



Geochemical Assessment of soil in Al-Nahrawan area, East Baghdad, Iraq

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Abstract

This study aims to assess the quality of soil in the Nahrawan area. Seventeen soil samples were collected from various locations in the Al-Nahrawan area at a depth of 20 cm in October 2024, highlighting the nature of each region (commercial, agricultural, industrial, and roadside sites). All soil samples were subjected to geochemical analysis to determine the concentration of principal oxides and some trace elements. The lab data were used to create the spatial analysis. It was found that, compared to national and international studies, the mean concentrations of CaO, MgO, Fe₂O₃, and P₂O₅ are higher than those reported in international research, whereas SiO₂, Al₂O₃, SO₃, K₂O, Na₂O, TiO₂, and MnO are lower than those reported in international studies. In addition, CaO, Al₂O₃, Fe₂O₃, K₂O, TiO₂, P₂O₅, and MnO concentrations are greater than the average of the national background, while SiO₂, MgO, SO₃, and Na₂O are lower than the national background. Trace elements were found, and the mean concentrations of Pb, Cd, and Zn were within the acceptable limits of national and international studies. However, the mean values of Ni and some Cu were greater than those reported in international research, while they were within the acceptable limit of the national background. Mean of Cr, Fe, and most V is greater than that of national and international studies. This increase in some trace elements is due to the process of burning fuel, which is carried out in large quantities in the Nahrawan region. This results from the deposition of residues and smoke from factories on the soil, as well as agricultural activities, and organic materials. According to the results of soil quality assessments, the Al-Nahrawan area soil has a considerable amount of trace element contamination. The results of the geo-accumulation index, enrichment factor, and contamination factor indicated that the pollution level was low to medium, except for Ni and Cr, which were highly polluted. The potential ecological risk index was low in all samples. The reason for the increase in these factors is due to human activities.

Keywords: Pollution, Al-Nahrawan area, East Baghdad, Soil, Trace elements.

تقييم جيوكيميائي للتربة في منطقة النهروان، شرق بغداد، العراق

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تهدف هذه الدراسة إلى تقييم جودة التربة في منطقة النهروان. جُمعت سبع عشرة عينة تربة من مواقع مختلفة على عمق 20 سم في أكتوبر 2024، مع التركيز على طبيعة كل منطقة (زراعية، سكنية، صناعية، ومواقع على جوانب الطرق). خضعت جميع عينات التربة لتحليل جيوكيميائي لتحديد تركيز الأكاسيد الرئيسية وبعض العناصر النزرة واستخدمت بيانات المختبر لإنشاء التحليل المكاني. وُجد أن الأكاسيد الرئيسية بالمقارنة مع الدراسة الوطنية والدولية فإن متوسط تركيز CaO , MgO , Fe_2O_3 and P_2O_5 أكبر من متوسط الدراسة الدولية، بينما Al_2O_3 , SiO_2 , K_2O , SO_3 , TiO_2 , Na_2O , MnO and أقل من متوسط الدراسة الدولية.

بالإضافة إلى ذلك فإن تركيز CaO , Al_2O_3 , Fe_2O_3 , K_2O , TiO_2 , P_2O_5 and MnO أكبر من متوسط الخلفية الوطنية، بينما SiO_2 , MgO , SO_3 and Na_2O أقل من المتوسط الوطني. وجد أن متوسط تركيز العناصر النزرة، Pb , Cd , Zn and ضمن الحد المقبول للدراسات الوطنية والدولية، ولكن متوسط Ni وبعض Cu أكبر من الدراسة الدولية بينما ضمن الحد المقبول للدراسة الوطنية. متوسط Cr , Fe وغالبية V أكبر من الدراسات الوطنية والدولية. يعود هذا الارتفاع في بعض العناصر النزرة إلى كثرة عمليات حرق الوقود في منطقة النهروان، وتساقط مخلفات المصانع ودخانها على التربة، الأنشطة الزراعية، والمواد العضوية. ووفقاً لنتائج تقييم جودة التربة، فإن تربة منطقة النهروان ملوثة بشكل كبير بالعناصر النزرة، كما أظهرت نتائج مؤشر التراكم الجيولوجي ومعامل التخصيب ومعامل التلوث أن مستوى التلوث يتراوح بين منخفض إلى متوسط، باستثناء النيكل والكروم الملوثين بشكل كبير، بينما مؤشر المخاطر البيئية المحتملة منخفض في جميع العينات. ويرجع سبب الزيادة في هذه العوامل إلى الأنشطة البشرية.

1. Introduction

Soil serves as a final sink for substances that humans discharge into the environment through various behaviours, due to its physicochemical properties [1]. These materials, which can be either organic or mineral pollutants, accumulate in the soil and pose a serious threat to the ecosystem as a whole because they disrupt the soil's chemical and physical balance, enter the food chain, and ultimately reach humans [2]. Soil pollution is closely related to the pollution of other environmental elements, such as air pollution and water pollution, due to its direct contact with them [3]. An environmental geochemical examination was conducted to analyse the presence of trace elements and principal oxides in the soil of the Nahrawan region during the summer season of 2024. The location of these samples was determined using the Global Positioning System (GPS).

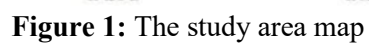
The Nahrawan area, located in eastern Baghdad, is one of the critical areas from an environmental standpoint, as this area is exposed to significantly increasing ecological pressures due to rapid urbanisation, urban and industrial expansion, and intense agricultural activities. With the expansion of fuel uses from coal, oil, natural gas and pesticides in various areas of life, many soil pollutants have spread into the environment [4]. Soil pollution refers to the degradation of land quality due to the build-up of dangerous contaminants, including industrial compounds, salts, and radioactive materials [5]. Soil pollution refers to the alteration of a soil's natural, chemical and biological properties by adding materials to it or removing materials from it [6]. Due to their potential toxicity and significance as essential nutrients, trace elements are especially concerning for the environment [7]. Any concentration below 1000 parts per million is considered a trace element in geochemistry [8]. Affinity, radius, and similarity of charges with other elements allow it to either adsorb into or replace these elements in the mineral composition [9]. Trace elements can be present in soil

as a result of artificial pollution or natural rock weathering [10]. The mobility and transformation of trace elements in the plant soil system, as well as their ecological toxicity, are strongly correlated with their concentration and structure [11]. Due to the influence of human activities (like industrial activities and agricultural activities), the soil in densely populated areas is constantly changing. Additionally, because the Nahrawan deposits are floodplains, the type and composition of the parent rocks in the study area greatly influence the trace element concentration of these deposits. Differentiating between anthropogenic inputs and natural background values is crucial for accurate assessment and understanding. However, anthropogenic inputs are much more than natural inputs in soil [12], acknowledging that background values vary from place to place. Found that the soil in the Nahrawan region had high concentrations of the trace elements Cd, Ni, Pb, and Cr [5], and soil samples' geochemistry revealed high levels of trace elements that were above permissible limits [8]. Furthermore, the regional distribution of trace elements was examined. Ultimately, heavy metal pollution was identified. The source of the pollution (natural or man-made) was classified using contamination factor (CF), enrichment factor (EF), index of geo-accumulation (I_{geo}), contamination degree (C_{deg}), pollution load index (PLI), and potential ecological risk index (PERI).

This study aims to assess the quality of soil in the Al-Nahrawan area by determining the accumulation of trace elements and identifying the sources of pollution in the soil in the study area.

1.1 Study area

Al-Nahrawan is located 33 km east of Baghdad, Iraq. Specifically, it is located in the southeastern region of the capital, Baghdad. The area is characterised by a mix of residential areas, agricultural land, and some industrial activities. The river's presence plays a crucial role in the local groundwater system close to the study area, influencing both groundwater availability and quality, and making it a critical site for assessing both natural and anthropogenic influences on the environment. The study area is bounded between latitudes ($32^{\circ} 90''$ - $33^{\circ} 40''$) and longitudes ($44^{\circ} 55''$ - $44^{\circ} 03''$) (Figure 1).



2. Materials and methods

Seventeen soil samples were collected in the study area at depths ranging from 0 to 20 cm as part of research conducted on 4 October 2024. All samples were labelled, placed in airtight polyethene bags for later analysis, and their exact location was determined using GPS data, as indicated in Table 1.

