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Mapping of Terrestrial Gamma Radiation in Soil Samples at Baghdad Governorate (Karakh Side), Using GIS Technology

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ABSTRACT

The radioactive field is one of the most important areas in human health. It must be studied to see the changes in the doses of human exposure. In this study, 46 soil samples were collected from different locations of Karakh side at Baghdad Governorate. The specific activity of natural radionuclides (terrestrial gamma radiation) ^{238}U, ^{232}Th and ^{40}K for soil samples were measured using gamma-ray spectroscopy with NaI(Tl) ("3×3") detector in low-background. Moreover, ten radiological hazard parameters, which include radium equivalent activity (Ra_{eq}), absorbed gamma dose rate (Dγ), external hazard index (H_{ext}), internal hazard index (H_{int}), representative gamma index ($I_{\gamma r}$), annual effective dose equivalent (AEDE) that includes the indoor and outdoor effective dose rate, and ELCR were calculated. It has also used GIS technology for mapping specific activity and radiological radiation parameters for all the samples under study. The results show that, the average value of specific activity of terrestrial gamma radiation ^{238}U, ^{232}Th, ^{40}K, $^{238}U+^{232}Th+^{40}K$ and ^{235}U were 16.47±0.94 Bq/kg, 9.72±0.43 Bq/kg, 367.95±11.13 Bq/kg, 394.15±11.90 Bq/kg and 0.76±0.043 Bq/kg respectively. While, the average value of radiological radiation parameters such as Ra_{eq}, H_{ex}, H_{in}, $I_{\gamma r}$, I_{α}, Exposure, D_r, AGED, $AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$, and ELCR in present study were 58.7183±2.017 Bq/kg, 0.1586±0.00546, 0.2032±0.00768, 0.4523±0.0151, 0.08237±0.0046, 3.367±0.113 μR/h, 28.8309±0.968 nGy/h, 207.1078±6.86 mSv/y, 0.1415±0.00475 mSv/y, 0.03541±0.00119 mSv/y, 0.177±0.00594 mSv/y and 0.6192 ±0.0208 respectively. The results indicate that the effective dose from terrestrial gamma radiation is everywhere across the area within the acceptable level, subject to the inherent spatial averaging of the measurements.

INTRODUCTION

The annual exposure of human population to radioactive radiations from all natural and artificial sources is regularly evaluated in the world. Natural radioactivity arises mainly from primordial radionuclides, such as ^{40}K and the nuclides from the ^{232}Th, ^{238}U series and their decay products, which occur at trace levels in all ground formations on the earth (Spinks et al. 1990). The study of natural radioactivity is important because naturally occurring radioactive materials (NORM) can serve as good biochemical and geochemical tracers in environment in case of geological events such as earthquakes and eruptions volcanic (Cherry et al. 2012). Gamma radiation emitted from natural radioactive isotopes, such as ^{238}U and ^{232}Th series and decomposition products and ^{40}K, which are found in trace levels in all land configurations, is the main external source of radiation to the human body. Gamma-ray emissions externally cause the risk exposure and internally cause inhalation of radon (Ting 2010, Clavensjö & Åkerblom 1992). Natural radioactivity and associated external exposure due to gamma radiation depend mainly on the local geographical and geological conditions that appear on different levels in every region of the world. The rate of natural gamma dose is an important contributor to the medium dose that the world's population receives (Eisenbud & Gesell 1997, White & Pharoah 2014). This terrestrial component arises due to primordial radionuclides that were synthesized during the creation of the planet, and has always accompanied life on the Earth. Both, humans and biota are exposed to an annual dose rate. Since, the natural flux is largely determined by soil and associated parent geological material, personal annual exposure to terrestrial gamma radiation is determined by the home location, the localities visited and the amount of time spent indoors and outdoors within a geological framework. Terrestrial gamma dose rates largely reflect the natural variation of potassium, uranium and thorium across the environment. The data sets provide a basis for studies of dose rates derived from both NORMs (naturally occurring radioactive materials) and TENORMs (technologically enhanced naturally occurring radioactive materials) (Bauer & Westfall 2011). The soil is one of the main contributors to background radiation. It is very interesting to know the radioactivity content of the soil over the world (Hayde 1994). Therefore, the knowledge of natural radioactivity of soil evaluation of radiation risks is important. Measurement of natural radioactivity in the soil is of great importance to many researchers all over the world, which led to a worldwide national survey in the past two decades. The measurement of natural radioactivity in the soil is very significant to determine the amount of changes in the natural background activity with due time or radioactivity leak (Sroor et al. 2001). Geostatistical techniques are useful components of GIS applications that are frequently applied. Geostatistics involves the analysis and estimation techniques which have been used to obtain the value of a variable dispersed in time and location. Many research and mappings have been done at different locations of countries in the world for natural radioactivity in soil samples using GIS technology (Doğan 2010, Hassan 2012, Yang et al. 2017, Çam et al. 2012, Einas et al. 2012). For this reason, the main purpose of this work is to evaluate the terrestrial gamma radiation in soil samples from most districts of Karakh side at Baghdad Governorate as well as to assess the health risks from background radiation through evaluating the ten radiological radiation parameters. Finally, it is drawn to establish the radiological map to be a reference for the next studies using GIS technical.

