Assessment of Radiation Levels and Geochemical Factors in Iraqi Soil

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Abstract

Radiation exposure related human hazards and environmental pollution caused by the natural and manmade radioactive materials needs inhibition. An accurate evaluation of the radiation levels and geochemical factors of soil play a vital role. In this perception, γ-ray spectroscopy with NaI (Tl) luminescence detector was used to assess the natural radioactivity level and associated radiological risk due to contaminated surface soil (33 samples) collected from the Waist province of Iraq. Compared to the stipulated global average, about 64% and 15% of the samples showed higher radioactivity concentration of ^{226}Ra and ^{40}K, respectively, whereas for 232Th it was lower. Furthermore, the statistical guides of the geo-accumulation and contamination factors were used to calculate the pollution levels in the soil samples. The geochemical factors for some polluting heavy metals (Ge, Se, Ag, Sn, Sb, Te, I, Ce, Hf, W, Hg, Ti, and Bi) in the samples revealed wide variation. The contamination factor and I-Geo-accumulation catalogues of the samples exhibited the pollution level fluctuations from very high (Hg of 1.88 ppm) to very low (W of 1.33 ppm, U of 1.87 ppm, Sn of 3.8 ppm, Sb of 2.99 ppm, Ti of 0.66 ppm and Ag of 1.92 ppm, Bi of 1 ppm) to moderate Se of 0.53 ppm, Hf of 1.81 ppm and I of 3.19 ppm). It was asserted that the observed intense adsorption of some specific metals on the surface soils was due to the natural sources in the clays and heavy minerals originated from the carbonates. Such heavy elements could move into the minerals structure of the surface soils from the anthropogenic urban wastes, agricultural and industrial activities.

Key Words: Radiation, Exposure, Pollution Level, Radiological Risk, Geochemical Factors.

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Introduction

Primarily, the natural radioactivity levels are decided by the complex environmental conditions and factors (both geology and geography), in which the surface soil compositions play a significant role (Manigandan *et al*, 2014). In fact, the uppermost layers of the surface soil are the main sources of the radiation exposure to human wherein the radionuclide of ^{238}U, ^{232}Th, and ^{40}K contribute predominantly. The γ-radiation exposure from such natural radioactive elements is substantially hazardous for the human body. In addition, the radon inhalation from the decay products of these radionuclide play a major role (Kapanadze *et al*, 2019).

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Being the primary part of the environment surface soil is continuously exposed and polluted through various harmful and radioactive materials, resulting from continuous urban expansion, growing agricultural activities, industrialization and economic advancements (Kolo *et al* , 2015). In the environment of earth, the natural radioactivity arises from different sources including the crust, rock, soil, plants, water and air wherein various radioactive elements enter into the soil through rain water and flow due to the disintegration of the rocks via the natural processes (Taskin *et al*, 2009). Intensive investigations in recent times revealed the link of radioactivity levels of the natural radionuclide's in the groundwater with the activity concentrations of uranium (U) and thorium (Th) as well as their decay products exist in the soil and rock layers worldwide. Depending on their mineralogy and geochemical compositions of the soils and bedrocks, their continual chemical reactions with water are responsible for the release of various dissolved components into the ecosystem (Vesterbacka, 2007). Some studies showed that the radioactive concentration of U is lowest in Poland (0.79 mg/kg) and highest in the United States (3.70 mg/kg). The observed high level of U in the soil is due multiple factors including the excessive fossil fuel burning in the power plants, discharge of nuclear wastes and fertilizers production (Kabata-Pendias *et al*, 2015). Soil is the significant parts of the ecosystem wherein the water, rocks and air coexist at the interface, thereby constantly exposed to several polluting agents arise from diverse anthropogenic activities.

Over the years, pollution assessment related to the heavy metals distribution in the soil have intensively been focused due to their serious concern and various hazards to the health of human, plants, animals and agricultures (Awadh, *et al*, 2015). Heavy metals such as Ge, Se, Ag, Sn, Sb, Te, I, La, Ce, Hf, W, Hg, Ti, and Bi penetrate into the ecosystem via the natural and anthropogenic means (Mbah *et al*, 2010). The main sources of the heavy metals in the soil from the anthropogenic activities are due to the excess use of commercial agrochemicals (fertilizers), irrigation waters, liming and other components utilized for the soil modification as well as decomposition or degradation of the atmosphere (Akoto *et al*, 2008). Various methods have been used to assess the heavy metals enrichment in the in the surface soils and bedrock wherein the geo-accumulation (I-geo) indexes are used as the quick tool for comparing the pollution levels at different locations (Al-Hejuje *et al*, 2018).

Depending on the sedimentation of the dominant local conditions related to the climatic and geological changes, the surface soils in Iraq display different degrees of development especially in the Wasit Province expanded over an area of 17.153 km^2 (Muslim *et al*, 2019). A study revealed that the soil in the Waist Governorate contains appreciable amounts of chemicals and organics (Hussein, 2016). The characterization of the soil texture showed a variation in the vertical and horizontal directions with the predominance of the sandy loam texture. In addition, the soil contamination consisted of various persistent toxic elements/compounds, chemicals, organic/inorganic salts, radioactive elements/materials and chemical agents that cause diseases. All these polluting agents have unfavourable/undesirable impacts on the ecosystems especially the health of animals and growth of plants (Saggini *et al*, 2017). Based on this factor, we assessed the radioactivity concentration of ^{238}U, ^{232}Th, and ^{40}K, contamination factors (CF) and I-geo indexes in 33 surface soil samples obtained from the Waist province of Iraq. The γ-ray spectroscopy with NaI (Tl) luminescence detector was used to measure the natural radioactivity level and associated radiological risk due to the contamination in the surface soil samples.

Geological Setting

Figure 1 illustrates the satellite map of the Wasit Province of Iraq. This area is situated at the north-east of Iraq, consisting of high mountains and separating Iraq from Iran by the border. The other part of the Wasit Governorate is called Mesopotamian region that is mostly enclosed by the quaternary deposits. The old geological outcrops in the region belong to the Pliocene age that characterize Bai Hassan and Mukdadiya formations (Sissakian *et al,* 2015).