Table 1: Coordinates, site name, and the number of sampling sites

Samples No.	Site name	Latitude	Longitude
S1	Sheikh Hatem	33,26804	44,60745
S2	Gurff Naddaf	33,25335	44,58805
S3	Shahba Company	33,38607	44,83885
S4	Diamond quarry	33,39643	44,83622
S5	Wadi Diyala Company	33,41165	44,83533
S6	Al-Rafael Company	33,42286	44,83759
S7	Akili	33,44109	44,83325
S8	Agricultural land	33,37290	44,74377
S9	Hospital street	33,38028	44,70895
S10	Agricultural land	33,30295	44,64161
S11	Village 8	33,28841	44,64300
S12	Washing station	33,30349	44,66327
S13	Water filtration plant	33,28602	44,66108
S14	Village 8	33,29531	44,64910
S15	Village 5 Bismayah	33,25212	44,60348
S16	Najadat village (Gargle)	33,29744	44,58621
S17	Al-Abidat	33,30149	44,57974

After that, each sample was prepared in a lab for the necessary analysis. The samples were dried in a laboratory oven set to 40°C. Next, sort the material through a 2 mm sieve after removing any large debris, stones, plant matter, and other contaminants. Then, grind the sample in an agate mortar for 10 minutes to homogenise and reduce it to a powder of 0.063 mm in size. (XRF) Analysis is one technique used in the Iraqi German Laboratory, Department of Geology, College of Science, University of Baghdad, to evaluate the concentration of some trace elements and major oxides in soil. The lab data were used to create the spatial analysis map using ArcGIS 10.4.1.

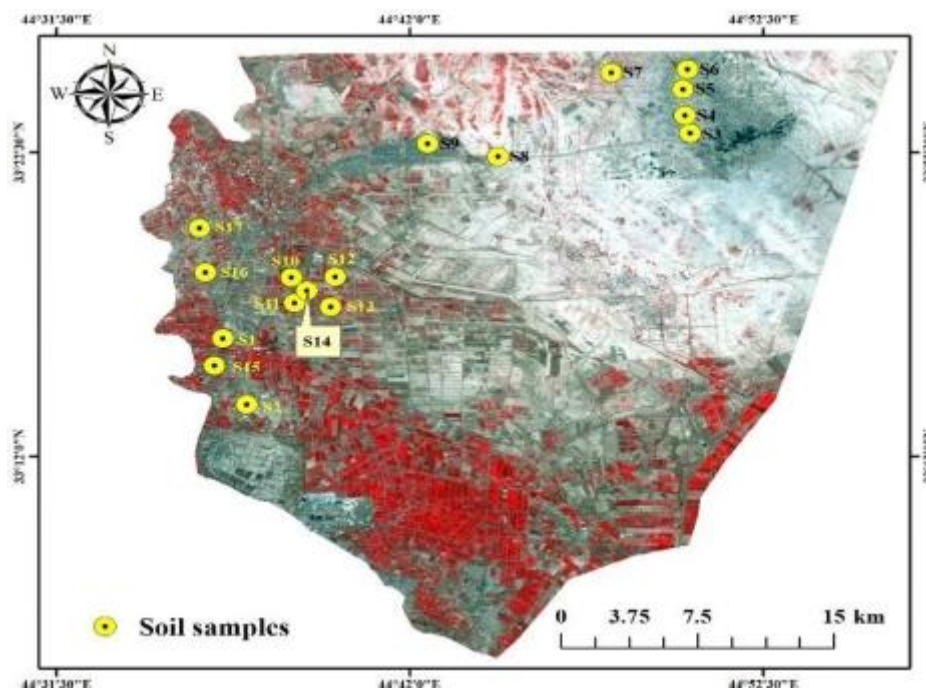


Figure 2 : The study area map shows the soil samples' location

3. Results

3.1 Major oxides

Table 2: Major oxides concentration in the study region in comparison to the background averages for the local and the world

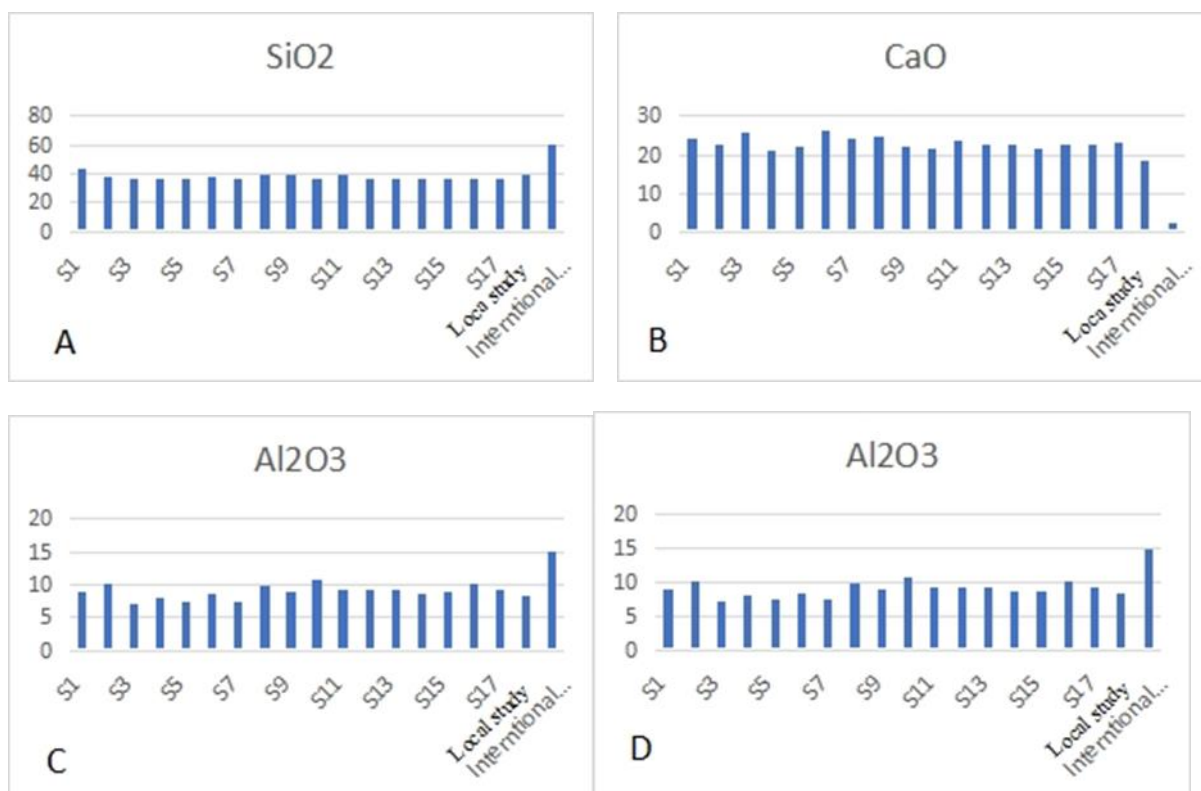
Sample No.	SiO ₂	CaO	Al ₂ O ₃	Fe ₂ O ₃	MgO	K ₂ O	Na ₂ O	SO ₃	TiO ₂	P ₂ O ₅	MnO
S1	43.11	23.98	9.09	5.31	3.60	1.16	1.22	0.73	0.57	0.47	0.05
S2	38.45	22.75	10.1	5.29	4.60	1.17	0.98	0.85	0.57	0.47	0.06
S3	36.84	25.65	7.15	5.16	3.35	1.26	1.73	2.01	0.56	0.50	0.05
S4	37.25	21.03	8.20	5.24	3.64	1.18	1.87	2.02	0.58	0.48	0.05
S5	36.4	22.17	7.46	6.28	3.74	1.24	1.57	2.91	0.57	0.48	0.05
S6	37.43	26.3	8.52	5.12	3.91	1.32	1.82	2.11	0.51	0.52	0.05
S7	36.02	24.37	7.49	5.18	4.37	1.32	1.95	2.01	0.55	0.52	0.05
S8	40.13	24.71	9.84	5.24	3.57	1.35	0.89	1.01	0.56	0.51	0.05

