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Environmental Geochemistry of some Heavy Metals and the Radioactivity in Urban Subsurface Soils, Southeast-Baghdad

Zinah Saleem Al-Ankaz[1]✉ | **Ruaa Issa Muslim**[1] | **Maitham Salman. Amana**[2]

1. Department of Geology, College of Science, Wasit University, Wasit, Iraq.
2. Department of Physics, College of Science, Wasit University, Wasit, Iraq.

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ABSTRACT

A geochemical evaluation was performed to determine the occurrences of many heavy metals as well as their natural activities, in the southeast-Baghdad. For this purpose, seventeen subsurface soil samples from the cited location were collected at a depth of 50-100 cm. Samples collection included many types of land uses such as open space, roadside, green land, industrial and commercial samples. The samples were characterized systematically using XRF and gamma-ray spectrometry with NaI (Tl) scintillation detector. The total average concentrations of heavy metals Ag, Sn, Sb, I, Hf, W, Th and U in the soil were 1.94, 3.13, 3.01, 2.82, 1.70, 72,5.66 and 0.85 ppm respectively. Heavy metals Sn, I and W appeared with high concentrations among the others as shown in total average, compared with the standard. The enrichment with Sn elements strictly appeared in green and commercial lands with an average 3.63 ppm, whereas I and W concentrated in industrial land 3.0 and 0.95 ppm respectively, indicating anthropogenic rather than autogenic. It was asserted that the observed elements can be used as pollution indicators to discover the state of the contamination. The EF values of the soils in some sites displayed enrichment with Sb and moderate with Ag reflected mild enrichment (EF > 2), confirming their level of pollution by the hazardous heavy metals. The contents of ^{238}U, ^{232}Th and ^{40}K in the samples varied from 34.64-48.54, 47.22-67.73, and 323.27-585.11 Bq/kg, respectively. The mean activities of ^{238}U, ^{232}Th and ^{40}K in the dry weight samples were correspondingly 41.25, 56.89, and 424.12 Bq/kg, which were higher than the global averages of 35, 30 and 400 Bq/kg, respectively. The radium equivalent levels in all samples were much lower than the global average (370 Bq/kg). In addition, all external and internal hazard indices were within the recommended limit. The average dose rate and gamma index levels were greater than the global average value.

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INTRODUCTION

Environmental pollution by heavy metals is a common problem worldwide because these metals are stable and toxic, with adverse impacts on the living system once the acceptable absorption stages are surpassed (Bashir et al., 2014).

Heavy metals cause serious hazards due to their toxicity, persistence, and non-degradability in the environment (Morin et al., 2008), With the fast industrial and economic growth, heavy metals appeared as a residual in the land use deposits emerged via numerous trails such as irrigation, streams, runoff and atmospheric statements. Generally, the land used deposits act as the final basin for heavy metal in the surrounding areas (Banat et al., 2005).

In the case of Mesopotamian (Iraq), the land's usage majorly contributed to the accumulation of several heavy metals that originated naturally as well as anthropogenic means. Statistical deposits catalogues that it is established that the sediments and soils in the Mesopotamian (Iraq)

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*Corresponding Author Email: *zsaleem@uowasit.edu.iq* are contaminated by major heavy metals like lead (Pb) and cadmium (Cd) in addition to minor ones such as nickel (Ni), zinc (Zn) and copper (Cu). Meanwhile, the deposits of the Tigris River are unpolluted by other heavy metals (Mayyahi, & Al-Zamili, 2019)

In this study, the land uses were identified as urban areas like the biggest districts of the Southeast-Baghdad in central Iraq including roadside, industrial, commercial, and green land soils and identify of various heavy metals especially near the factories. Conversely, the areas having green soil were used to produce crops. Industrial wastes considers the main contributors of heavy metals in the soil (Manta et al., 2002). Constant accumulation of heavy metals in the cultivation of soils may enhance the metal content in the vegetables, thus increasing human health hazards (Chen et al., 2011). Awadh (2009) concluded the anthropogenic activities in Baghdad City are the major responsible cause of pollution.