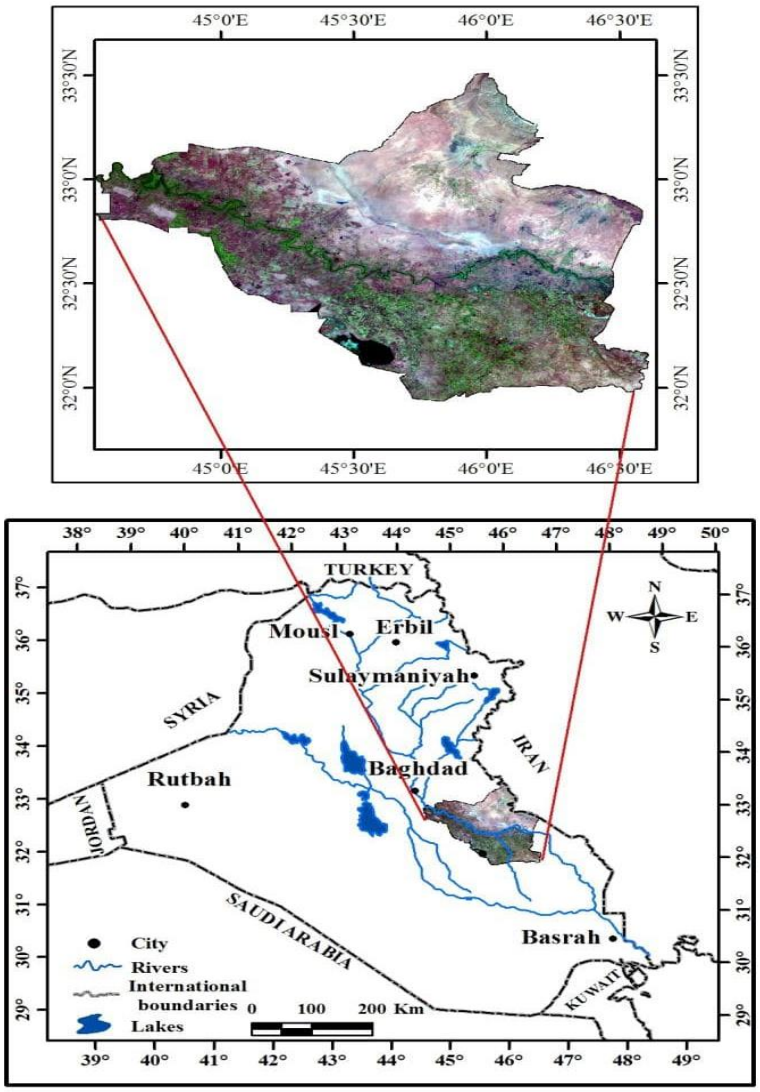

Figure 1. Local satellite map of the Wasit Province of Iraq

Materials and Methods

Studied Region

The coordinate of the Wasit region lies between (455275_650665E) and (3533292_3708312 N) with respect to the UTM coordinate system that is situated in the southern part of the central area of Iraq. The barmaid border crossing in Wasit connects Iraq and Iran. The climate of Wasit is dry (desert atmosphere) with average summer temperature above 40 ^{o}C. The rainfall is very rare and the winter is intense. This remote region is chosen for collection the surface soil samples for the present study.

Field and Sampling Works

A total of 33 stations within the Waist province were selected to collect the soil samples during the month of April, 2020. The samples were obtained using clean plastic scoop and stored in polyethylene bags purchased from the local market**.** The sites for the samples collection (Al Suwayra to Al Hayy city of Wasit) were carefully selected based on the large city distribution, population communities, industrial activities (thermal power plants) and agricultural lands (Figure 2). The characteristics of the soil samples (code and symbol) together with the site coordinates are shown in Table 1 and Figure 2. The geological formations and topographies of the chosen sites were detected through the field trips to get an in-depth understanding of the data. First, the soil samples were oven dried at 110 ^{o}C. Then, samples were crushed and sieved in 2 mm mesh sieve. Afterward, the samples were transferred to a 100 ml Marinelli beaker and sealed for approximately one month to achieve a secular equilibrium. Finally, the radioactivity of the samples was measured using the gamma ray spectrometer.

The activity concentration (A_C in the unit of Bq/kg) of ^{232}Th and ^{238}U was measured using the radioactive

nuclide of thallium (^{208}Tl), bismuth (^{214}Bi) and potassium (^{40}K) with the energy of 2614.511 KeV, 1764.539 KeV and 1460.822 KeV, respectively. The activity concentration of U-238, Th-232 series and K-40 in the soil samples were evaluated using the expression (Al-Gazaly *et al*, 2014):

$$A_C = C_a/\varepsilon P_\gamma \, M_S \qquad (1)$$

where C_a is the energy count rate per second, ε is the detector efficiency, P_γ is the probability of γ-ray emission and M_S is the sample weight in kilograms.

The absorbed dose in the air (DR in nGy/h) was calculated in terms of the terrestrial nuclides' concentrations at a distance of 1 meter above the ground surface via the relation (Hussein 2019; Kumar *et al, 2017).*

$$DR = 0.427A_{Ra} + A_{Th} + 0.043A_K \qquad (2)$$

where A_{Ra} is the specific activity of ^{226}R (U-238), A_{Th} is the specific activity of ^{232}Th (Th-232), and A_K is the specific activity of ^{40}K (K-40) in Bq/Kg.

The value of radium equivalent element concentration (Ra_{eq}) was used to evaluate the concentration risk of U-238, Th-232 and K-40 activity (Bq/Kg) via the expression (Amana, 2017; Aldhuhaibat *et al*, 2021):

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad (3)$$

Heavy elements pollution in the surface soil sample was assessed and the Geo-accumulation index (I-geo) was calculated using (Boszke *et al*, 2004):

$$I_{geo} = \ln(\frac{cn}{1.5Bn}) \qquad (4)$$

where cn denotes the measured concentration of heavy metals in the soil samples, Bn is the geochemical background (Sinex *et al,* 1981), factor 1.5 is used to indicate the probable changes of the background data due to the lithological differences. The values of I-geo were categorized into seven grades according to (Buccolieri *et al,* 2006). The concentration of heavy elements pollution in the surface soil sample was also assessed by the contamination factor CF index, CF was calculated as the following equation:

$$CF = Cmetal \,/\, Cbackground\ value \qquad (5)$$

Where $Cmetal\ is$ the element concentration in contaminated surface soil sample and $Cbackground\ value$ is the corresponding background value. The values of CF was categorized into 4 grades (Qingjie *et al*, 2008).