S9	39.26	22.02	8.85	5.22	3.92	1.52	0.71	0.57	0.73	0.18	0.09
S10	37.13	21.71	10.8	6.24	3.57	1.35	0.84	0.01	0.56	0.51	0.05
S11	39.69	23.5	9.34	5.88	4.84	1.35	0.62	0.04	0.47	0.51	0.04
S12	36.68	22.65	9.29	6.18	3.25	1.37	1.12	0.84	0.55	0.51	0.05
S13	37.18	22.42	9.27	6.80	4.75	1.28	1.23	1.33	0.45	0.51	0.04
S14	36.19	21.54	8.59	6.93	4.52	1.38	0.98	1.15	0.44	0.53	0.04
S15	36.5	22.66	8.84	6.15	3.47	1.83	1.54	1.14	0.52	0.59	0.02
S16	37.12	22.64	10.1	5.07	3.27	1.73	1.33	1.18	0.50	0.57	0.02
S17	37.25	23.15	9.19	6.11	3.69	1.28	1.22	1.11	0.55	0.52	0.05
Min	36.02	21.0	7.15	5.07	3.25	1.16	0.62	0.01	0.44	0.18	0.02
Max	43.11	26.3	10.8	6.93	4.84	1.83	1.95	2.91	0.73	0.59	0.09
Mean	37.80	23.1	8.95	5.72	3.88	1.35	1.27	1.23	0.54	0.49	0.04
[5]	39.09	18.23	8.43	3.74	4.65	1.22	1.49	1.21	ND	ND	ND
[13]	60	2	15	5	1.5	1.6	1.3	ND	0.67	0.19	0.07

ND: No data

The results of major oxides were in the order $\text{SiO}_2 > \text{CaO} > \text{Al}_2\text{O}_3 > \text{Fe}_2\text{O}_3 > \text{MgO} > \text{K}_2\text{O} > \text{Na}_2\text{O} > \text{SO}_3 > \text{TiO}_2 > \text{P}_2\text{O}_5 > \text{MnO}$. SiO_2 concentrations ranged from 36.02% to 43.11% with a mean of 37.80% (Table 2). SiO_2 concentration in the study area is within the acceptable limit of [5, 13], except S1, S8, S9, and S11, which are higher than [5] (Figure 3A). This could be caused by exposure to crystalline silica dust, which is involved in construction and demolition activities. The source of SiO_2 may be the calcium silicates, which have become the most significant sources for soil treatments, and wind action both transport silica from fragile farm soil [14]. CaO level ranging from 21.03% to 26.3% with a mean of 23.1% (Table 2). CaO in the study area is relatively higher than the CaO of [5,13] (Figure 3B). CaO is present in many industrial and human waste (urine and faeces). Al_2O_3 is a common oxide found in silicate minerals that can be released during weathering [15]. Al_2O_3 ranging from 7.15% to 10.84% with a mean of 8.95% (Table 2). All Al_2O_3 concentrations in the study area are higher than [5], except S3, S4, S5, and S7 within the acceptable limit of [5] (Table 3; Figure 3C). While all Al_2O_3 concentrations are within the acceptable limit of [13]. This increase is due to engineering and construction works, residues of brick factories, and agricultural activities. Fe_2O_3 ranged from 5.07% to 6.93% with a mean of 5.72% (Table 2). All Fe_2O_3 concentrations in the study area are higher than the concentrations of [5,13] (Figure 3D). This is related to reduction processes, weathering severity, and parent material [16]. Additionally, organic substances such as wastewater and industrial contaminants cause Fe_2O_3 to be present in the soil. MgO ranging from 3.25% to 4.84% with a mean of 3.88% (Table 2; Figure 3E). MgO concentration in this study is within the acceptable limit of [5], except S11 and S13, which are higher than [5], while all land use types have MgO concentration much higher than [13]. The MgO concentration increased in the study area's soil due to industrial activities, fertilisers and pesticides (like MgSO_4), and agricultural activities. K_2O ranging from 1.16% to 1.83% with a mean of 1.35% (Table 2). All K_2O concentrations of soil samples in the study area are within the acceptable limit of [13], except S15, and S16 exceed of [13] (Table 2), while K_2O is higher than [5], except S1, S2, and S4 are within the

acceptable limit of K_2O [5], as shown in (Figure 3F). K_2O is mostly anthropogenic and comes from fertilisers, irrigation water, especially from wells and rivers, which contain a high percentage of K. Na_2O , ranging from 0.62% to 1.95% with a mean of 1.27% (Table 2). Na_2O concentration of most soil samples within the acceptable limit of [5,13] except S3, S4, S5, S6, S7, and S15 are higher than [5,13] (Table 2; Figure 3G). The high concentration is due to the use of salt irrigation water (from rivers or wells) that contains a high percentage of dissolved salts (such as sodium chloride $NaCl$), extreme evaporation, poor soil drainage, industrial activities, and fertilisers and pesticides (like $NaNO_3$). SO_3 ranging from 0.01% to 2.91% with a mean of 1.23% (Table 2). The mean concentration of SO_3 within acceptable limit of [5] (Table 2; Figure 3H), except S3, S4, S5, S6, S7, and S13 are higher than [5]. The percentage of sulfur trioxide increased as a result of the use of fuel oil, which produced sulfate ions [17]. TiO_2 is the most resistant to weathering processes [18]. TiO_2 ranging from 0.44% to 0.73% with a mean of 0.54% (Table 2). TiO_2 concentration in soil samples is within the acceptable limit, except S9 exceeds the TiO_2 concentration of [13] (Table 3; Figure 3I). TiO_2 increased due to industrial activities and agricultural activities. P_2O_5 concentration in the study area ranged from 0.18% to 0.59% with a mean of 0.49% (Table 2). All P_2O_5 concentrations in soil samples were higher than the P_2O_5 of [13] (Table 2; Figure 3J), except the mean concentration of P_2O_5 in S9 was within the acceptable limit. P_2O_5 in soil is derived from fertilisers and wastewater from homes and factories. MnO ranged from 0.02% to 0.09% with a mean of 0.04% (Table 2). All MnO concentrations in soil samples were within the acceptable limit, except S9 exceeded [13] (Table 3; Figure 3K). This is because MnO is mostly derived from parent rock rather than man-made sources and is closely linked to organic matter in soil [19].