Precipitates of the streets are accumulated on their edges, where heavy metal appear in the soils as a result of pollutants that release by vehicles, especially when the high density of the traffic (Awadh, 2015). Road dust composition and quantity can be indicate to the environmental pollution (Banerjee 2003). Ahmed and Ishiga (2006) and Al-Khashman (2007), showed that the main sources of the polluted Road dust are vehicular emission, oil burning and industrial plants. To determine the geochemical trends of various land soils and make a comparative evaluation regarding the occurrences of various heavy metals a quantity called the enrichment factor (EF) is measured (Sinex & Helz, 1981). Living systems are always at risk due to the exposure to ambient ionizing radiation from ^{40}K, ^{238}U series and ^{232}Th series in addition to their decay products that broadly extend to the land(Damla et al., 2011)**.**The goal of the search is**,** environmental geochemistry valuation and Distribution of heavy metals and radio activity of ^{40}K, ^{238}U series and ^{232}Th series in urban subsurface soil Landscape in southeast-Baghdad/ Mid-Mesopotamian

MATERIALS AND METHODS

Methods included soil samples collection, preparation, and characterization from used lands.

In this work, mid-Mesopotamian region in the central part of Iraq (southeast-Baghdad) was selected which was located between N 32° 30′ 19.89″, 32° 29′ 35.967″, and E 45° 40′ 12.4″ 55° 50.1′ 16″. A total of seventeen soil samples were collected during the dry season (in 2021) from a depth of 50-100 cm and analyzed. The GPS was used to set the locations of samples as shown in Figure 1. Table 1 list the details of the collected subsurface soils.

These samples, were chosen from different land uses spread over all locations as indicated (green spaces, urban, industrial uncultivated, and land roadside). Generally, the soil from the used land was collected using a stainless-steel hand corer and stored in the clear plastic bags of 5 kg each before being transferred to the laboratory for further drying, testing, and analyses.

The collected soil samples were dried in a chamber at a fixed temperature and homogenized using an agate grout before being sieved. For the geochemical analyses of various trace elements, The XRF method was used to detect and quantify the heavy metals present in the soil samples. This done at German Laboratory Spectra, Germany 2010 depends on (Ene et al., 2009). Radiological examinees: One kilogram of the sample was sent to the test center of the Ministry of Environment to detect the radiation level. Physical modeling was achieved on the models via removing impurities and then drying wet samples by standard methods of modeling. The system efficiency using a Gamma Spectrometer System based tall purity germanium detector with an effecter of 30% and resolution 2Kev at the energy line 1.33Mev energy-to-peer Co-60 depend on (Amana et al., 2021).

Software-based Analyses

The values of EF for the heavy metals as toxic wastes in the soils were calculated using the

Table 1. Details of soil samples, land uses types, and site coordinates.

Sample No.	Land uses	Locations	
		E	N
O1	Open spaces	45° 42′ 30′′	32° 32′ 34′′
O2	Open spaces	45° 50′ 25′′	32° 34′ 02′′
O3	Open spaces	45° 44′ 53′′	32° 32′ 0′′
R4	Roadside	45° 45′ 00′′	32° 32′ 10′′
R5	Roadside	45° 48′ 10′′	32° 32′ 20′′
R6	Roadside	45° 50′ 00′′	32° 32′ 40′′
G7	Green land	45° 45′ 25′′	32° 30′ 10′′
G8	Green land	45° 45′ 28′′	32° 30′ 25′′
I-9	Industrial	45° 45′ 35′′	32° 30′ 30′′
I-10	Industrial	45° 45′ 40′′	32° 30′ 40′′
I-11	Industrial	45° 45′ 45′′	32° 26′ 04′′
I-13	Industrial	45° 45′ 48′′	32° 26′ 10′′
I-13	Industrial	45° 45′ 55′′	32° 26′ 20′′
I-14	Industrial	45° 50 ′ 05′′	32° 26′ 28′′
I-15	Industrial	45° 51′ 45′′	32° 26′ 35′′
C16	Commercial	45° 52′ 48′′	32° 26′ 42′′
C17	Commercial	45° 52′ 50′′	32° 26′ 50′′