Table 1. Details of the soil samples with their codes, symbols, sites and site coordinates (A: Agriculture, B: Urban, C: Industrial, D: uncultivated and E: land Roadside).

Number of Sites	Site	Sample Code	Soil Symbol	Coordinates	
				E	N
1	Al Suwayra	SU.1	B	480421.8414	3641127.727
2		SU.2	A	479066.3141	3648435.86
3		SU.3	C	476483.6818	3644671.697
4	Taj Aldin	TJ.4	A	486552.6477	3658566.738
5		TJ.5	B	485403.0405	3649709.517
6		TJ.6	C	482196.1909	3654112.979
7	Al Aziziya	AZ.7	A	489509.3071	3645991.649
8		AZ.8	A	492232.1314	3646906.733
9		AZ.9	C	504416.9304	3642016.033
10	Al Zubaydia	ZD.10	C	508793.9744	3627587.783
11		ZD.11	C	512071.4413	3626571.577
12		ZD.12	D	514214.7962	3629082.091
13	Al Numaniya	NM.13	A	535404.9753	3606276.648
14		NM.14	C	539336.8817	3601725.874
15		NM.15	A	541964.5048	3601721.43
16	Al Ahrarr	AH.16	C	562293.3835	3596062.489
17		AH.17	C	551668.2042	3596893.957
18		AH.18	A	552426.3434	3576281.334
19	Al- kut	K.19	D	576113.0585	3604479.704
20		K.20	C	558039.5729	3606822.791
21		K.21	C	574302.1989	3613622.462
22		K.22	C	565847.6824	3622526.747
23		K.23	B	574948.3455	3601389.901
24	Badrah	BR.24	B	586715.234	3664125.089
25		BR.25	D	584586.5294	3666026.704
26	Jassa	JN.26	E	581053.4177	3648615.209
27		JN.27	E	582742.6197	3652552.909
28	AL Hayy	HY.28	C	595072.7068	3567835.297
29		HY.29	C	596279.3452	3565466.802
30		HY.30	B	598283.4833	3560624.11
31		HY.31	A	596091.0682	3552429.837
32	Muwafaqiya	MQ.32	B	586715.9772	3570881.462
33		MQ.33	B	589769.8106	3570467.686

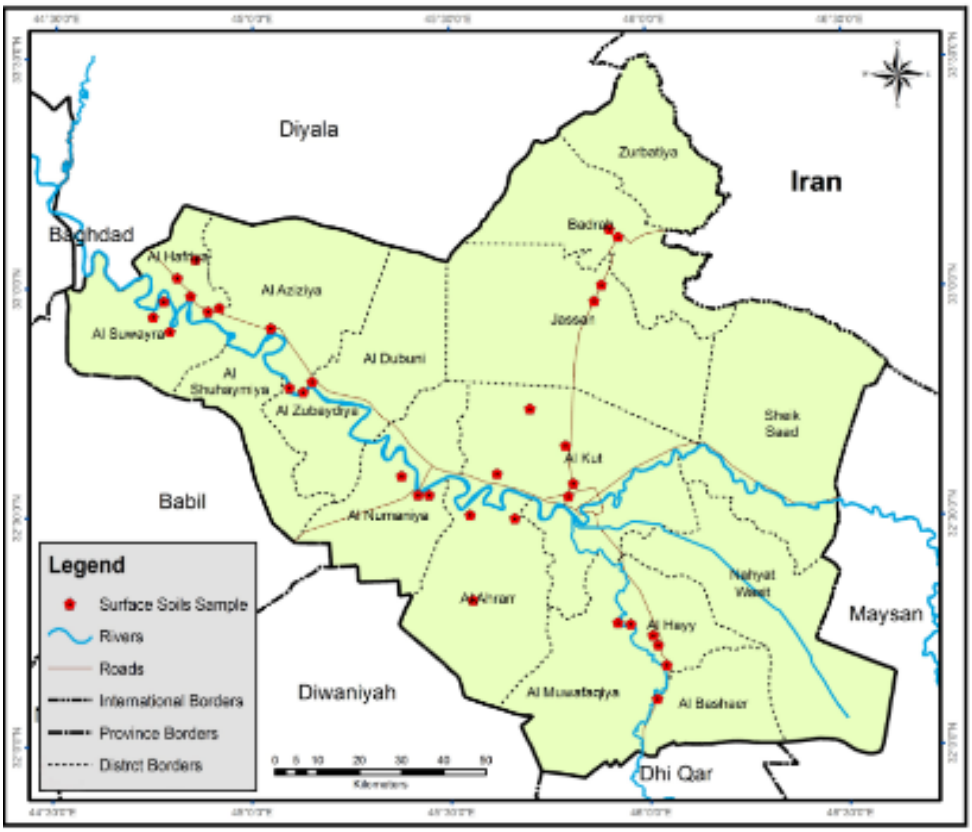

Figure 2. Selected sites (red dots) of the Waist province for the collection of surface soil samples

Results and Discussion

Measurement of ^{40}K, ^{232}Th and ^{238}U Radioactivity Concentration

Table 2 displays the measured activity concentrations of the radionuclide in the surface soil samples. The highest concentration for uranium-238 (^{236}U) with 43.62 Bq/kg that was observed in the Al NM.15 soil with the average value of 37.30 Bq/kg and the lowest one was 27.75 Bq/kg measured in the Al MQ.33 soil. The obtained mean value of ^{226}Ra in the soil was slightly higher compared to the world average of ^{238}U (35 Bq/kg) (El-Sayed *et al*, 2015). The difference in the activity concentrations measured at various sites may be because of the mineral contents' variations in the soil which can be attributed to the local geological changes. In addition, the detected radionuclide levels in the studied soil samples revealed significant variations which can be due to the alterations of the soil formations and textures in the region. For the thorium-232 series, the highest value of Radium-228 (29.26 Bq/kg) was detected in the JN.26 soil and the lowest (14.22 Bq/kg) was observed in the NM.14 soil with an average of 22.49 Bq/kg. According to (UNSCEAR, 2000) (Gregory *et al,* 2014), all measured values of the activity concentration were within the globally acceptable limit of 30 Bq/kg. For potassium-40, the lowest value (229.20 Bq/kg) was recorded in the JN.26 soil and the highest (720.65 Bq/kg) was found in the ZD.12 soil with an average of 346.73 Bq /kg, which was lower than the global average of 400 Bq/kg.