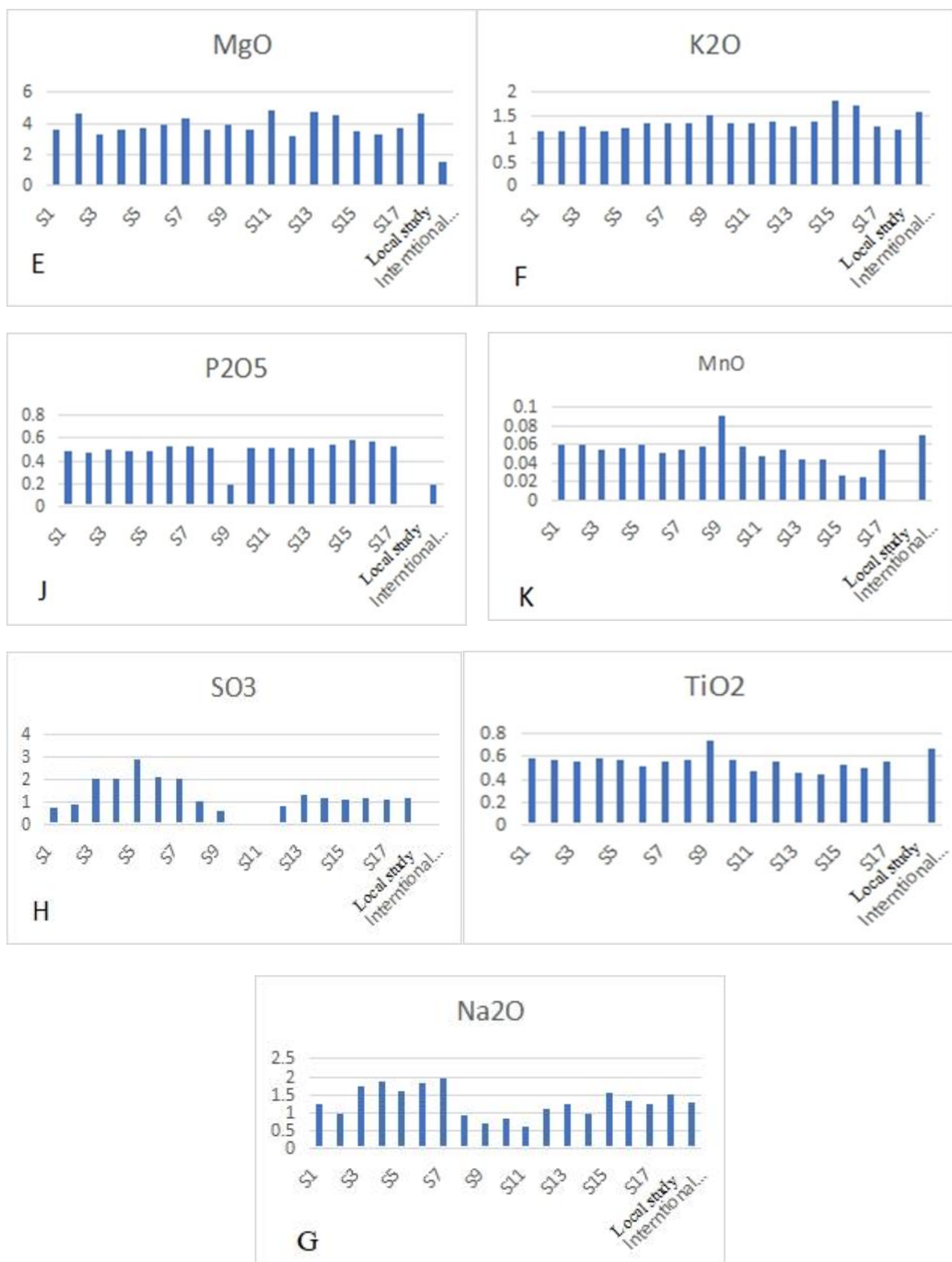


Figure 3: Major oxide distribution patterns by land-use category are compared to local and global studies

3.2 Trace elements

Trace elements can contaminate soil and spread through wind, water, and plant uptake [20]. In this study, Pb concentration ranged from 6.7 ppm to 11.8 ppm with a mean of 8.2

ppm (Table 3). All Pb concentrations in soil samples were within the acceptable limit of [4,21] (Figure 4A). Pb is the most critical element that needs to be removed from the soil because it has a very harmful effect on human health and the environment [22]. Cd concentration in all soil samples was below the detection limit (BDL) (Table 3). Ni concentration ranged from 60.2 ppm to 139 ppm with a mean of 66.8 ppm (Table 3). Ni concentration in soil samples is within the acceptable limit of [4], but higher than [21], as shown in Figure 4B. Ni is inserted into the soil through human activities [23]. High levels are attributed to the burning of heavy fuels, the adsorption of clay minerals, industrial and urban pollution, and the use of phosphate fertilisers and pesticides. There is a strong link between airborne Ni and V [24]. Copper (Cu) is essential for life but becomes toxic in soil when concentrations exceed natural levels [25]. Cu concentration ranged from 12.2 ppm to 34 ppm with a mean of 15.1 ppm (Table 3). All Cu concentrations in the study area are within the acceptable limit of [4], except S9, which exceeds [4], but Cu concentration in the study area exceeds [21], except S3, S4, S5, S6, S7, S8, S10, S11, and S12 are within the acceptable limit (Figure 4C). This increase depends on the parent rocks, the geographical area, industrial activities, and agricultural practices. Cr concentration ranging from 79.3 ppm to 489 ppm with a mean of 251 ppm (Table 3). All Cr concentrations are higher than Cr of [4,21] (Figure 4D). The increase of Cr in Iraqi soil is due to clastic sediments that formed the stratigraphic column of the Mesopotamian plain [26], as well as fuel combustion, fertilisers and wastewater. Zn concentration ranged from 39.8 ppm to 87.6 ppm with a mean of 45.8 ppm (Table 3). All Zn concentrations within the acceptable limit of [21], except S9, exceed [21] (Figure 4E). This increase is attributed to household waste as well as household products that contain Zn, such as batteries, pigments, and paints. So, waste disposal leads to soil pollution around landfills [27]. Fe concentration ranging from 35466 ppm to 48478 ppm with a mean of 39862 ppm (Table 3; Figure 4F). All Fe concentrations in soil samples are higher than [4]. V concentration ranging from 41.5 ppm to 108 ppm with a mean of 65.3 ppm (Table 3). V concentration in soil samples is higher than [21], except S13, S14, S15 and S16 within the acceptable limit of [21] (Figure 4G). This increase in Fe and V is due to fossil fuel combustion, as the process of burning fuel is carried out in large quantities, resulting in the fall of residues and smoke from factories on the soil. Combustion emissions are a primary source of elevated V levels in soil [28]. The source of Fe and V in the soil is its parent rocks [29][30].

Table 3: The concentrations of trace elements in ppm for each land-use type are compared with Local study and international background values

Sample No.	Pb	Cd	Ni	Cu	Cr	Zn	Fe	V
S1	8.1	BDL	67.1	14.1	396	45.6	37145	76.7
S2	8.4	BDL	66	14.1	489	46.0	37005	75.6
S3	8.2	BDL	63	13.7	321	45.6	36096	67.7
S4	8	BDL	65.8	12.6	355	44.8	36656	78.9
S5	7.7	BDL	63.9	12.2	430	44.7	43931	67.2
S6	8	BDL	63	14	283	44.1	35816	68.8
S7	8.3	BDL	61	13.8	396	44.6	36236	69.4
S8	7.9	BDL	65.1	13.1	292	45.6	36656	67.7
S9	11.5	BDL	139	34	184	87.6	36516	108
S10	7.9	BDL	65.1	13.1	292	45.6	43651	67.7
S11	7.3	BDL	62.7	13.3	210	41.5	41133	62.7
S12	7	BDL	65.2	14	311	43.9	43231	61.6
S13	7	BDL	61.7	15.5	147	39.8	47569	50.9
S14	6.7	BDL	60.2	14.1	199	42.2	48478	51.5
S15	11.8	BDL	64.1	25.4	79.3	42.5	43022	48.7
S16	7.9	BDL	62.6	14.7	86.2	42.4	35466	41.5
S17	8.5	BDL	64.3	14.8	281	44.8	42742	71.7
Mean	8.3	BDL	68.3	15.7	279	46.5	40079	66.8
Min	6.7	BDL	60.2	12.2	79.3	39.8	35466	41.5
Max	11.8	BDL	139	34	489	87.6	48478	108
(Al-sultani, 2006) [4]	62.3	12.5	174	29.4	72.4	ND	32035	ND
(Kabata-pendi and Pendias, 2001) [21]	25	1.1	18	14	42	62	ND	60

ND: No data; BDL: Below detection limit



Figure 4: Concentration of trace elements of soil for land-use categories compared with local and international background