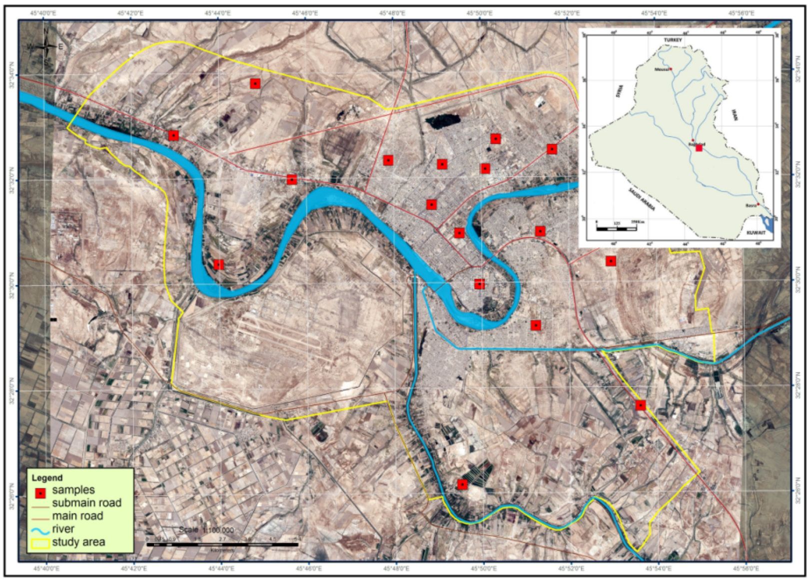

Fig. 1. Location and sampling map of the study area

expression (Swennen &Van Damme, 2000):

$$EF=[C_{metal}/C_{normalize}]soil\ /[C_{metal}/C_{normalize}]\ control \quad (1)$$

C_{metal} and $C_{normalizer}$ are the concentrations of heavy metals and regular ones in contaminated sediment and uncontaminated control specimen. The values of EF were used to differentiate between the metals originating from the anthropogenic happenings and natural processes, thus assessing the degree of anthropogenic influence. Based on the values of EF, pollution is categorized into 5 classes (Sutherland, 2000) wherein, EF less than 2 signifies a deficiency to minimal enrichment, EF in the range of 2 to 5 is called moderate enrichment, EF in the range of 5 to 20 denotes a significant enrichment, EF in the range of 20 to 40 characterizes very high enrichment, and EF above 40 indicates extremely high enrichment. The impacts of the anthropogenic origins upsurge with the increase of EF values(Sutherland, 2000) . The concentrations (in Bq /kg) of ^{238}U, ^{232}Th series, and ^{40}K in the tested soil samples were evaluated using the following expression (Al-Gazaly et al., 2014):

$$\mathrm{Ac}=Ca/(\,\varepsilon\, P\gamma\ Ms) \tag{2}$$

where A_C, Ca, ε, Pγ, and Ms are the activity concentration of each sample, energy counting rate per second, detector efficiency, absolute emission probability of γ-ray and sample weight (kg).

Radium equivalent activity (Ra-eq(due to the existence of irregular radionuclides distribution in the soils and sediments as well as the radiation exposure hazards of the soil cannot be evaluated from the effective dose only. To determine the exposure risks due to radioactivity, the hazards related to all primitive radionuclides like ^{238}U, ^{232}Th and ^{40}K must be considered, yielding the radium equivalent (Bq/Kg) (Shams, 2013). The radium equivalent was obtained via (Salama & Hassan, 2019):

$$\mathrm{Ra-eq}= ARa\ +\ 1.43\,ATh\ +\ 0.077AK \tag{3}$$

where A_{Ra}, A_{Th} and A_K are the corresponding activity concentrations of ^{238}U, ^{232}Th and ^{40}K.

The values of internal and external hazard indices that correspond to the extreme equivalent exposure of radium must be below unity to keep the minimum level of the radiation hazard which. Internal exposure to radon alpha particles absorbed through structure materials can cause harm to the respiratory organs. According to the International Atomic Energy Agency recommendation, the radiation dose limit must be less than 1mSv/y (Guidebook, 1989). These indices for the studied solid samples were evaluated using (Kabata-Pendias & Szteke, 2015):

$$H_{ex} = \mathrm{ARa}/370\ +\ \mathrm{ATh}/259\ +\ \mathrm{AK}/4810\ \leq\ 1 \tag{4}$$

$$H_{in} = \mathrm{ARa}/185\ +\ \mathrm{ATh}/259\ +\ \mathrm{AK}/4810\ <\ 1 \tag{5}$$

The absorbed dose (D) can be calculated using the following formula:

$$\mathrm{D}= 0.462\ \mathrm{ARa} + 0.604\ \mathrm{ATh} + 0.0417\mathrm{AK} \tag{6}$$