Some soil samples showed a relatively higher value of ^{40}K (Table 2) than the global average set by (UNSCEAR, 2000) (Gregory *et al,* 2014). The observed high concentration of ^{40}K can be attributed to the abundance of large amounts of clay deposits in the Wasit area, wherein large quantities of fertilizers enriched in potassium are used for the agricultural activities (Issa *et al,* 2013). In addition, the highest equivalent radium content was calculated to be 125.20 Bq/kg in sample No.12 and the lowest (74.31 Bq/kg) one was recorded in sample MQ.33 with the mean value of 96.17 Bq/kg. The radium content in all samples were below the global average (370 Bq/kg) reported in (UNSCEAR, 2000) (Lee *et al*, 2002). The estimated absorbed dose rate was ranged from 35.23 to 61.48 nGy/h, where the lowest dose rate was observed in MQ.33 sample whereas the highest one occurred in ZD.12 with the mean value of 45.66 nGy/h. In short, the measured values were lower than the reported world average (57 nGy/h) (Issa *et al,* 2013; Kapanadze *et al, 2019).*

Table 2. Values of activity concentration, radium equivalent and dose rate for the studied soil samples

Activity Concentration				Radium Equivalent	Dose Rate
Sample Code	^{238}U	^{232}Th	^{40}K	Ra_{eq}	**D nGy/h**
	Bq/kg				
SU.1	40.97	21.95	295.35	95.10	44.87
SU.2	39.37	20.32	317.20	92.86	44.04
SU.3	34.62	17.88	317.92	84.68	40.36
TJ.4	38.87	26.01	357.40	103.59	49.01
TJ.5	43.58	24.79	355.21	106.39	50.34
TJ.6	41.62	17.47	268.92	87.32	41.29
AZ.7	42.17	21.54	315.23	97.25	46.00
AZ.8	40.35	22.76	310.86	96.83	45.74
AZ.9	39.72	16.66	485.11	100.91	48.93
ZD.10	39.5	20.73	322.88	94.00	44.58
ZD.11	38.97	28.04	335.77	104.93	49.42
ZD.12	41.81	19.51	720.65	125.20	61.48
NM.13	42.51	24.79	339.48	104.11	49.19
NM.14	39.5	14.22	468.72	95.93	46.63
NM.15	43.62	27.23	337.73	108.57	51.15
AH.16	27.87	26.01	313.27	89.20	42.09
AH.17	34.62	22.35	320.26	91.25	43.23
AH.18	31.75	21.13	408.58	93.43	44.83
K.19	32.5	26.01	303.65	93.08	43.83
K.20	38.75	23.57	292.51	94.98	44.74
K.21	40.01	23.98	341.23	100.58	47.60
K.22	35.37	26.82	311.30	97.71	45.98
K.23	40.25	23.17	282.25	95.11	44.75
BR.24	28.75	17.47	468.75	89.83	43.68
BR.25	42.87	17.07	517.22	107.11	51.97
JN.26	40.25	29.26	229.20	99.75	46.32
JN.27	40.53	26.82	361.81	106.76	50.47
HY.28	29.01	22.76	329.00	86.89	41.25
HY.29	34.02	19.10	253.85	80.89	38.16
HY.30	33.87	21.54	278.09	86.09	40.62
HY.31	32.62	27.64	309.99	96.02	45.16
MQ.32	33.12	25.20	307.59	92.85	43.78
MQ.33	27.75	18.29	264.99	74.31	35.23
Ave.	37.30	22.49	346.73	96.17	45.66
Max.	43.62	29.26	720.65	125.20	61.48
Min.	27.75	14.22	229.20	74.31	35.23

Geochemical Indexes of Surface Soil Samples

The trace elements concentrations in the surface soil samples remain different conferring to their degree of particles sedimentation, number of heavy metals deposition, particles size and existence or absence of organic matter. Heavy metals including Ge, Ag, Sn, Se, Sb, Te, Ce, I, Hf, W, Hg, Ti and Bi were detected in the surface soil of Wasit. The amount of carbonate in the soil samples was recorded to be 33.8% and 5.25% for the dolomite (Muslim *et al*, 2019). Moreover, the concentrations of certain trace elements in the categories of the land use soil in the studied area (ppm) were assessed and presented in Table 3. The elemental concentrations of Th, Sn, and I were relatively higher among the fourteen heavy metals detected in the surface soil samples, while the contents of Se and Ge were the lowest (Figure 3). The presence of anthropogenic Sb was mainly due to the excess fossil fuel combustion (Media, no date). The Bi distribution in the soil was due to the agricultural activities, where fertilizers, sewage sludge and various types of phosphate waste solutions were exploited to enhance the soil fertility (Kabata-Pendias *et al*, 2007).