3.3 Spatial distribution of trace elements

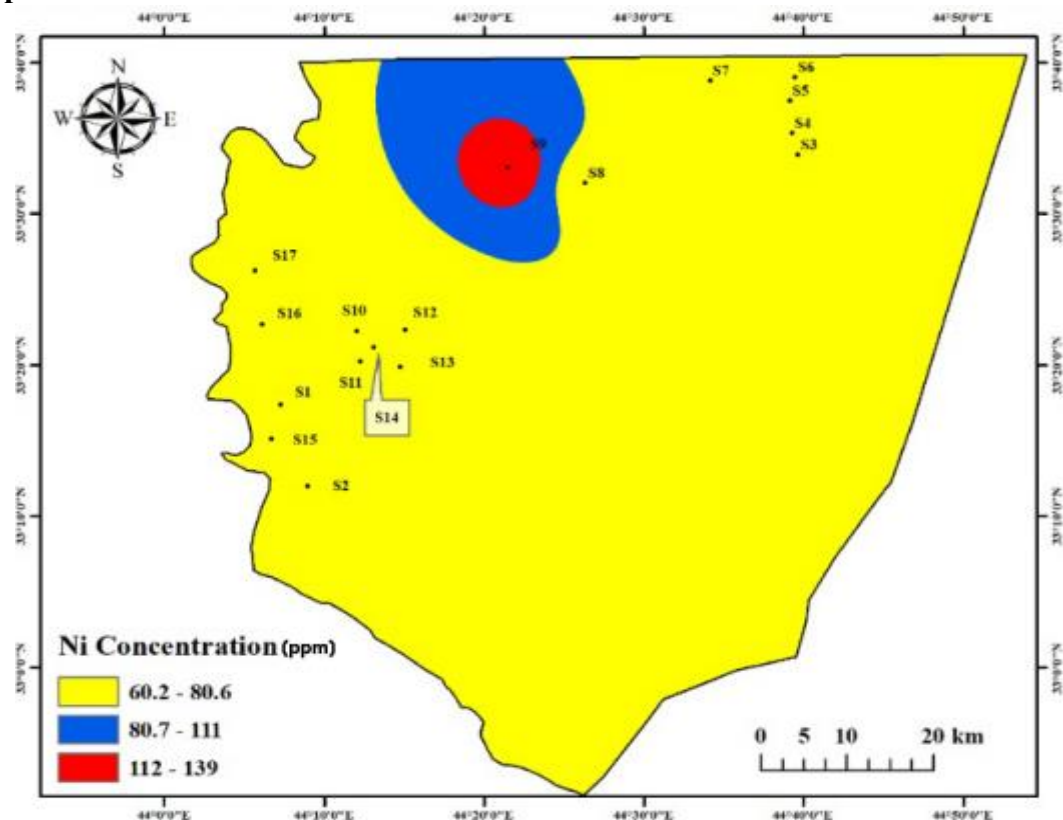


Figure 5: Spatial distribution map of Ni in soils of the study area

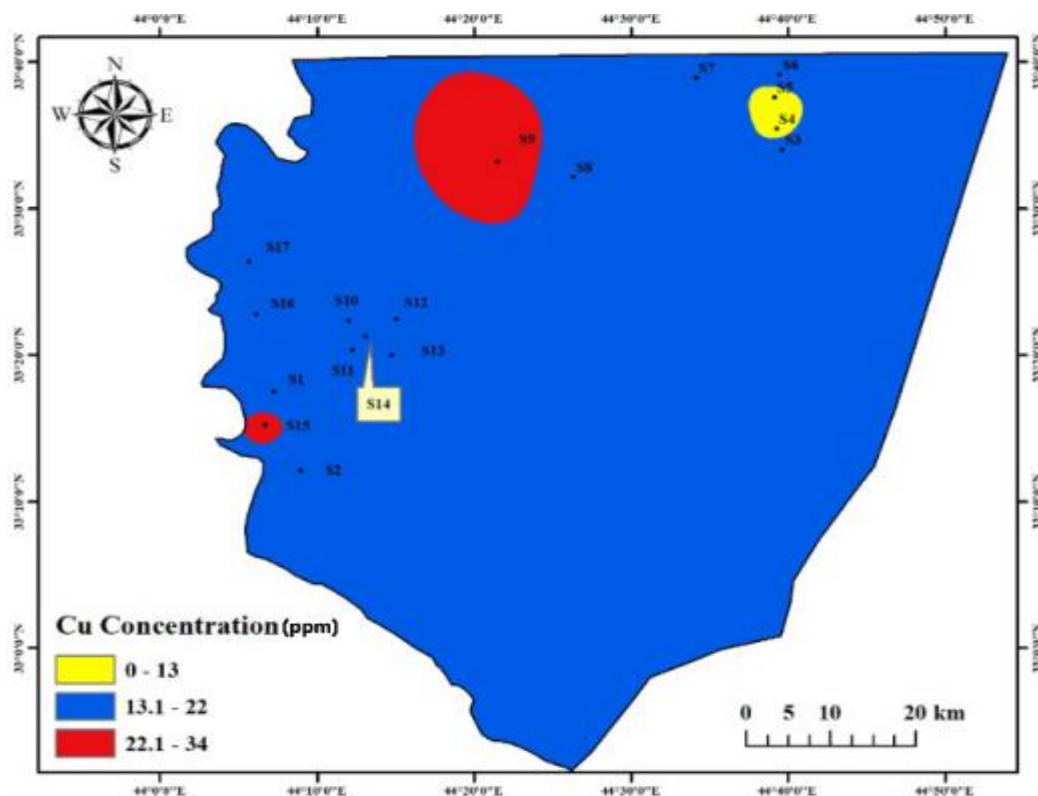


Figure 6: Spatial distribution map of Cu in soils of the study area

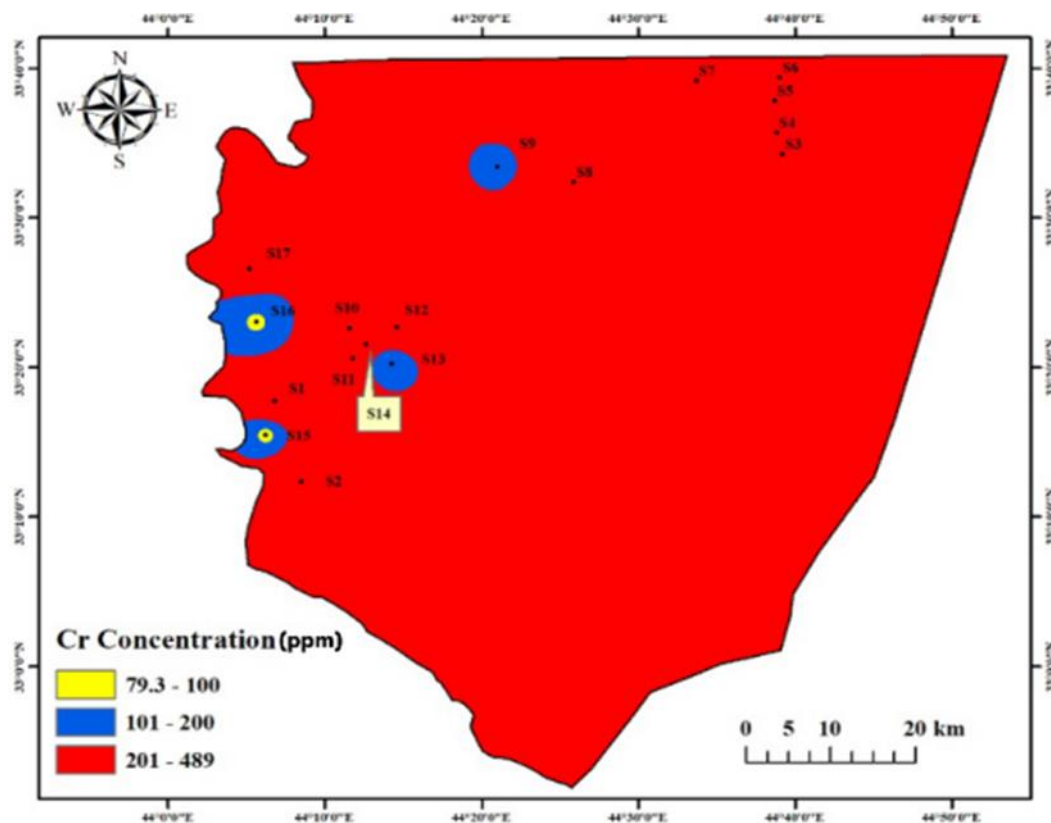


Figure 7: Spatial distribution map of Cr in soils of the study area

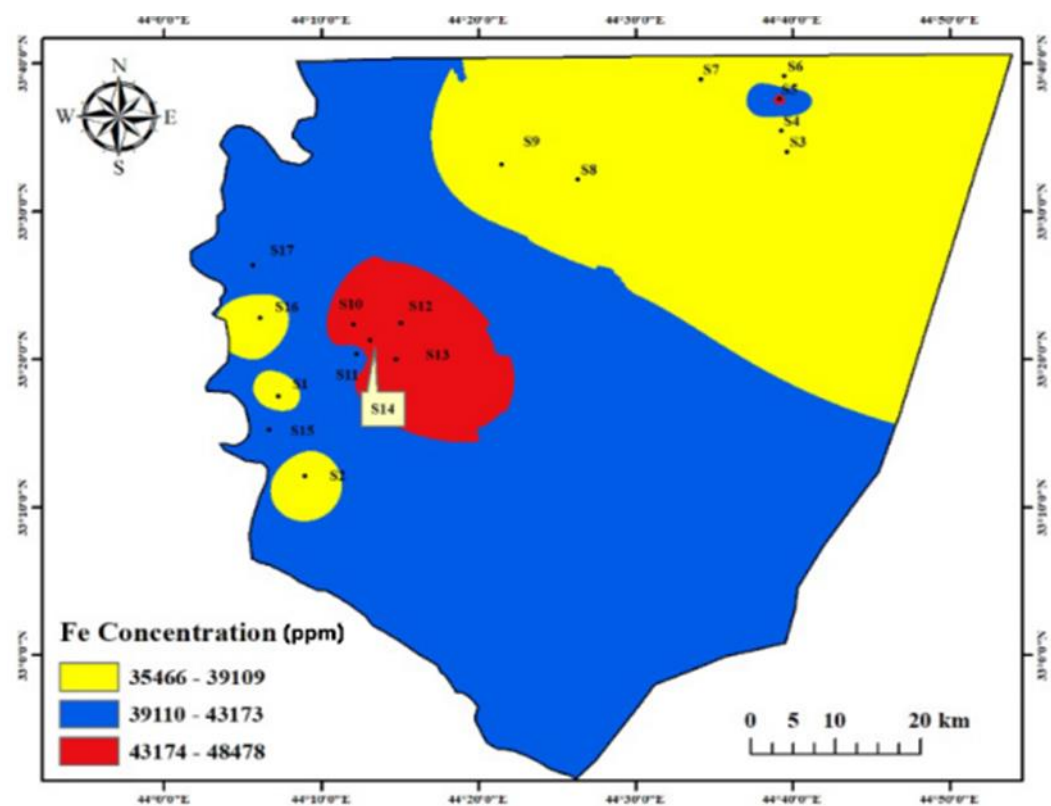


Figure 8: Spatial distribution map of Fe in soils of the study area

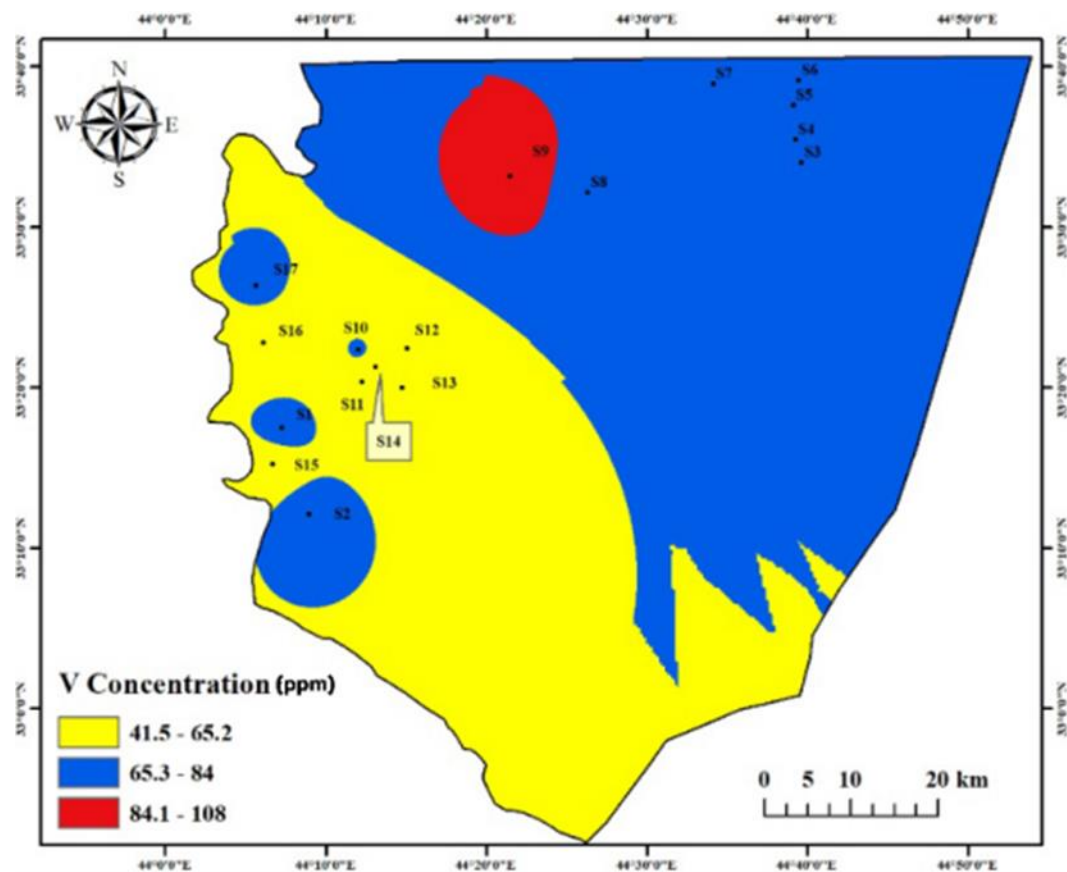


Figure 9: Spatial distribution map of V in soils of the study area

3.4 Soil quality assessment

Table 4: Mean value of Geo-accumulation I_{geo} for the study area

Sam ple No.	I_{geo} Pb	Polluti on level	I_{geo} Ni	Polluti on level	I_{geo} Cu	Pollutio n level	I_{geo} Cr	Pollutio n level	I_{geo} Zn	Polluti on level	I_{geo} Fe	Polluti on level	I_{geo} V	Polluti on level
S1	- 2.2 1	practic ally unpoll uted	1.3 1	modera tely pollute d	- 0.57	practical ly unpollut ed	2.6 5	moderat ely to strongly	- 1.0 2	practic ally unpollu ted	- 0.3 7	practic ally unpoll uted	- 0.2 3	practic ally unpoll uted