Where D is the dose rate at 1 m above the ground, and A_{Ra}, A_{Th} and A_K are the activity concentrations (Bq/kg) of ^{238}U, ^{232}Th and ^{40}K, respectively, in the soil sample (Diab et al., 2008). Also, Gamma index (Iγ). Another radiation risk index, the Iγ representative level index, is determined from the following formula (NEA-OECD (1979).

$$I\gamma = \frac{ARa}{150} + \frac{ATh}{100} + \frac{AK}{1500} \tag{7}$$

Where A_{Ra}, A_{Th}, and A_K as defined in the equation above.

RESULTS AND DISCUSSION

In this study, the obtained heavy metals concentration in ppm in the subsurface soil samples were listed in Table 2.

The results of the geochemical and environmental concentrations of the heavy metals and their behavior in the subsurface soils are presented in terms EFs, and the natural activities of ^{238}U, ^{232}Th, and ^{40}K in the used soils and deposits were expressed in terms of the radium equivalent, external and internal hazard indices.

The geochemical analyses of the studied subsurface soil samples showed a heterogeneous distribution of the heavy metals such as Ag, Sn, Sb, I, Hf, W, Th and U, which may be due to the irregular human activities connected to industries, agricultures, irrigations and businesses in the Urban areas that use large land areas.

Figure 2 displays the average concentration of the heavy metals in the subsurface soils of the samples collected from different land used such as open space, roadside, green land, industrial and commercial land. Generally, the heavy metals Sn, I and W appeared with high concentrations among the others as showed in total average (T.Av.) in table 2, compared with the standard of Kabata-Pendias & Szteke (2015) and Ali & Khan(2019).

The enrichment with Sn elements strictly appeared in green and commercial lands with an average (3.63 ppm), whereas I and W concentrated in industrial land (3.0 and 0.95 ppm) respectively. The contamination with Sn, I and W could be resulted from the anthropogenic sources such as solid and liquid wastes from the industries also, the absorption of the heavy metals into the soils surface layer might have emerged from the anthropogenic urban wastes, green spaces, and industrialized activities in Iraq thus leading to the pollution of Mesopotamian

Table 2. Concentration in ppm of identified heavy metals in the subsurface soil samples compared with the standard of (Kabata-Pendias & Szteke, 2015) *, and (Ali & Khan 2019)**. Av.O= Average of open space samples, Av.R= Average of Road side samples, Av.G= Average of Greenland samples, Av.I= Average of industrial samples and Av.C= Average of commercial samples

Sample no.	Land use	Ag	Sn	Sb	I	Hf	W	Th	U
		ppm							
O1	Open space	2.3	1.41	3.01	3	2.3	1.03	5.2	0.5
O2		2	3.65	3.01	1.3	1	1.03	6.2	1
O3		2	2.06	3.01	1.1	2.1	1.03	6.1	1
Av. O		2.10	2.37	3.01	1.80	1.80	1.03	5.83	0.83
R4	Road side	2	4.22	3.01	3	1.2	4.04	6.6	0.6
R5		2	3.65	3.01	1.3	1.6	1.27	6.3	1
R6		2	1.59	3.01	3	1	1.03	4.3	1
Av.R		2	3.15	3.01	2.43	1.27	2.11	5.7	0.87
G7	Greenland	2	3.65	3.01	3	1.6	1.27	5.7	0.7
G8		2	3.65	3.01	3	2.8	1.03	5.4	1
Av.G		2	3.63	3.01	3	2.2	1.15	5.55	0.85
I-9	Industrial land	2	3.65	3.01	7.1	2.5	1.11	5.8	1
I-10		2	3.65	3.01	3	1.3	1.03	4.8	1
I-11		2	3.65	3.01	2	1.2	1.27	6.3	0.4
I-12		2	0.56	3.01	3	1.2	1.03	5.5	1
I-13		2	3.65	3.01	3	1	1.03	5.9	1
I-14		2	3.28	3.01	3	1	26.3	5.2	1
I-15		2	3.65	3.01	2.1	2.3	1.03	5.7	0.6
Av.I		2	3.16	3.01	3.31	1.5	4.7	5.6	0.86
C16	Commercial	2	3.65	3.01	3	3	0.87	5.3	1
C17		0.7	3.6	3	3	1.8	1.03	6	0.7
Av.C		1.35	3.63	3.01	3.00	2.40	0.95	5.65	0.85
T. Av.		1.94	3.13	3.01	2.82	1.70	2.73	5.66	0.85
Standard*,**		3.4	1.7	4	2.8	3.3*	1.0*	7.6	3.7