According to the measured geochemical indices the concentrations of U and Th were coherent which existed in the +4 and +6 oxidation states in most of the geological environment. These elements might have substituted for REEs in some minerals and connected to the apatite and sphene. General carriers of Th and Ce were the minerals of monazite and cheralite, respectively. The observed higher concentration of U were mainly emerged from the fossil fuel-based power plants, nuclear wastes, and P

fertilizer-related works (Kabata-Pendias *et al*, 2015). Additionally, Th and U mobility during the weathering could greatly depend on the abundance of these host minerals. Upon mobilization, these elements could be very liable to precipitate in the form of hydroxides or adsorb, thereby forming some organic complexes and varieties of stable compounds including oxide, carbonate, phosphate, vanities and arsenate. Highest value of U concentration was found in the JN.2 soil sample (Table 3)

Table 3. Detected heavy metals concentration in various soil samples (ppm)

Sample Code	Ge	Se	Ag	Sn	Sb	Te	I	Hf	W	Hg	Ti	Bi	Th	U
SU.1	0.5	0.3	2	4.97	3.01	3	3	1.7	0.6	1	0.2	1	5.4	1
SU.2	0.5	0.5	2	3.65	0.45	3	4	1	1.27	1	0.6	1	5	0.4
SU.3	0.7	0.5	2	9.39	5.23	2.9	8.2	1	1.03	1	0.9	1	4.4	1
TJ.4	0.3	0.5	1.2	3.65	3.01	3	2.9	1.5	2.46	1	1	1	6.4	0.6
TJ.5	0.2	0.5	2.7	2.34	3.01	3	3	3	1.03	1	1	1	6.1	1
TJ.6	0.5	0.5	2	3.65	3.01	3	3	1.2	1.03	1	1	1	4.3	1
AZ.7	0.2	0.5	2	3.65	3.01	3	3	2.8	1.03	1	0.2	1	5.3	1
AZ.8	0.3	0.5	2	2.72	3.01	3	3	2.3	1.18	1	1	1	5.6	0.4
AZ.9	0.2	0.5	2	3.65	3.01	3	3	1	1.03	1	1	1	4.1	1
ZD.10	0.5	0.3	2.4	3.65	3	3	3.5	1.6	1.03	1	0.1	1	5.1	1
ZD.11	0.5	0.5	0.3	3.65	3	3	2.8	1.4	1.19	1	0.4	1	6.9	0.6
ZD.12	0.2	1	2	3.65	3	3	3	1	1.03	1	1	1	4.8	1.5
NM.13	0.5	0.5	0.8	3.65	3	3	1.7	3.6	1.03	1	0.1	1	6.1	1
NM.14	0.2	0.5	2	5.71	0.6	3	3	1	1.03	1	0.2	1	3.5	0.4
NM.15	0.5	0.5	2	2.34	3	3	3	2	2.62	1	1	1	6.6	1
AH.16	0.3	0.5	0.7	3.65	3.01	3	3	1.3	1.27	1	0.2	1	6.4	1
AH.17	0.3	0.5	2	3.65	3.01	3	3	1	1.27	1	0.8	1	5.5	1.6
AH.18	0.5	0.6	2	3.65	3.01	3	3	1.7	1.03	1	1	1	5.2	0.7
K.19	0.3	0.5	2	3.65	3.01	3	0.6	1.9	1.19	1	0.6	1	6.4	0.6
K.20	0.3	0.5	2	3.65	3.01	3	7.1	2.5	1.11	1	0.4	1	5.8	1
k.21	0.4	0.5	2	0.56	3.01	3	3	1.2	1.03	1	0.1	1	5.5	1
k.22	0.5	0.5	2	3.65	3	3	3	1	1.03	1	1	1	5.9	1
k.23	0.5	0.5	2	4.22	3	3	3	1.2	4.04	1	0.6	1	6.6	0.6
BR.24	0.5	0.5	2	1.59	3.01	3	3	1	1.03	1	1	1	4.3	1
BR.25	0.5	0.7	2	3.65	3.01	3	3	1	1.27	1	1	1	4.2	1.9
JN.26	0.5	0.5	2	3.65	3.01	3	3	1	1.03	1	0.1	1	0.2	8.5
JN.27	0.5	0.5	2	5.53	3	3	1.4	1	1.03	1	1	1	1	10
HY.28	0.5	0.5	2	3.65	3	3	0.4	1	1.03	1	0.2	1	5.6	0.9
HY.29	0.5	0.8	2	3.65	3	3	3	1	0.71	1	1	1	4.7	1.8
HY.30	0.1	0.5	2	3.653	3	3	3	2.3	1.19	1	1	1	5.3	0.7
HY.31	0.2	0.5	2	3.279	3	3	3	2.3	1.03	1	1	1	6.8	0.6
MQ.32	0.2	0.5	2	3.65	3	3	3	1.2	1.27	1	1	1	6.2	1
MQ.33	0.5	0.5	3.4	3.65	3	3	4.6	2	1.03	1	0.2	1	4.5	1.2
Min.	0.1	0.3	0.3	0.56	0.45	2.9	0.4	1	0.6	1	0.1	1	0.2	0.4
Max.	0.7	1	3.4	9.39	5.23	3	8.2	3.6	4.04	1	1	1	6.9	10
Mean	0.39	0.53	1.92	3.80	2.92	2.99	3.19	1.61	1.31	1.00	0.66	1.00	5.05	1.67
B.G.			0.3 -3.4	0.6 - 1.7	0.05-4.0		2.8					0.42	6.1-7.6	2.3-3.7

The dispersion of some heavy metals in certain common minerals such as mica (7.23%) and feldspar (8.8%) in the Wasit region was reported (Muslim *et al,* 2019). The contents of these heavy metals in the clay fraction, organic matter as well as Fe and Mn sesquioxide could reduce their mobility and the migration rates (Gri *et al*, 2000). In the unpolluted sites, the presence of Sn in the soil samples was mainly due to the contents of the bedrocks that occurred at the background level. However, for the contaminated sites, the concentration of Sn was significantly higher (up to 1000 mg kg^{-1}) near the smelter regions (Schäfer *et al,* 1984). Briefly, the concentration of Sn in the Al Suwayra station was very high due to the presence of many industries and related pollution (Table 3).