S2	- 2.1 5	practic ally unpoll uted	1.2 8	modera tely pollute d	- 0.57	practical ly unpollut ed	2.9 5	moderat ely to strongly	- 1.0 1	practic ally unpollu ted	- 0.3 7	practic ally unpoll uted	- 0.2 5	practic ally unpoll uted
S3	- 2.1 9	practic ally unpoll uted	1.2 2	modera tely pollute d	- 0.61	practical ly unpollut ed	2.3 4	moderat ely to strongly	- 1.0 2	practic ally unpollu ted	- 0.4 1	practic ally unpoll uted	- 0.4 1	practic ally unpoll uted
S4	- 2.2 2	practic ally unpoll uted	1.2 8	modera tely pollute d	- 0.73	practical ly unpollut ed	2.4 9	moderat ely to strongly	- 1.0 5	practic ally unpollu ted	- 0.3 9	practic ally unpoll uted	- 0.1 8	practic ally unpoll uted
S5	- 2.2 8	practic ally unpoll uted	1.2 4	modera tely pollute d	- 0.78	practical ly unpollut ed	2.7 7	moderat ely to strongly	- 1.0 5	practic ally unpollu ted	- 0.1 2	practic ally unpoll uted	- 0.4 2	practic ally unpoll uted
S6	- 2.2 2	practic ally unpoll	1.2 2	modera tely pollute	- 0.58	practical ly unpollut	2.1 6	moderat ely to strongly	- 1.0 7	practic ally unpollu	- 0.4 2	practic ally unpoll	- 0.3 8	practic ally unpoll