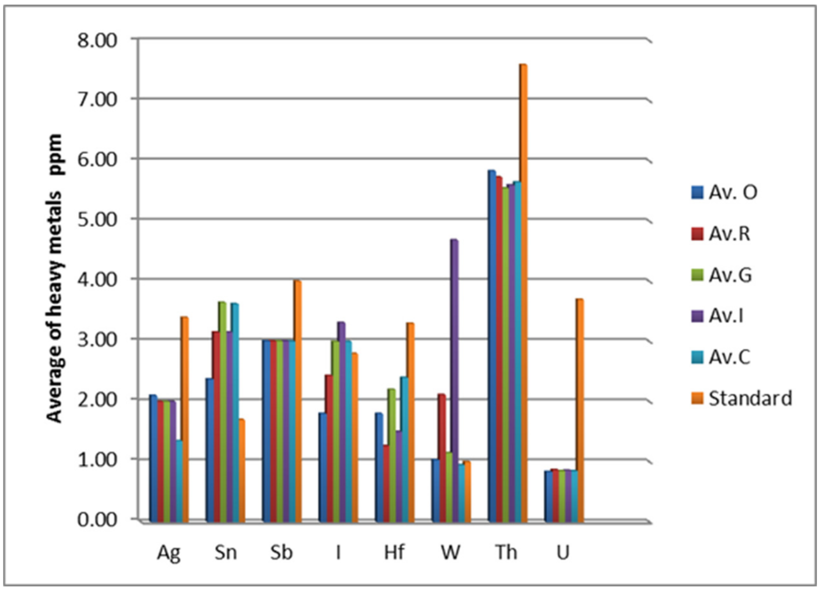

Fig. 2. The average of heavy metals distributed in different land use types O=Open space, R= Road side, G=Green land, I=Industrial and C=Commercial lands compared with standard of (Kabata-Pendias & Szteke, 2015) *, and (Ali & Khan 2019)**.

soils (Amana et al., 2021). The concentrations of Ag, Sb, Hf, Th and U in the subsurface soils were comparatively lower than the standard (Figure 2).

The deposition of Sn in the subsurface soils was due to the agricultural activities, uses of fertilizers, sludge of sewages and different types of phosphate wastes use to improve the fertility of the soils (Kabata-Pendias & Szteke, 2015).

In most of the geological situations, the oxidation state of U and Th are +4 and +6, respectively, affecting EEs of certain minerals associated to the apatite and sphene. Additionally, the mobility of Th and U through the weathering can considerably be governed by the abundance of these host minerals. Depending on the mobility, these elements are susceptible to precipitate or adsorbed as hydroxides, producing various organic complexes and stable compounds of oxides, carbonates, phosphates, vanities, and arsenates (Amana et al.,2021). As shown in Table 2, the maximum content of U in the soil samples was approximately 1 ppm which is consistent with the most recorded soils and parental rocks abundant of the elements. The predominance of I in the studied soils is positively linked to the clay contents and calcareous soils. Moreover, in calcareous minerals various factors such as clay, calcium exchangeable and biological carbon can vary with respect to their texture (Gerzabek et al., 1999).

The aerial depositions plus the biogenic concentrations affected the concentrations of I in the surface and subsurface soils. The high content of I (2.82ppm) in the present study matched with the one documented for the industrial soils. Based on the geochemical analysis can be asserted that the heavy metals in the studied soil samples were originated from the combined natural and anthropological activities. It is needless to mention that the mineralogy and chemistry of the soils are dynamical in nature, thus ever changing over time (Abed et al.,2015). The major minerals of silicates are the heavy metals which emerged due to the chemical weathering mainly through the hydrolysis process of the soils. With changes of the environment and geological epoch the concentrations of the heavy metals in the soils are altered (Al-Bassam, 1980).

Environmental enrichment assessment (Enrichment Factor (EF)

The values of the enrichment factors provide valuable information regarding the geochemical

Table 3. Average values of EF and pollution levels due to heavy metals in the subsurface soil samples.