GEOLOGY OF BAGHDAD SOIL

Baghdad is located in central Iraq at coordinates latitude 33°18'03.56''N, longitude 44°25'07.11''E, which is located between the coordinates latitude 33°31'53.29''N, longitude 44°20'14.12''E at the entrance of the Tigris River from the north, and coordinate latitude 33°5'74.43''N, longitude 44°31'45.44''E at the exit of the Tigris River from the south. The range of height above sea level of Baghdad is 29-44m. Generally, the soil of Baghdad area has been derived from around areas especially Mesopotamian plain and the desert (Hatab et al. 1986). Most soils of Baghdad area are therefore secondary soils (residual soils) derived from the above regions, transported from the place of weathering and accumulated as a result of sedimentation. Besides, Baghdad soil strata are affected by river course changes during previous decades leading to coarse silt deposits and giving different depositional stratigraphy every few meters. Thus, Baghdad strata are erratic, somewhat nonhomogeneous with a water table near ground. This soil, generally, is alkaline with poor permeability (Albusoda 2016). Baghdad soil is characterized by its high salinity due to dryness, rainfall scarcity and evaporation leading to groundwater upward movement and causing fluctuation of groundwater levels in the area (Hatab et al. 1986). Baghdad lies in the middle of Iraq within the Mesopotamian Plain. The Tigris River passes through the city dividing it into two parts; Karkh and Rasafa. The study area is restricted to Karkh area which it is located at latitudes (33º19'-33º31'N) and longitudes (44º24'-44º40'E) with an area of about 1350km^2 approximately (Fig. 1). Karkh is historically the name of the western half of Baghdad, Iraq, or alternatively, the western shore of the Tigris River as it ran through Baghdad. In a more limited sense, Karkh is one of nine administrative districts in Baghdad, with Mansour district to the west, Kadhimiya district to the northwest, and the Tigris to the north, east and south. The Green Zone (International Zone) is in this district.

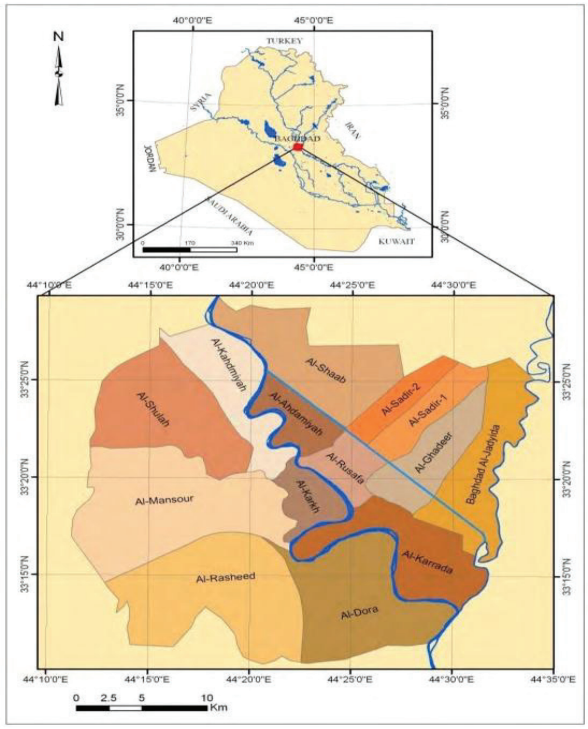

Fig. 1: Location map of the study area.

MATERIALS AND METHODS

Sample Collection and Preparation

In this study, 46 samples of soil were collected from 46 areas of Karakh side from Baghdad governorate. The collected samples were transferred to labelled closed polyethylene bags and taken to the laboratory of radiation detection and measurement in the Physics Department, Faculty of Science, University of Kufa. The sample codes, locations, and coordinates by GPS are given in Table1 .

