loam, and loam [19]. S1 (B), S2 (A, B), S3 (A, B), S4 (A, B), and S5 (A, B) (A, B), and S10 (A) were of loam, while S6 (A) was of clay size.

3.3.2 pH

The pH of soil samples from the study region varies between 7.44 and 7.87, with an average value of 7.634 (Table 3), indicating that the soil is slightly alkaline.
Pb is retained less firmly and is more soluble under low soil pH (pH =5, acidic environments). Lead is retained more tightly in the soil at pH levels that are close to neutral or higher (pH>6.5, neutral to basic conditions), and its solubility is very low [20].
Because the amount of Cd released into solution from adsorption sites is dependent on the pH of the environment, acid soils can be expected to have higher levels of mobility and availability to plants [21] (Table 5, and Figure 6).

Table 5: pH values of soil samples

Sample	pH for depth (0-20) cm	pH Depth (20-40) cm
S 1	7.81	7.75
S 2	7.87	7.71
S 3	7.6	7.67
S 4	7.57	7.62
S 5	7.48	7.61
S 6	7.52	7.69
S 7	7.64	7.56
S 8	7.62	7.44
S 9	7.59	7.61
Mean	7.633	7.628
Range	7.48 to 7.87	7.44 to 7.75

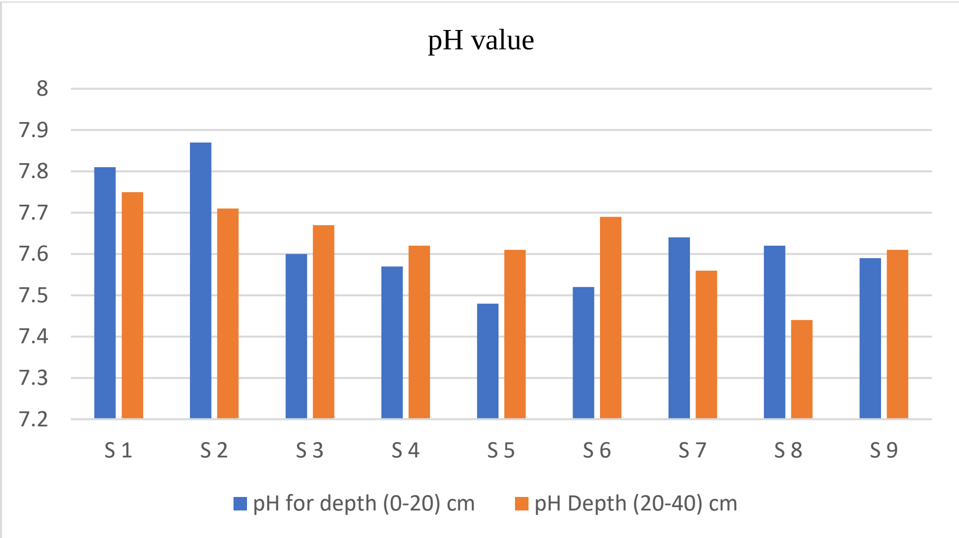

Figure 6: pH value for soil samples.

To establish the relation between pH, Lead, and Cd concentration correlation coefficient was used in this study. Correlation coefficients often aim to study whether there is some association between 2 observed variables and to estimate the strength of this relationship by using the Pearson equation [22].

$$r_{xy} = \frac{\sum X \quad Y - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left[\left(\sum X^2 - \frac{(\sum X)^2}{n_x}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{n_y}\right)\right]}} \quad (4)$$

Where:
X, Y = the variations (in this study Vanadium concentration and pH)
r = Correlation coefficient
n = Number of observations

Table 6: correlation coefficient results for Pb with pH

X	X^2	Y	Y^2	$X \quad Y$
14.2	201.64	7.81	60.9961	110.902
12.25	150.0625	7.87	61.9369	96.4075
12.25	150.0625	7.6	57.76	93.1
16.15	260.8225	7.57	57.3049	122.2555
12.25	150.0625	7.48	55.9504	91.63
10.6	112.36	7.52	56.5504	79.712
13.35	178.2225	7.64	58.3696	101.994
10.6	112.36	7.62	58.0644	80.772
13.35	178.2225	7.59	57.6081	101.3265
$\sum X =$ 115	$\sum X^2 =$ 1493.815	$\sum Y =$ 68.7	$\sum Y^2 =$ 524.5408	$\sum X \quad Y =$ 878.0995
Result	0.149079			

The result of the equation indicates that there is a positive relationship between Pb concentration and pH value in the study area that is mean when the pH is high Pb concentration is high too.