Samples	Ag	Sn	Sb	I	Hf	W	Th	U
O1	4.32	0.53	5.02	1.32	0.08	0.23	0.41	0.22
O2	5.03	1.04	6.73	0.65	0.10	0.30	0.64	0.59
O3	4.00	1.46	5.35	0.61	0.04	0.24	0.52	0.47
R4	4.44	1.62	5.94	0.68	0.07	0.33	0.58	0.52
R5	4.41	0.70	5.90	1.56	0.04	0.27	0.40	0.52
R6	5.44	2.29	7.28	1.92	0.06	1.29	0.75	0.38
G7	4.22	1.54	5.64	1.49	0.11	0.26	0.47	0.50
G8	4.16	1.52	5.57	1.47	0.06	0.31	0.49	0.34
I-9	5.78	2.11	7.73	4.82	0.14	0.38	0.70	0.68
I-10	4.57	1.67	6.12	1.08	0.05	0.34	0.60	0.22
I-11	9.04	0.51	12.09	3.19	0.10	0.55	1.04	1.06
I-12	3.67	1.34	4.91	1.30	0.04	0.22	0.45	0.43
I-13	4.51	1.65	6.04	1.11	0.10	0.27	0.54	0.32
I-14	4.05	1.33	5.42	1.43	0.04	6.26	0.44	0.48
I-15	4.28	1.56	5.73	1.51	0.05	0.26	0.43	0.50
C16	4.21	1.54	5.64	1.49	0.12	0.22	0.47	0.50
C17	1.65	1.70	6.30	1.67	0.08	0.29	0.59	0.39
Mean	4.66	1.42	6.55	1.72	0.08	0.97	0.58	0.49

Table 4. Mean values of EF and their category for the major heavy metals in the studied soils

Heavy metals	Mean	EF Category
Silver (Ag)	4.66	Moderate enrichment
Tin (Sn)	1.42	Deficiency to minimal enrichment
Antimony (Sb)	6.55	Significant Enrichment
Iodine (I)	1.72	Deficiency to minimal enrichment
Hafnium (Hf)	0.08	Deficiency to minimal enrichment
Tungsten (W)	0.97	Deficiency to minimal enrichment
Thorium (Th)	0.58	Deficiency to minimal enrichment
Uranium (U)	0.49	Deficiency to minimal enrichment

trends, enabling a comparison amongst soil qualities collected from different areas (Sinex & Helz, 1981). Table 3 summarizes the obtained EF values depend on the expression (1) of Swennen and Van Damme (2010), where is categories of various heavy metals present in the subsurface soil samples (Table 4) explain the Worldwide range value of EF depend on (Sutherland, 2000).The studied subsurface soils were found to be enriched with the elements Ag, and Sb, indicating their considerable enrichment with Sb and moderate enrichment with Ag. The EF values of the soils in some sites displayed mild enrichment (EF > 2), confirming their level of pollution by the hazardous heavy metals. Subsurface soil samples were deficient in minimal enrichment with, Sn, I, Hf, W, Th and U.

The upper peak indicated the soils enrichment with Sb followed by relatively low amount of Ag (Figure 3). The obtained pollution of the soils was mainly caused by the urban activities connected to agricultures, industries, businesses, and residences.

Natural Activity in the Used Land

The concentrations of the radioactive elements ^{238}U (^{226}Ra), ^{232}Th (^{228}Ra) (actinium), and ^{40}K were measured and shown in Table5. Elements like ^{226}Ra and ^{232}Th revealed the highest activity concentrations of 48.54 ,67.73, and 585.11Bq/kg, in the sample No. I-14for (238U, 232Th)