The samples with the mean weight of 1kg were collected at the depth of 15cm from the upper layer using a plastic cup and then put in plastic bags. Prior to the analysis, the samples were dried, crushed and homogenized. Thereafter, before subjecting the samples to gamma spectrometer,

Table 1: Location name, sample codes, and coordinates.

No.	Location name	Sample code	Coordinates (° ' ")	
1	Aamiriya	K1	33 18 09.9 N	44 17 03.0 E
2	Shuala	K2	33 22 03.7	44 16 30.3
3	AL- Jamaah	K3	33 19 06.3	44 19 08.1
4	Near halib biladi	K4	33 19 32.9	44 10 06.8
5	Near Taji gas	K5	33 26 17.4	44 16 13.1
6	Al- washash	K6	33 19 32.2	44 21 10.4
7	Tarmiyah	K7	33 40 22.5	44 23 56.8
8	College of Agriculture – Abu Ghraib	K8	33 18 36.0	44 12 52.8
9	Sabaa Al Bour	K9	33 27 46.0	44 09 09.9
10	Jhazaliya	K10	33 20 31.8	44 16 36.0
11	Tajyat	K11	33 22 33.5	44 24 47.8
12	Shurtah 4^{th}	K12	33 14 48.5	44 18 34.9
13	Kadhimiya	K13	33 22 12.2	44 20 38.5
14	Khan Dhari	K14	33 17 54.1	44 03 31.1
15	Dora Refinry	K15	33 15 41.5	44 25 10.3
16	Shuhada Al Sydia	K16	33 14 06.3	44 21 07.3
17	Latifiya	K17	32 57 47.8	44 21 20.1
18	AL-Rasheed	K18	33 07 00.8	44 22 03.2
19	Abu Disher	K19	33 12 33.2	44 22 58.8
20	Al Alam	K20	33 14 50.6	44 20 38.3
21	Shati Tajiyat	K21	33 24 10.1	44 19 33.6
22	AL- Taifiya	K22	33 21 09.9	44 21 53.1
23	Quirish	K23	33 10 57.8	44 21 50.6
24	AL- Aamel	K24	33 16 42.2	44 19 28.6
25	Abu Ghraib	K25	33 18 12.8	44 10 08.4
26	Allawi	K26	33 19 37.3	44 23 03.3
27	Toma	K27	33 15 18.0	44 23 36.5
28	Qadissiya	K28	33 16 51.2	44 21 24.8
29	AL-Raay	K29	33 13 54.8	44 19 23.8
30	Mansour	K30	33 18 53.2	44 20 48.7
31	Harthiya	K31	33 18 12.6	44 21 54.6
32	AL- Jihad	K32	33 16 18.5	44 17 17.9
33	Shaqaq AL- Salam	K33	33 15 49.9	44 18 52.2
34	Suwaib	K34	33 13 18.6	44 17 44.2
35	Manshaet Nasr (Taji)	K35	33 35 17.9	44 13 56.3
36	Project 14 Ramadan	K36	33 44 48.2	44 19 23.3
37	Shuhada Abu Ghraib	K37	33 18 17.6	44 07 33.8
38	Hurriya	K38	33 21 14.7	44 19 07.3
39	Malef	K39	33 12 53.3	44 19 29.6
40	AL- Mekanek	K40	33 13 41.8	44 24 22.7
41	Mahmudiyah	K41	33 03 14.8	44 21 27.0
42	AL- Sahaa	K42	33 13 31.9	44 23 42.3
43	Rahmaniya	K43	33 20 34.3	44 22 19.8
44	Bayaa	K44	33 16 23.1	44 20 43.3
45	Saidya	K45	33 15 34.9	44 21 09.7
46	Al Radwan Company	K46	33 19 33.9	44 01 30.7

the containers were sealed for a month to ensure the secular equilibrium between ^{226}Ra, ^{232}Th, and their progenies (Al-Hamidawi 2014).