Table 7: correlation coefficient results for Cd with pH

X	X^2	Y	Y^2	$X \quad Y$
1.06	1.1236	7.81	60.9961	8.2786
1.085	1.177225	7.87	61.9369	8.53895
1.015	1.030225	7.6	57.76	7.714
1.015	1.030225	7.57	57.3049	7.68355
0.985	0.970225	7.48	55.9504	7.3678
0.99	0.9801	7.52	56.5504	7.4448
1.28	1.6384	7.64	58.3696	9.7792
1.21	1.4641	7.62	58.0644	9.2202
1.06	1.1236	7.59	57.6081	8.0454
$\sum X =$ **9.7**	$\sum X^2 =$ 10.5377	$\sum Y =$ 68.7	$\sum Y^2 =$ 524.5408	$\sum X \quad Y =$ 74.0725
Result	0.279496			

As shown in Table 7 Cd has a positive relationship with pH.

3.3.3 Electrical conductivity (EC)

The amount of moisture that soil particles contain has an impact on the soil's electrical conductivity. Clays has a high conductivity, silts have a medium conductivity, and sands has a low conductivity. As a result, the size and texture of soil particles have a significant impact on EC correlations [23]. The soil is slightly saline, according to the EC values of the soil samples, which varied from 2.38 to 3.01 and had an average value of 2.571 as in Table 8,9 and figure 7.

Table 8: Soil classification according to the system of [24]

Salinity class	*EC value (ds.m^{-1})*
Non-saline	0-2
Very slightly saline	2-4
Slightly saline	4-8
Moderately saline	8-16
Strongly saline	>16

Table 9: EC value of soil samples

Sample	*EC for depth (0-20) ds.m^{-1}*	*EC For Depth (20-40) ds.m^{-1}*
S1	2.44	2.48
S2	2.43	2.65
S3	2.38	2.48
S4	2.48	2.41
S5	2.86	2.38
S6	2.66	2.61
S7	2.46	2.54
S8	2.75	3.01
S9	2.66	2.61
Mean	2.574	2.568
Range	2.38 to 2.86	2.38 to 3.01

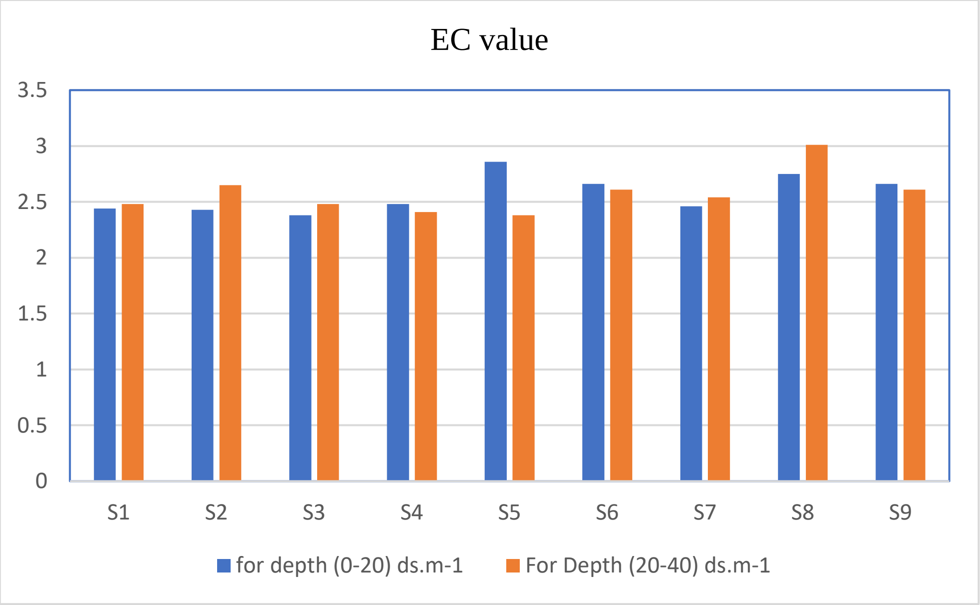

Figure- 7 EC value of the soil samples

3.3.4 Organic matter (OM%)

The portion of the soil that is made up of plant or animal tissue in various stages of decomposition is known as soil organic matter [25]. The test results of all soil samples in the study area showed that the concentration values of organic matter (OM%) ranged from 0.48%-0.89% with a mean of 0.612% as shown in Table 10 and Figure 8.

Table 10: Organic matter (OM%).