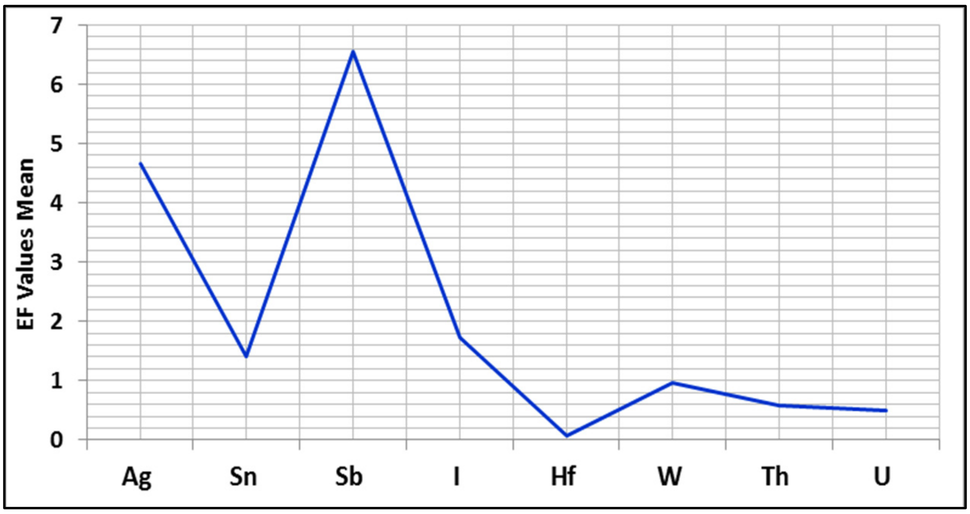

Fig. 3. Variation of EF against different heavy metals.

and sample No. I-13 for K-40 respectively. According to international standards, the average concentration of Ra, Th and K on the earth crust are correspondingly about 35, 30and 400 Bq/kg (Mehra, 2011) wherein the background radioactivity on earth is interrelated with the types of rocks. Higher contents of these radioactive elements are associated to phosphate and granite rocks (Abbady, 2005)**.** A study was made to determine the contents of Ra, Th and K exist in the calc-silicate rocks (Santos et al.,2010),wherein a geochemical evaluation of various heavy metals and natural activities in the used land deposits at the central and mid-Mesopotamian region was performed.

The samples C17 and G8 exhibited the lowest values of ^{226}Ra and ^{232}Th activity concentrations of 34.64 and 47.22 Bq/kg, respectively. The sample R6 and I-13 displayed the corresponding lowest (323.27 Bq/kg) and highest (585.11 Bq/kg) activity concentrations of ^{40}K (Table 5). The activity concentrations of the elements ^{238}U, ^{232}Th, and ^{40}K in the lands were observed to vary considerably in the studied areas which can be ascribed to the alterations of soil mineral compositions due to geological factors (Kumar, 2017). In brief, all soil samples displayed appreciably lower radium levels than the world average (370 Bq/kg), indicating their external, and internal hazard indices within the safety limit (Table 5). Furthermore, the values of radium equivalent ranged from 130.40 to 177.95 Bq/kg with a mean value of 155.73 Bq/kg, confirming their occurrence below the recommended maximum level of 370 Bq/kg (IAEA, 1989). Table (5) displays the estimated absorbed gamma dose rates (D), which range from 59.45 nGyh at the C17 site to 81.04 nGyh at the O2 site. It had a mean of 71.35nGyh. The required worldwide mean value of 60 nGyh' was exceeded by median dose rates (UNSCEAR, 2000). There is a variation in the values of the radioactivity level indicators in last column in Table (5) from 0.94 at site (C17) to 1.28 at site (O2), with an average of 1.131 for all values above a maximum of one (Alam et al., 1999) except for sample C17. As a result of these findings, there is a high level of radiation danger and potential threats to human health.

For human safety, the radiological hazard indicator should be below unity for achieving an acceptable radium dose equivalent of 370 (Bq/Kg). In this regard, internal radiation exposure is the main reason for lung diseases. The values of internal hazard index can vary in the range of 0.44 and 0.61 with a mean value of 0.53 (Figure 4). In this study, the obtained hazard indices of all soil samples were below unity, confirming their acceptability without causing any health hazard (Orgun et al., 2007).

Table 5. Activity concentrations, Radium equivalent, Internal (H_{in}) and External (H_{ex}) hazard indices, Dose rates, and Gamma index