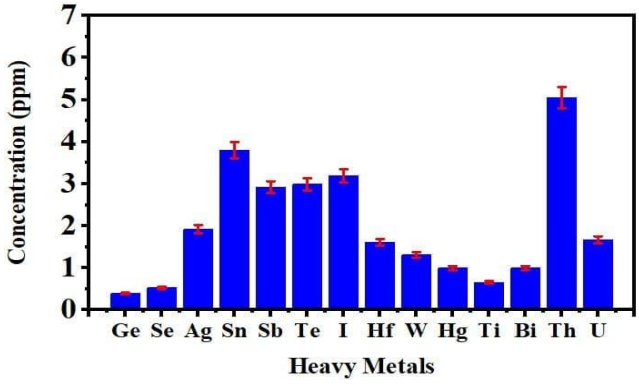

Figure 3. Relative abundance of heavy metals in the surface soils of Wasit province

Generally, the surface soil samples possess the same I value like the parent rocks. The aerial depositions and biogenic concentrations affect the accumulation on the surface and subsurface of the soil. The abundance of I in the soil indicates a correlation to the texture (Gerzabek *et al*, 1999) wherein a positive correlation is found only to the clay containing soil without any calcareous soils. In fact, the light soils in the humid climatic areas have low I, whereas the soils with high humus and clay have high I. In the current study, the high content of *I* (8.2 ppm) was recorded in the urban soils especially for the landfills areas (SU.7 sample in Table 4). Based on the interpretation of geochemistry it can be argued that the observed heavy metals in the studied soil samples were derived from both natural inputs and human activities (Abed *et al*, 2015).

Table 4 presents the values of CF for different heavy metals in the studied surface soils enrichment factors (*EF*), contamination factor (*CF*) and *I-geo.* The geo-accumulation indices were used to evaluate the radioactive metals contamination in the studied surface soil samples of the Wasit region. For better evaluation of the anthropogenic causes the input *CF was* measured and used to categorize the level of metals pollution of in the soil samples. The quotient was obtained by dividing every metal concentration (Table 4).

Table 4. Values of CF for different heavy metals in the studied surface soils

Heavy Metals														
Sample Code	**Ge**	**Se**	**Ag**	**Sn**	**Sb**	**Te**	**I**	**Hf**	**W**	**Hg**	**Ti**	**Bi**	**Th**	**U**
SU.1	0.20	0.30	5.00	2.48	6.69	0.75	1.76	1.70	0.19	10	0.20	0.67	0.56	0.59
SU.2	0.20	0.50	5.00	1.83	1.00	0.75	2.35	1.00	0.37	10	0.60	0.67	0.52	0.24
SU.3	0.28	0.50	5.00	4.68	11.71	0.73	4.82	1.00	0.30	10	0.90	0.67	0.46	0.59
TJ.4	0.12	0.50	3.00	1.83	6.69	0.75	1.71	1.50	0.72	10	1.00	0.67	0.67	0.35
TJ.5	0.08	0.50	6.75	1.17	6.69	0.75	1.76	3.00	0.30	10	1.00	0.67	0.64	0.59
TJ.6	0.20	0.50	5.00	1.83	6.69	0.75	1.76	1.20	0.30	10	1.00	0.67	0.45	0.59
AZ.7	0.08	0.50	5.00	1.83	6.69	0.75	1.76	2.80	0.30	10	0.20	0.67	0.55	0.59
AZ.8	0.12	0.50	5.00	1.36	6.69	0.75	1.76	2.30	0.35	10	1.00	0.67	0.58	0.24
AZ.9	0.08	0.50	5.00	1.83	6.69	0.75	1.76	1.00	0.30	10	1.00	0.67	0.43	0.59
ZD.10	0.20	0.30	6.00	1.83	6.69	0.75	2.06	1.60	0.30	10	0.10	0.67	0.53	0.59
ZD.11	0.20	0.50	0.75	1.83	6.69	0.75	1.65	1.40	0.35	10	0.40	0.67	0.72	0.35
ZD.12	0.08	1.00	5.00	1.83	6.69	0.75	1.76	1.00	0.30	10	1.00	0.67	0.50	0.88
NM.13	0.20	0.50	2.00	1.83	6.69	0.75	1.00	3.60	0.30	10	0.10	0.67	0.64	0.59
NM.14	0.08	0.50	5.00	2.86	1.34	0.75	1.76	1.00	0.30	10	0.20	0.67	0.36	0.24
NM.15	0.20	0.50	5.00	1.17	6.69	0.75	1.76	2.00	0.77	10	1.00	0.67	0.69	0.59
AH.16	0.12	0.50	1.75	1.83	6.69	0.75	1.76	1.30	0.37	10	0.20	0.67	0.67	0.59
AH.17	0.12	0.50	5.00	1.83	6.69	0.75	1.76	1.00	0.37	10	0.80	0.67	0.57	0.94
AH.18	0.20	0.60	5.00	1.83	6.69	0.75	1.76	1.70	0.30	10	1.00	0.67	0.54	0.41
K.19	0.12	0.50	5.00	1.83	6.69	0.75	0.35	1.90	0.35	10	0.60	0.67	0.67	0.35
K.20	0.12	0.50	5.00	1.83	6.69	0.75	4.18	2.50	0.33	10	0.40	0.67	0.60	0.59
k.21	0.16	0.50	5.00	0.28	6.69	0.75	1.76	1.20	0.30	10	0.10	0.67	0.57	0.59
k.22	0.20	0.50	5.00	1.83	6.69	0.75	1.76	1.00	0.30	10	1.00	0.67	0.61	0.59
k.23	0.20	0.50	5.00	2.11	6.69	0.75	1.76	1.20	1.19	10	0.60	0.67	0.69	0.35
BR.24	0.20	0.50	5.00	0.80	6.69	0.75	1.76	1.00	0.30	10	1.00	0.67	0.45	0.59
BR.25	0.20	0.70	5.00	1.83	6.69	0.75	1.76	1.00	0.37	10	1.00	0.67	0.44	1.12
JN.26	0.20	0.50	5.00	1.83	6.69	0.75	1.76	1.00	0.30	10	0.10	0.67	0.02	5.00
JN.27	0.20	0.50	5.00	2.76	6.69	0.75	0.82	1.00	0.30	10	1.00	0.67	0.10	5.88
HY.28	0.20	0.50	5.00	1.83	6.69	0.75	0.24	1.00	0.30	10	0.20	0.67	0.58	0.53
HY.29	0.20	0.80	5.00	1.83	6.69	0.75	1.76	1.00	0.21	10	1.00	0.67	0.49	1.06
HY.30	0.04	0.50	5.00	1.83	6.69	0.75	1.76	2.30	0.35	10	1.00	0.67	0.55	0.41
HY.31	0.08	0.50	5.00	1.64	6.69	0.75	1.76	2.30	0.30	10	1.00	0.67	0.71	0.35
MQ.32	0.08	0.50	5.00	1.83	6.69	0.75	1.76	1.20	0.37	10	1.00	0.67	0.65	0.59
MQ.33	0.20	0.50	8.50	1.83	6.69	0.75	2.71	2.00	0.30	10	0.20	0.67	0.47	0.71
Min.	0.04	0.3	0.75	0.28	1	0.73	0.24	1	0.19	10	0.1	0.67	0.02	0.24
Max.	0.28	1	8.5	4.68	11.71	0.75	4.82	3.6	1.19	10	1	0.67	0.72	5.88
Mean	0.16	0.53	4.80	1.90	6.50	0.75	1.88	1.61	0.38	10.00	0.66	0.67	0.53	0.98