Sample	*OM% for depth (0-20) cm*	*OM% for depth (20-40) cm*
S1	0.89	0.53
S2	0.61	0.54
S3	0.62	0.61
S4	0.48	0.62
S5	0.63	0.67
S6	0.58	0.65
S7	0.56	0.61
S8	0.62	0.59
S9	0.60	0.61
Mean	0.621	0.033
Range	0.48 to 0.89	0.53 to 0.67

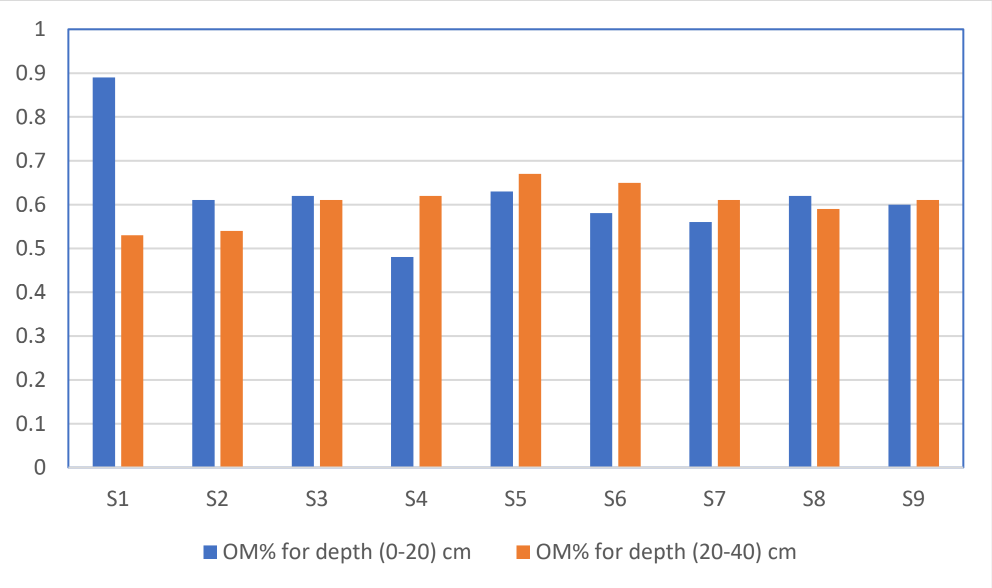

Figure 8: The OM% concentration for soil samples.

4. Discussion

The Pb in soil samples ranged from 7.2- 19.5 ppm and Cd concentrations were between 0.84 and 1.37 ppm. These values are all within [11] -permissible limits, suggesting that they are within the usual range. The research soil's pH ranges from 7.44 to 7.87, with a mean of 7.63, indicating a slightly alkaline soil and very little saline in the study area. The concentration values of organic matter (OM%) ranged from 0.48%-0.89% with a mean of 0.60. Grain size analyses showed that the soil ranged between loam-clay loam and clay.

5. Conclusions

To investigate the effects of oil and oil factories on the local soil and the pollution that emerges from them, this study employed some analyses to determine the pollutant components, including:

- The geochemical analysis of the studied soil samples showed that Pb and Cd concentrations in soil samples are within the permitted values in all locations.
- According to geographical distribution and contour maps, Pb concentration is at its maximum in the study area in S A9 (19.5) and the maximum concentration of Cd was at SB7
- Grain size analyses of eighteen (18) soil samples show that samples S1(A) and S7(A, B) are clay loam, whereas samples S1(B), S2(A, B), S3(A, B), S4(A, B), S5(A, B), S6(B), S8(A, B) and S9(A, B) are loam. S6 (A) are clay-sized particles.
- The pH of soil samples from the research region indicates that the soil of the study area is slightly alkaline and very slightly saline.

6. Recommendation

- Examine the presence of radiation in the study area.
- Research should be conducted regularly seasonally, to determine the change in pollutant concentrations in the soil.
- Check for any potentially dangerous trace elements in food that produce grown near to an oil field site to assess any potential direct health effects.
- Conduct regular blood tests on workers in the oil fields to assess the levels of trace elements in their blood and search for any possible health problems.

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References:

[1] A. Agwa, A. M. Saleem and R. Sadiq, "Fate of Drilling Waste Discharges in the Egyptian Red Sea & Associated Ecological Risks: An Aquivalence-based Fuzzy Analysis," *Stochastic Environmental Research and Risk Assessment*, vol. 27, pp. 169-181, 2012.

[2] A. K. Pendias, *Trace elements in soils and plants, 4th ed., Boca Raton: Taylor and Francis group*, 2010.