Gamma Radiation Measurement

The samples were placed directly on the NaI(Tl) detector (3"×3") crystal dimension and the supplier of the company (Alpha Spectra, Inc.-12I12/3) for the gamma analysis. The exposure time for each sample to the detector was 5 hours (Al-Hamidawi 2014, Abojassim et al. 2016, Mirza et al. 2017). Three types of calibrations including energy, resolution, and efficiency calibrations were performed for gamma spectrometer**.** The ^{152}Eu, ^{137}Cs, ^{60}Co, ^{22}Na and ^{54}Mn standard sources were used for efficiency calibration which was produced in Amersham International Plc. (U.K.). The parallel measurements of the International Atomic Energy Agency (IAEA) intercomparison sediment samples (IAEA-300 and IAEA-315) were used for checking the precision and accuracy. An empty polyethylene container with the same geometry and measuring conditions as those used for the samples to determine the background due to the existence of natural radionuclides in the environment. The uncertainties in the calibration of the peak areas of these photopeaks were ±2% (Harb 2004). The specific activity of the samples adopted on the Bismuth (^{214}Bi) at energy 1764.5keV is equivalent to the specific activity of Uranium (^{238}U). While the specific activity adopted on the Thallium (^{208}Tl) at energy 2614keV is equivalent to the specific activity of Thorium (^{232}Th). The specific activity concentrations of radionuclides ^{40}K have been calculated by using the energy 1460.80keV (Mirza et al. 2017, Abojassim 2017).

CALCULATIONS

Specific Activity (A): The specific activity (activity concentration) of the gamma-emitting radionuclides in the sample can be calculated from the following equation (Al-Hamidawi 2014, Abojassim et al. 2016, Mirza et al. 2017):

$$A\left(\frac{Bq}{kg}\right) = \frac{N}{I_\gamma \, \varepsilon M T} \qquad \ldots(1)$$

Where, A is the specific activity of the radionuclide in the sample, N is the net area under photopeak, I_γ is the probability of gamma decay, ε is the efficiency of the gamma-ray detector, M is the weight of the measured sample in Kg, and T is the life time for collecting the spectrum in seconds. But, the specific activity of ^{235}U was calculated by (Harb 2004, Abojassim 2017):

$$A_{235_U} = \frac{A_U}{21.7} \qquad \ldots(2)$$

External hazard index (H_{ex}): The external hazard index for samples under investigation is given by the following equation (Krieger 1981):

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad \ldots(3)$$

Where, A_U, A_{Th} and A_k are the specific activity of ^{238}U, ^{232}Th and ^{40}K, respectively.

Internal hazard index (H_{in}): Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index. It can be calculated according to the following equation (Venturini & Nisti 1997):

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad \ldots(4)$$

Representative Level Index (I_γ): Radiation hazards due to the specified radionuclides of ^{238}U(^{226}Ra), ^{232}Th and ^{40}K were assessed by another index called representative level index ($I_{\gamma r}$), The following equation can be used to calculate $I_{\gamma r}$ for soil samples under the study (Abojassim 2017).

$$I_{\gamma r} = \left(\frac{1}{150}\right)A_U + \left(\frac{1}{100}\right)A_{Th} + \left(\frac{1}{1500}\right)A_K \qquad \ldots(5)$$

Alpha index (Iα): Alpha index has been developed to assess the excess alpha radiation due to the radon inhalation originating from building materials. The alpha-indexes were determined using the equation below (Krieger 1981):

$$I_\alpha = \frac{A_U}{200\left(\frac{Bq}{kg}\right)} \qquad \ldots(6)$$

Radium Equivalent Activity (Ra_{eq}): The radiological hazard associated with samples contained radionuclides, namely ^{238}U, ^{232}Th, and ^{40}K, can be assessed using a common radiological index, called radium equivalent activity. It can be expressed mathematically as (Abojassim et al. 2017):

$$Ra_{eq}\left(\frac{Bq}{kg}\right) = A_U + 1.43\,A_{Th} + 0.077\,A_K \qquad \ldots(7)$$

Exposure rate ($\dot{X}$) : The gamma ray exposure rate in air, at 1 m above an infinitely extended and thick slab, due to ^{238}U, ^{232}Th series and ^{40}K uniformly distributed in the material, is given by (Kahn et al. 1983, Venturini & Nisti 1997):

$$\dot{X}\left(\frac{\mu R}{h}\right) = 1.90\,A_U + 2.82\,A_{Th} + 0.197\,A_K \qquad \ldots(8)$$

Where, $\dot{X}$ is the exposure rate (μR/h), the activity concentrations are given in pCi/g. The constants on the righthand side of Equation 8 are related to the average gamma ray energies for each radionuclide or series.