Samples No.	Activity Concentration (Bq/Kg)			Ra_{eq}	H_{in}	H_{ex}	D(nGy/h)	Iγ
	U-238	Th-232	K-40					
O1	44.57	57.95	395.35	157.88	0.54	0.44	72.07	1.14
O2	47.32	61.47	528.92	175.94	0.60	0.49	81.04	1.28
O3	39.34	62.32	417.2	160.58	0.54	0.45	73.21	1.16
R4	38.27	51.04	435.77	144.81	0.49	0.40	66.68	1.05
R5	42.68	58.23	437.73	159.65	0.54	0.44	73.14	1.15
R6	41.85	56.01	323.27	146.83	0.50	0.40	66.64	1.05
G7	37.64	49.88	379.92	138.22	0.47	0.38	63.35	1.00
G8	36.57	47.22	428.72	137.10	0.46	0.38	63.29	1.00
I-9	40.83	56.01	457.46	156.14	0.53	0.43	71.76	1.13
I-10	43.56	54.79	355.21	149.26	0.52	0.41	68.03	1.07
I-11	42.13	57.54	515.23	164.08	0.55	0.45	75.70	1.19
I-12	39.34	65.76	410.86	165.01	0.55	0.45	75.02	1.19
I-13	38.75	62.66	585.11	173.40	0.57	0.48	80.14	1.27
I-14	48.54	67.73	422.88	177.95	0.61	0.49	80.96	1.28
I-15	43.83	52.51	520.65	159.00	0.54	0.44	73.67	1.16
C16	41.46	56.79	369.48	151.11	0.52	0.41	68.86	1.09
C17	34.64	49.35	327.26	130.40	0.44	0.36	59.45	0.94
Min.	34.64	47.22	323.27	130.40	0.44	0.36	59.45	0.94
Max.	48.54	67.73	585.11	177.95	0.61	0.49	81.04	1.28
Ave.	41.25	56.89	424.12	155.73	0.53	0.43	71.35	1.131
World Limit	35	30	400	370	>1	>1	60	1

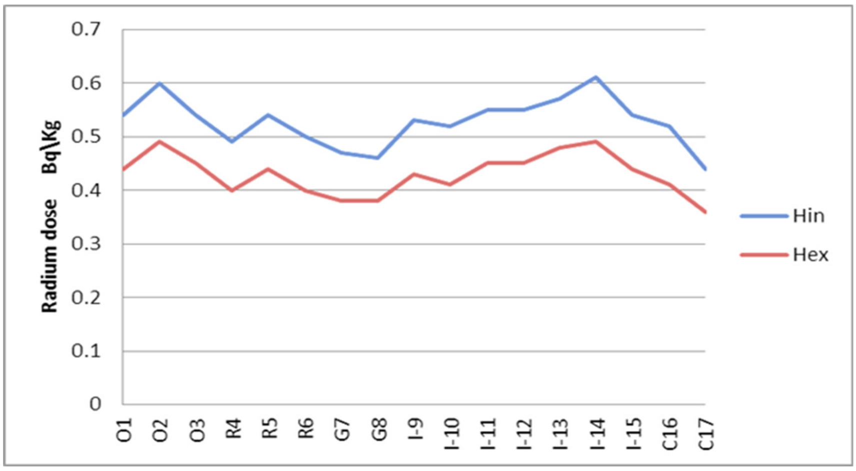

Fig. 4. External and enteral index levels in studied subsurface soil samples. Hin (internal hazard), Hex (external hazard).

CONCLUSION

1. The mean concentrations of the heavy metals in the soils followed the trend of Th > W > Sn > = Sb= I= Ag > Hf > U
2. > Ti. The geochemical analysis of the mean concentrations showed a positive correlation among these elements, suggesting their common origin from the parent rocks and human activities (agricultures, irrigation, business, industries, and residences).
3. Heavy metals Sn, I and W appeared with high concentrations among the others, compared

with the standard. The enrichment with Sn elements strictly appeared in green and commercial lands, whereas I and W concentrated in industrial land, indicating an anthropogenic activity rather than autogenic

4. Various heavy metals in the soil samples showed a moderately homogenous distribution with high contents of Ag and Sb and low enrichments of other elements which indicated different anthropogenic activities. These elements were used as pollution indicators and their hazard indices were calculated.
5. The obtained EF values of the soils shown enrichment with Sb and moderate with Ag and displayed an anthropoid impact and various heavy metals mobility in the soil
6. The mean activities of ^{238}U, ^{232}Th, and ^{40}K were higher than the global averages. Radium equivalent levels of all samples were much lower than global mean levels. The external and internal hazard indices of the soil samples were both below the acceptable limit, suggesting they are safe to settle in. Also, the arithmetic mean of the soil samples is over the upper limit of dose rate and gamma index indicating their safety for human settlements.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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