[3] B. A. Raji and B. W. Jimba, "The distribution and geochemical assessment of trace elements from the semi-arid to sub-humid savanna of Nigeria," *Environmental Earth Sciences*, vol. 73, pp. 3555-3564, 2014.

[4] G. M. Pierzynski, G. F. Vance and J. T. Sims, *Soils and Environmental Quality, Tennessee: CRC Press*, 2004.

[5] Y. W. Lansdown Richard, *Lead toxicity: history and environmental impact, Baltimore: Johns Hopkins University Press*, 1986.

[6] M. L. Bloemena, B. Markert and H. Lieth, "The distribution of Cd, Cu, Pb and Zn in topsoils of Osnabrück in relation to land use ," *The Science of the Total Environment*, vol. 166, pp. 137-148, 1995.

[7] D. C. Adriano, *Trace Elements in Terrestrial Environments, New York: Springer*, 2001.

[8] M. Al-Rawi, "East Baghdad Super-Giant Field Under a Populated Area," *GEO Ex Pro*, 2016.

[9] S. Z. Jassim and J. C. Goff, Geology of Iraq, Dolin Prague and Moravian Museum: Brno, 2006.

[10] T. Buday and S. Z. Jasim, *The Regional Geology of Iraq, Volume II; Tectonism, Magmatism and, Mosul: Dar AL-Kutub Publishing House*, 1987.

[11] W. H. O, Guidelines for safe recreational water environments. Volume 1, Coastal and fresh waters, World Health Organization, 2004.
[12] O. Jerome and M. Jozef, "Quantitative assessment of worldwide contamination of air, water and soils by trace metals," *National Water Research Institute*, vol. 333, pp. 134-139, 1988.
[13] K. Alina, *Trace elements in soils and plants, Boca Raton: CRC Press*, 2001.
[14] H. Yasir, T. Lin, Y. Muhammad, H. Bilal and Z. Afsheen, "Comparative efficacy of organic and inorganic amendments for cadmium and lead immobilization in contaminated soil under rice-wheat cropping system," *Chemosphere*, vol. 113, 2018.
[15] Fadhel, M. A.;Abdulhussein,F.M., "Accumulation Detection of Cadmium in some land-use soil of Baghdad city, Iraq," *Iraqi Journal of Science*,, vol. 63, p. 3570–3577, 2022.
[16] L. Tania, Trace metal geochemistry and weathering mineralogy in a quaternary coastal plain, Bells Creek catchment, Pumicestone Passage, Southeast Queensland, Australia, Southeast Queensland, Australia: PhD thesis, Queensland University of Technology, 2004.
[17] V. Reinier, "Human exposure to soil contamination: a qualitative and quantitative analysis towards proposals for human toxicological intervention values (partly revised edition)," PBL Netherlands Environmental Assessment Agency, The Hague, South Holland, Netherlands, 1994.
[18] M. Helmut and R. H.M., "Characteristics of Natural and Urban Soils," in Dealing with Contaminated Sites , Springer, 2010, pp. 91-134.
[19] K. K. Robert and J. Cutler, *Environmental Science, Pennsylvania : McGraw-Hill Higher Education*, 2008.
[20] Abdulhussein,F.M., "Hydrochemical Assessment of Groundwater of Dibdibba Aquifer in Al-Zubair Area, Basra, South of Iraq and its Suitability for IrrigationPurposes.," *Iraqi Journal of Science*, pp. 135-143, 2018.
[21] A. Andersson and K. O. Nilsson, "Influence of Lime and Soil pH on Cd Availability to Plants," Agricultural college of sweden, Upsalla Sweden, 1974.
[22] A. Nishimura, Y. Tabuchi, M. Kikuchi, R. Masuda, K. Goto and T. Iijima, "The Amount of Fluid Given During Surgery That Leaks Into the Interstitium Correlates With Infused Fluid Volume and Varies Widely Between Patients," *Anesthesia and Analgesia* , vol. 123, pp. 925-932, 2016.
[23] N. Akiko, T. Yoko and K. Mutsumi, "Precision Farming Tools: Soil Electrical Conductivity. Virginia Cooperative Extension," *anesthesia-analgesia*, vol. 123, pp. 442-508, 2016.
[24] U. (. R. C. Service), " Soil Quality Indicators: pH. (National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory," Agricultural Research Service, 1998.
[25] F. Megan, A. Carl and K. Quirine, "Agronomy Fact Sheet Series," Fact Sheet , 2008.