Absorbed Dose Rate in Air (D_r): The main contribution to the absorbed dose rate in the air comes from terrestrial gamma-ray radionuclides present in trace amounts in the soil, the measurements of dose rate depend on measurements of specific activity concentrations of radionuclides, mainly ^{238}U, ^{232}Th and ^{40}K. The UNSCEAR 2008 report explains that the absorbed dose rate in air 1 meter above the ground surface can be given by (UNSCEAR 2008):

$$D_r\left(\frac{nGy}{h}\right) = 0.462\,A_U + 0.604\,A_{Th} + 0.0417\,A_K \qquad \ldots(9)$$

Annual gonadal equivalent dose (AGED): According to UNSCEAR (1988), the gonads are considered as the organs of the interest. However, the annual gonadal equivalent dose (AGED) for the residents in the study area due to the specific activities of ^{238}U, ^{232}Th and ^{40}K was calculated using Equation 10 given by Arafa (2004) and Okogbue & Nweke (2018) as:

$$AGED\left(\frac{mSv}{y}\right) = 3.09\,A_U + 4.18\,A_{Th} + 0.314\,A_K \qquad \ldots(10)$$

Annual Effective Dose Equivalent (AEDE): The annual effective dose equivalent (AEDE) can be calculated from the absorbed dose by applying the dose conversion factor of 0.7 (Sv/Gy) with an outdoor occupancy factor of 0.2 and 0.8 for indoor (UNSCEAR 1993, UNSCEAR 2000).

$$AEDE_{outdoor}\left(\frac{mSv}{y}\right) = \left[D_r\left(mGy/hr\right)\times 8760\,hr\times 0.2\times 0.7\,Sv/Gy\right]\times 10^{-6} \qquad \ldots(11)$$

$$AEDE_{indoor}\left(\frac{mSv}{y}\right) = \left[D_r\left(mGy/hr\right)\times 8760\,hr\times 0.8\times 0.7\,Sv/Gy\right]\times 10^{-6} \qquad \ldots(12)$$

Excess Lifetime Cancer Risk (ELCR): This gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being. It is given as (Al-Hamidawi 2014, Abojassim et al. 2017):

$$ELCR = AEDE\times DL\times RF \qquad \ldots(13)$$

Where, AEDE is the total of Annual Effective Dose Equivalent ($AEDE_{outdoor}$ + $AEDE_{indoor}$), DL is the average Duration of Life (estimated to be 70 years) and RF is the Risk Factor (Sv), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

RESULTS AND DISCUSSION

The specific activities of radionuclides ^{238}U, ^{232}Th, ^{40}K and ^{235}U were measured in selected soil samples from different locations of Karakh side from Baghdad governorate and their radiation hazard parameters are listed in Table 2. The comparison between the specific activity in Bq/kg for all the samples is shown in Fig. 2, which is drawn by GIS technology. From Table 2, the specific activity of ^{238}U ranged from 3.16±0.31 Bq/kg in sample K15 to 33.33±0.92 Bq/kg in sample K28 with the mean value of 16.47±0.94 Bq/kg. However, the specific activity of ^{232}Th varied from 2.41±0.16 Bq/kg in sample K19 to 15.92±0.39 Bq/kg in sample K38 with the mean value of 9.72±0.43. In addition, the values of ^{40}K were 171.50±2.35 Bq/kg in sample K16 and 496.78±3.71 in sample K43 with the mean value of 367.95±11.13, while for ^{235}U were ranged 0.15-1.54 Bq/kg with the mean value of 0.76±0.043. In general, the activity concentrations indicate that $^{40}K > ^{238}U > ^{232}Th$. This agrees that the association among the radionuclides may be because uranium and thorium decay series come from the same origin and exist together in nature. Whereas potassium is from a different origin (Tanaskovic et al. 2012). The errors as noted in the table include the statistical uncertainty in the peak area, calibration and counting errors. The UNSCEAR recommended standard indicate that the worlds average specific activity of ^{238}U, ^{232}Th and ^{40}K are 33 Bq/kg, 45 Bq/kg and 420 Bq/kg respectively (UNSCEAR 2008). It was found that all the values of ^{238}U specific activities were lower than the world's average activity recommended by UNSCEAR (2008) as shown in Fig. 3. Also, as shown in Fig. 3, which is drawn by GIS technology, all values of specific activity of ^{232}Th were within the UNSCEAR (2008) report. While, for ^{40}K, it is clear that the specific activities, with the exception of K7, K21, K25, K26, K28, K31, K32, K35, K36, K38, K43 and K44 samples were only found to be higher than the worldwide average, as shown in Fig. 4 which is drawn by GIS technology. In some samples, the values are more than the highest allowable concentration in the region because of the increase in the concentration of potassium nuclide in some areas of the region which is due to the existence of agricultural land and areas containing phosphate fertilizers in which the focus increasingly peer-potassium (^{40}K). The values obtained for radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), representative level index ($I_{\gamma r}$) and alpha index (I_{α}) are presented in Table 3. As can be seen from Table 2, the radium equivalent activity (Ra_{eq}) values for soil samples varied from 24.95 to 86.46 Bq/kg with an average 58.7183 ±2.017 Bq/kg. All the values are lower than 370 Bq/kg (OECD 1979). It may be concluded that