		uted		d		ed				ted		uted		uted
S7	- 2.1 7	practic ally unpoll uted	1.1 7	modera tely pollute d	- 0.60	practical ly unpollut ed	2.6 5	moderat ely to strongly	- 1.0 6	practic ally unpollu ted	- 0.4 0	practic ally unpoll uted	- 0.3 7	practic ally unpoll uted
S8	- 2.2 4	practic ally unpoll uted	1.2 6	modera tely pollute d	- 0.68	practical ly unpollut ed	2.2 1	moderat ely to strongly	- 1.0 2	practic ally unpollu ted	- 0.3 9	practic ally unpoll uted	- 0.4 1	practic ally unpoll uted
S9	- 1.7 0	practic ally unpoll uted	2.3 6	modera tely to strongl y	0.69	unpollut ed to moderat ely	1.5 4	moderat ely polluted	- 0.0 8	practic ally unpollu ted	- 0.3 9	practic ally unpoll uted	- .02 6	practic ally unpoll uted
S10	- 2.2 4	practic ally unpoll uted	1.2 6	modera tely pollute d	- 0.68	practical ly unpollut ed	2.2 1	moderat ely to strongly	- 1.0 2	practic ally unpollu ted	- 0.1 3	practic ally unpoll uted	- 0.4 1	practic ally unpoll uted
S11	- 2.3 6	practic ally unpoll uted	1.2 1	modera tely pollute d	- 0.65	practical ly unpollut ed	1.7 3	moderat ely polluted	- 1.1 6	practic ally unpollu ted	- 0.2 2	practic ally unpoll uted	- 0.5 2	practic ally unpoll uted
S12	- 2.4 2	practic ally unpoll uted	1.2 7	modera tely pollute d	- 0.58	practical ly unpollut ed	2.3 0	moderat ely to strongly	- 1.0 8	practic ally unpollu ted	- 0.1 5	practic ally unpoll uted	- 0.5 4	practic ally unpoll uted
S13	- 2.4 2	practic ally unpoll uted	1.1 9	modera tely pollute d	- 0.43	practical ly unpollut ed	1.2 2	moderat ely polluted	- 1.2 2	practic ally unpollu ted	- 0.0 1	practic ally unpoll uted	- 0.8 2	practic ally unpoll uted
S14	- 2.4 8	practic ally unpoll uted	1.1 5	modera tely pollute d	- 0.57	practical ly unpollut ed	1.6 5	moderat ely polluted	- 1.1 3	practic ally unpollu ted	- 0.0 1	practic ally unpoll uted	- 0.8 0	practic ally unpoll uted
S15	- 1.6 6	practic ally unpoll uted	1.2 4	modera tely pollute d	0.27	practical ly unpollut ed	0.3 3	Unpollut ed to moderat ely	- 1.1 2	practic ally unpollu ted	- 0.1 5	practic ally unpoll uted	- 0.8 8	practic ally unpoll uted
S16	- 2.2 4	practic ally unpoll uted	1.2 1	modera tely pollute d	- 0.51	practical ly unpollut ed	0.4 5	Unpollut ed to moderat ely	- 1.1 3	practic ally unpollu ted	- 0.4 3	practic ally unpoll uted	- 1.1 1	practic ally unpoll uted
S17	- 2.1 4	practic ally unpoll uted	1.2 5	modera tely pollute d	- 0.50	practical ly unpollut ed	2.1 5	moderat ely to strongly	- 1.0 5	practic ally unpollu ted	- 0.1 6	practic ally unpoll uted	- 0.3 2	practic ally unpoll uted

Table 5: EF concentration of trace elements in the study area

Sam ple No.	EF val ue Pb	Lev el	EF val ue Ni	Level	EF val ue Cu	Level	EF val ue Cr	Level	EF val ue Zn	Level	EF val ue Fe	Level	EF val ue V	Level
S1	0.68	Low	7.89	Significant	2.13	Moderate	19.9	Significant	1.55	Low	2.45	Moderate	2.70	Moderate
S2	0.65	Low	7.19	Significant	1.97	Low	22.8	Very high	1.45	Low	2.26	Moderate	2.47	Moderate
S3	0.71	Low	7.59	Significant	2.12	Moderate	16.5	Significant	1.59	Low	2.44	Moderate	2.44	Moderate
S4	0.71	Low	8.13	Significant	2.00	Moderate	18.8	Significant	1.60	Low	2.54	Moderate	2.92	Moderate
S5	0.63	Low	7.29	Significant	1.78	Low	21.0	Very high	1.48	Low	2.81	Moderate	2.30	Moderate
S6	0.84	Low	9.25	Significant	2.64	Moderate	17.8	Significant	1.88	Low	2.95	Moderate	3.03	Moderate
S7	0.72	Low	7.41	Significant	2.15	Moderate	20.6	Very high	1.57	Low	2.47	Moderate	2.53	Moderate
S8	0.67	Low	7.72	Significant	1.99	Low	14.8	Significant	1.57	Low	2.44	Moderate	2.41	Moderate
S9	1.08	Low	18.2	Significant	5.73	Significant	10.3	Significant	3.33	Significant	2.69	Moderate	4.25	Moderate
S10	0.67	Low	7.72	Significant	1.99	Low	14.8	Significant	1.57	Low	2.91	Moderate	2.41	Moderate
S11	0.81	Low	9.66	Significant	2.63	Moderate	13.8	Significant	1.85	Low	3.56	Moderate	2.90	Moderate
S12	0.74	Low	9.67	Significant	2.67	Moderate	19.7	Significant	1.89	Low	3.60	Moderate	2.74	Moderate
S13	0.84	Low	10.3	Significant	3.33	Moderate	10.5	Significant	1.93	Low	4.47	Moderate	2.55	Moderate
S14	0.74	Low	9.28	Significant	2.79	Moderate	13.1	Significant	1.88	Low	4.20	Moderate	2.38	Moderate
S15	1.17	Low	8.88	Significant	4.52	Moderate	4.71	Moderate	1.71	Low	3.35	Moderate	2.02	Moderate
S16	0.79	Low	8.76	Significant	2.64	Moderate	5.16	Significant	1.72	Low	2.78	Moderate	1.74	Low
S17	0.84	Low	8.83	Significant	2.61	Moderate	16.5	Significant	1.78	Low	3.29	Moderate	2.95	Moderate

Table 6: Mean value of CF of trace elements for the study area

Sam ple No.	Pb	Lev el	Ni	Level	Cu	Level	Cr	Level	Zn	Level	Fe	Level	V	Level
S1	0.3 2	Lo w	3.7 2	Consider able	1.0	Moder ate	9.4 2	Very high	0.7 3	Low	1.1 5	Moder ate	1.2 7	Moder ate
S2	0.3 3	Lo w	3.6 6	Consider able	1.0	Moder ate	11. 6	Very high	0.7 4	Low	1.1 5	Moder ate	1.2 6	Moder ate
S3	0.3 2	Lo w	3.5	Consider able	0.9	Low	7.6 4	Very high	0.7 3	Low	1.1 2	Moder ate	1.1 2	Moder ate
S4	0.3 2	Lo w	3.6 5	Consider able	0.9	Low	8.4 5	Very high	0.7 2	Low	1.1 4	Moder ate	1.3 1	Moder ate
S5	0.3 0	Lo w	3.5 5	Consider able	0.8	Low	10. 2	Very high	0.7 2	Low	1.3 7	Moder ate	1.1 2	Moder ate
S6	0.3 2	Lo w	3.5	Consider able	1	Low	6.7 3	Very high	0.7 1	Low	1.1 1	Moder ate	1.1 4	Moder ate
S7	0.3 3	Lo w	3.3 8	Consider able	0.9	Moder ate	9.4 2	Very high	0.7 1	Low	1.1 3	Moder ate	1.1 5	Moder ate
S8	0.3 1	Lo w	3.6 1	Consider able	0.9	Low	6.9 5	Very high	0.7 3	Low	1.1 4	Moder ate	1.1 2	Moder ate
S9	0.4 6	Lo w	7.7 2	Very high	2.4	Moder ate	4.3 8	Conside rable	1.4 1	Moder ate	1.1 3	Moder ate	1.8	Moder ate
S10	0.3 1	Lo w	3.6 1	Consider able	0.9	Low	6.9 5	Very high	0.7 3	Low	1.3 6	Moder ate	1.1 2	Moder ate
S11	0.2 9	Lo w	3.4 8	Consider able	0.9	Low	5	Conside rable	0.6 6	Low	1.2 8	Moder ate	1.0 4	Moder ate
S12	0.2 8	Lo w	3.6 2	Consider able	1	Moder ate	7.4 0	Very high	0.7 0	Low	1.3 4	Moder ate	1.0 2	Moder ate
S13	0.2 8	Lo w	3.4 2	Consider able	1.1 0	Moder ate	3.5	Conside rable	0.6 4	Low	1.4 8	Moder ate	0.8 4	Low
S14	0.2 6	Lo w	3.3 4	Consider able	1.0	Moder ate	4.7 3	Conside rable	0.6 8	Low	1.5 1	Moder ate	0.8 5	Low
S15	0.4 7	Lo w	3.5 6	Consider able	1.8	Moder ate	1.8 8	Moderat e	0.6 8	Low	1.3 4	Moder ate	0.8 1	Low
S16	0.3 1	Lo w	3.4 7	Consider able	1.0	Moder ate	2.0 5	Moderat e	0.6 8	Low	1.1 0	Moder ate	0.6 9	Low
S17	0.3 4	Lo w	3.5 7	Consider able	1.0	Moder ate	6.6 9	Very high	0.7 2	Low	1.3 3	Moder ate	1.1 9	Moder ate