The guide of I-Geo accumulation indices quantitatively characterizes the pollution levels in the soil sediment. It involves seven grades fluctuating from uncontaminated to the extent of exceedingly polluted soil (Buccolieri *et al*, 2006). When the presented overall pollution indices (I-geo and CF) of the heavy metals are consistent it indicates that the studied samples are affected by the same kind of sediments in their regions, thereby related to the mineralogical compositions nature of the deposit materials' sources (Alabadi *et al*, 2016). Table 5 shows the calculated values of I-geo for the studied surface soil samples collected from the Wasit province.

Table 5. Values of I-geo accumulation indices (I-Geo) for heavy elements in the soil samples

Heavy Metals														
Sample Code	**Ge**	**Se**	**Ag**	**Sn**	**Sb**	**Te**	**I**	**Hf**	**W**	**Hg**	**Ti**	**Bi**	**Th**	**U**
SU.1	-2.0	-0.5	1.2	0.5	1.50	-0.69	0.16	-2.9	0.6	1.9	-2.01	-0.81	-0.98	-0.94
SU.2	-2.0	0.0	1.2	0.2	-0.40	-0.69	0.45	-3.4	1.3	1.9	-0.92	-0.81	-1.06	-1.85
SU.3	-1.7	0.0	1.2	1.1	2.05	-0.73	1.17	-3.4	1.0	1.9	-0.51	-0.81	-1.19	-0.94
TJ.4	-2.5	0.0	0.7	0.2	1.50	-0.69	0.13	-3.0	2.5	1.9	-0.41	-0.81	-0.81	-1.45
TJ.5	-2.9	0.0	1.5	-0.2	1.50	-0.69	0.16	-2.3	1.0	1.9	-0.41	-0.81	-0.86	-0.94
TJ.6	-2.0	0.0	1.2	0.2	1.50	-0.69	0.16	-3.3	1.0	1.9	-0.41	-0.81	-1.21	-0.94
AZ.7	-2.9	0.0	1.2	0.2	1.50	-0.69	0.16	-2.4	1.0	1.9	-2.01	-0.81	-1.00	-0.94
AZ.8	-2.5	0.0	1.2	-0.1	1.50	-0.69	0.16	-2.6	1.2	1.9	-0.41	-0.81	-0.94	-1.85
AZ.9	-2.9	0.0	1.2	0.2	1.50	-0.69	0.16	-3.4	1.0	1.9	-0.41	-0.81	-1.26	-0.94
ZD.10	-2.0	-0.5	1.4	0.2	1.50	-0.69	0.32	-3.0	1.0	1.9	-2.71	-0.81	-1.04	-0.94
ZD.11	-2.0	0.0	-0.7	0.2	1.50	-0.69	0.09	-3.1	1.2	1.9	-1.32	-0.81	-0.74	-1.45
ZD.12	-2.9	0.7	1.2	0.2	1.50	-0.69	0.16	-3.4	1.0	1.9	-0.41	-0.81	-1.10	-0.53
NM.13	-2.0	0.0	0.3	0.2	1.50	-0.69	-0.41	-2.2	1.0	1.9	-2.71	-0.81	-0.86	-0.94
NM.14	-2.9	0.0	1.2	0.6	-0.11	-0.69	0.16	-3.4	1.0	1.9	-2.01	-0.81	-1.41	-1.85
NM.15	-2.0	0.0	1.2	-0.2	1.50	-0.69	0.16	-2.7	2.6	1.9	-0.41	-0.81	-0.78	-0.94
AH.16	-2.5	0.0	0.2	0.2	1.50	-0.69	0.16	-3.2	1.3	1.9	-2.01	-0.81	-0.81	-0.94
AH.17	-2.5	0.0	1.2	0.2	1.50	-0.69	0.16	-3.4	1.3	1.9	-0.63	-0.81	-0.96	-0.47
AH.18	-2.0	0.2	1.2	0.2	1.50	-0.69	0.16	-2.9	1.0	1.9	-0.41	-0.81	-1.02	-1.29
K.19	-2.5	0.0	1.2	0.2	1.50	-0.69	-1.45	-2.8	1.2	1.9	-0.92	-0.81	-0.81	-1.45
K.20	-2.5	0.0	1.2	0.2	1.50	-0.69	1.02	-2.5	1.1	1.9	-1.32	-0.81	-0.91	-0.94
K.21	-2.2	0.0	1.2	-1.7	1.50	-0.69	0.16	-3.3	1.0	1.9	-2.71	-0.81	-0.96	-0.94
K.22	-2.0	0.0	1.2	0.2	1.50	-0.69	0.16	-3.4	1.0	1.9	-0.41	-0.81	-0.89	-0.94
K.23	-2.0	0.0	1.2	0.3	1.50	-0.69	0.16	-3.3	4.0	1.9	-0.92	-0.81	-0.78	-1.45
BR.24	-2.0	0.0	1.2	-0.6	1.50	-0.69	0.16	-3.4	1.0	1.9	-0.41	-0.81	-1.21	-0.94
BR.25	-2.0	0.3	1.2	0.2	1.50	-0.69	0.16	-3.4	1.3	1.9	-0.41	-0.81	-1.23	-0.29
JN.26	-2.0	0.0	1.2	0.2	1.50	-0.69	0.16	-3.4	1.0	1.9	-2.71	-0.81	-4.28	1.20
JN.27	-2.0	0.0	1.2	0.6	1.50	-0.69	-0.60	-3.4	1.0	1.9	-0.41	-0.81	-2.67	1.37
HY.28	-2.0	0.0	1.2	0.2	1.50	-0.69	-1.85	-3.4	1.0	1.9	-2.01	-0.81	-0.94	-1.04
HY.29	-2.0	0.5	1.2	0.2	1.50	-0.69	0.16	-3.4	0.7	1.9	-0.41	-0.81	-1.12	-0.35
HY.30	-3.6	0.0	1.2	0.2	1.50	-0.69	0.16	-2.6	1.2	1.9	-0.41	-0.81	-1.00	-1.29
HY.31	-2.9	0.0	1.2	0.1	1.50	-0.69	0.16	-2.6	1.0	1.9	-0.41	-0.81	-0.75	-1.45
MQ.32	-2.9	0.0	1.2	0.2	1.50	-0.69	0.16	-3.3	1.3	1.9	-0.41	-0.81	-0.84	-0.94
MQ.33	-2.0	0.0	1.7	0.2	1.50	-0.69	0.59	-2.7	1.0	1.9	-2.01	-0.81	-1.16	-0.75
Min.	-3.6	-0.5	-0.7	-1.7	-0.4	-0.73	-1.85	-3.4	0.6	1.9	-2.71	-0.81	-4.28	-1.85
Max.	-1.7	0.7	1.7	1.1	2.05	-0.69	1.17	-2.2	4	1.9	-0.41	-0.81	-0.74	1.37
Mean	-2.35	0.03	1.07	0.12	1.38	-0.69	0.07	-3.04	1.30	1.90	-1.12	-0.81	-1.22	-0.88