Table 7: C_{deg} values of trace elements for the study area

Sample No.	C _{deg} value	Contamination level
S1	19.42	considerable degree of contamination
S2	21.59	considerable degree of contamination
S3	17.14	considerable degree of contamination
S4	18.3	considerable degree of contamination
S5	19.87	considerable degree of contamination
S6	16.32	considerable degree of contamination
S7	18.83	considerable degree of contamination
S8	16.57	considerable degree of contamination
S9	21.11	considerable degree of contamination
S10	16.79	considerable degree of contamination
S11	14.46	considerable degree of contamination
S12	17.17	considerable degree of contamination
S13	13.07	considerable degree of contamination

S14	14.18	considerable degree of contamination
S15	12.35	considerable degree of contamination
S16	11.11	moderate degree of contamination
S17	16.65	considerable degree of contamination

Table 8: PLI values of trace elements of soil samples in the study area

Sample No.	PLI value	status of pollution
S1	1.46	Polluted
S2	1.51	Polluted
S3	1.37	Polluted
S4	1.42	Polluted
S5	1.42	Polluted
S6	1.36	Polluted
S7	1.41	Polluted
S8	1.36	Polluted
S9	1.93	Polluted
S10	1.39	Polluted
S11	1.28	Polluted
S12	1.37	Polluted
S13	1.23	Polluted
S14	1.26	Polluted
S15	1.28	Polluted
S16	1.09	Polluted
S17	1.42	polluted

Table 9: value of PERI and ecological risk level of soil samples in the study area

Sample NO.	Pb	Ni	Cu	Cr	Zn	Fe	V	Risk level	RI value	Risk degree
S1	1.6	18.6	5	18.84	0.73	1.15	2.54	Low	45.92	Low
S2	1.65	18.3	5	23.28	0.74	1.15	2.52	Low	50.12	Low
S3	1.6	17.5	4.5	15.28	0.73	1.12	2.24	Low	40.73	Low
S4	1.6	18.25	4.5	16.9	0.72	1.14	2.62	Low	43.11	Low
S5	1.5	17.75	4	20.4	0.72	1.37	2.24	Low	45.74	Low
S6	1.6	17.5	5	13.46	0.71	1.11	2.28	Low	39.38	Low
S7	1.65	16.9	4.5	18.84	0.71	1.13	2.3	Low	43.73	Low
S8	1.55	18.05	4.5	13.9	0.73	1.14	2.24	Low	39.87	Low
S9	2.3	38.6	12	8.76	1.41	1.13	3.6	Low	64.2	Low
S10	1.55	18.05	4.5	13.9	0.73	1.36	2.24	Low	40.09	Low
S11	1.45	17.4	4.5	10	0.66	1.28	2.08	Low	35.29	Low
S12	1.4	18.1	5	14.8	0.7	1.34	2.04	Low	41.34	Low
S13	1.4	17.1	5.5	7	0.64	1.48	1.68	Low	33.12	Low
S14	1.3	16.7	5	9.46	0.68	1.51	1.7	Low	34.65	Low
S15	2.35	17.8	9	3.76	0.68	1.34	1.62	Low	34.93	Low
S16	1.55	17.35	5	4.1	0.68	1.1	1.38	Low	29.78	Low
S17	1.7	17.85	5	13.38	0.72	1.33	2.38	Low	39.98	Low

4. Discussion

Major oxides in soil samples are in order of $\text{SiO}_2 > \text{CaO} > \text{Al}_2\text{O}_3 > \text{Fe}_2\text{O}_3 > \text{MgO} > \text{K}_2\text{O} > \text{SO}_3 > \text{Na}_2\text{O} > \text{TiO}_2 > \text{P}_2\text{O}_5 > \text{MnO}$ percent. As compared to the local study [5] and international study [13], the mean concentrations of CaO, MgO, Fe_2O_3 , and P_2O_5 are greater than those of the international study, whereas SiO_2 , Al_2O_3 , SO_3 , K_2O , Na_2O , TiO_2 , and MnO are lower than those of the international study (Table 2). In addition, CaO, Al_2O_3 , Fe_2O_3 ,

K₂O, TiO₂, P₂O₅, and MnO concentrations are greater than the average of the national background, while SiO₂, MgO, SO₃, and Na₂O are lower than the national background.

Because of the influence of human activity (like industrial activities and agricultural activities) soil in densely populated places is constantly changing. Additionally, since the Nahrawan deposits are floodplains, the type and composition of the parent rocks in the study area greatly influence the trace element concentration of these deposits.

The concentrations of Pb, Cd, and Zn in soil samples were within acceptable limits of local and international studies, except Zn in S9 is greater than international. Ni and Cu concentrations within the acceptable limits of the local study, except for S9, exceed the local study, while Ni and some Cu concentrations are higher than those of the international study. The concentrations of Fe and Cr were higher than those reported in local and international studies. Most V concentrations are higher than the international study, except for V in S13, S14, S15, and S16, which are within the acceptable limit.

An increase in some trace elements because the process of burning fuel is carried out in a large quantity in the Nahrawan region, coal waste disposal in brick factories, because of the fall of residues and smoke of factories on the soil, organic materials, and agricultural activities all these are may lead to an increase in its trace elements concentrations in the region and we do not neglect the effect of source rocks in that. According to the results of soil quality assessments of the Al-Nahrawan area, soils have a considerable contamination of Ni, Cu, Cr, Fe, and V. All results of I_{geo} indicate unpolluted, except that Ni and Cr are moderately to strongly polluted. EF and CF were shown to indicate pollution from low to medium, except that Ni and Cr were greatly polluted, and EF in relation to Cu and Zn in S9 showed significant enrichment, while PERI showed low in all samples. The reason for the increase in these factors is due to human activities, such as industrial and agricultural activities.

5. Conclusions

- Al-Nahrawan soil has high pollution due to rapid urban and industrial expansion, and intense agricultural activities. A result of fuel use from coal, oil, natural gas and pesticides in various areas of life.
- The mean concentrations of CaO, MgO, Fe₂O₃, and P₂O₅ are greater than international whereas, SiO₂, Al₂O₃, SO₃, K₂O, Na₂O, TiO₂, MnO are lower than international. In addition, CaO, Al₂O₃, Fe₂O₃, K₂O, TiO₂, P₂O₅, and MnO concentrations are greater than the average of the national background, while SiO₂, MgO, SO₃, and Na₂O are lower than the national background.
- The concentrations of Pb, Cd, and Zn in soil samples were within the acceptable limit of national and international limits, except Zn in S9 is greater than the international limit, which increases because of household waste as well as household products that contain zinc, such as batteries, pigments, and paints. Concentrations of Fe and Cr were greater than national and international limits. The increase in Cr due to the industrial activity, wastewater, fertilisers and coal-fired power stations are the primary human source of Cr emissions into the atmosphere, while increasing in Fe due to the availability of iron in the petroleum and in different concentrations, because the process of burning fuel is carried out in large quantities in the Nahrawan region and because of the fall of residues and smoke of factories on the soil. Most V concentrations greater than the international limit, except V in S13, S14, S15, and S16, are within an acceptable limit. Increase in V concentration due to fossil fuel combustion, disposal from coal waste and fly ash in brick factories. Ni and Cu concentrations are within the acceptable limit of the national limit, except that S9 exceeds the national limit, while Ni and some Cu concentrations are higher than the international limit. Burning heavy fuels and the adsorption of clay minerals, phosphate fertilisers, pesticides, and parent rocks are the

causes of the elevated concentration. We do not neglect the effect of source rocks on increasing the concentrations of trace elements.

- The GIS technique uses the spatial analyst extension in ArcMap to prepare the map to predict the spatial distribution of the element.
- Based on the spatial distribution map, there is a high accumulation of the concentration of Ni, Cr, Fe, V, and some Cu in the Nahrawan area because of the presence of a large number of factories and agricultural activities.
- According to the results of soil quality assessments, Al-Nahrawan soils have a considerable amount of trace element contamination.
- I_{geo} indicates that practically unpolluted was <0 , except Ni and Cr, which are moderately to strongly polluted, were (1-2, 2-3). EF and CF indicate pollution from low to medium, except that Ni and Cr are greatly polluted, and EF in relation to Cu and Zn in S9 are significantly enriched, while PERI showed low in all samples. And C_{deg} values indicate a considerable degree of contamination in all soil samples except S16, which indicates a moderate degree of contamination. PLI values showed pollution in all samples. The pollution in these factors is due to human activities.

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