Generally, if the CF <1 is a low pollution cause; 1≤CF<3 is a moderate pollution cause; 3≤CF<6 is a considerable pollution cause; and CF≥6, is a very high pollution cause (Gong *et al,* 2006). I geo level (Pollution < 0 Unpolluted, 1 Unpolluted to Moderate 1-2, Moderate Polluted 2-3 Moderate to high Polluted 3-4, High Polluted 4-5, High to Extremely Polluted 5-6, >5 extremely Polluted) (Buccolieri *et al,* 2006*)*. In the current study, the results of the CF plus I-Geo accumulation indexes for heavy metals in the surface soil samples are investigated with the mean values of CF and I-Geo below the level of pollution. Thus, Table 6 documented the decision on the distribution of heavy metals or their soil content and their environmental effluence, it indicates that Ge, Te, Ti, Bi, W, Th and U are low or unpolluted grade, whereas Ag, Sb, I, Sn, Hf are moderate to considerable grade. Hg records are noted to be very high polluted according to the CF values.

Table 6. Pollution grades for the max plus mean values contamination and I-geo accumulation indices of the trace elements in the studied surface soil samples.

Elements	Mean	Grade	Mean	Grade
Ge	0.16	Low	-2.35	Unpolluted
Se	0.53	Low	0.03	Unpolluted
Ag	4.8	Considerable	1.07	Moderate
Sn	1.9	Moderate	0.12	Unpolluted
Sb	6.5	Considerable	1.38	Moderate
Te	0.75	Low	-0.69	Unpolluted
I	1.88	Moderate	0.07	Moderate
Hf	1.61	Moderate	-3.04	Unpolluted
W	0.38	Low	1.3	Moderate
Hg	10	Very High	1.9	Moderate
Ti	0.66	low	-1.12	Unpolluted
Bi	0.67	Low	-0.81	Unpolluted
Th	0.53	Low	-1.22	Unpolluted
U	0.98	low	-0.88	Unpolluted

Conclusions

Considering the concern of environmental radiation exposure to human and associated radioactive contamination, this paper took an attempt to prove the identity and quantify various sources (contents of heavy metals) of harmful radiation in the surface soil (33 samples) of Wasit province of Iraq. The highest radioactivity level for ^{226}Ra (43.62 Bq/kg), ^{232}Th (29.26 Bq/kg) and ^{40}K (720.65 Bq/kg) was detected at the NM.13, JN.26 and ZD.12 sites, respectively. The mean concentration of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples was 37.30, 22.49, and 346.73 Bq/kg, respectively. The measured and estimated radium equivalent value was correspondingly 74.31 and 125.20 Bq/kg with the average value of 96.17 Bq/kg which was lower than the world average (370 Bq/kg) set by UNSCEAR, 2000. The measured absorbed doses at a distance of 1 m from the ground at all locations were lower than the reported ones, where the average radiation doses was discerned to be 45.66 nGy/h. The mean concentration of the elements in the studied soil samples showed the trend of Th > Sn > I > Te> Sb > Ag > Hf > U > W > Hg = Bi > Ti > Se and Ge. The obtained values of the CF and I-geo accumulation indices indicated that the surface soil samples had fluctuating levels from very highly polluted with Hg to considerably unpolluted with Sb, and Ag to moderately and unpolluted with Sn, I, Hf, Ge, Se,W, Te, Ti Bi, U and Th. In addition, certain heavy metals were concentrated in the soils as an ordinary source of the clays and heavy minerals maybe incorporated onto the minerals of carbonates. The absorption of these elements into the structure of the surface soils might have resulted from the anthropogenic urban wastes, agricultural and industrial activities. This indicator can be the probable sources of the contamination in the surface soil of Wasit province. Present results were consistent with the geochemical assessments, indicating the insignificant content of uranium, thorium and heavy metals in the studied soil samples. It was established that the surface soil in the Wasit region is safe for the humankind without any harmful environmental radiation exposure.

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