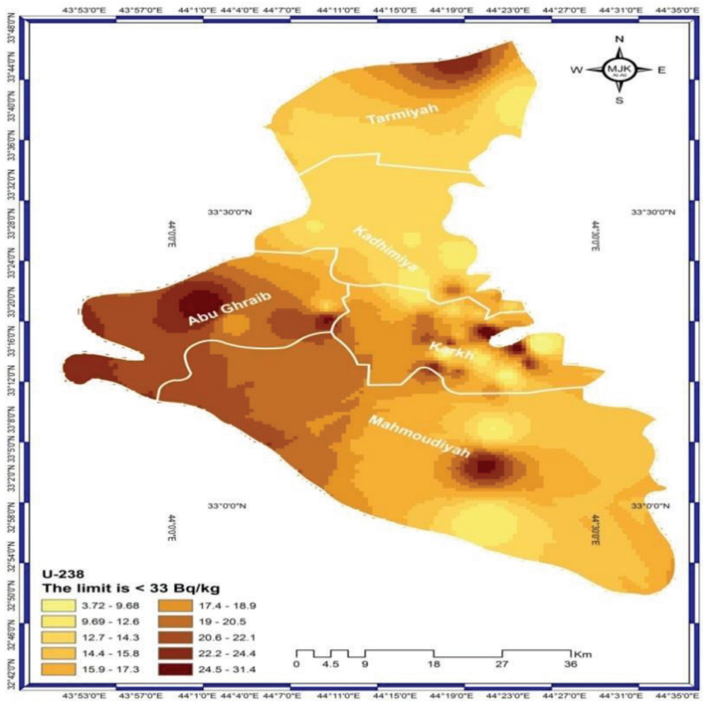

Fig. 2: The choropleth maps of the values of specific activity of ^{238}U and comparison of the results with word average activity UNSCEAR (2008).

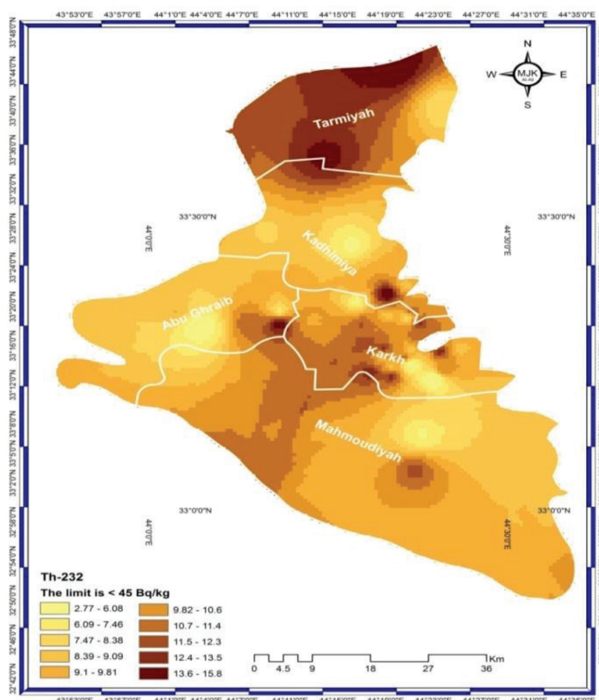

Fig. 3: The choropleth maps of the values of specific activity of ^{232}Th and comparison of the result with word average activity UNSCEAR (2008).

Table 2: Specific Activity of ^{238}U, ^{232}Th, ^{40}K and ^{235}U with their uncertainties.

Sample code	Specific Activity in (Bq/kg)				
	^{238}U	^{232}Th	^{40}K	^{238}U +^{233}Th +^{40}K	^{235}U
K1	20.44±0.78	11.48±0.35	367.45±3.44	399.37	0.94
K2	10.91±0.57	9.66±0.32	379.70±3.50	400.27	0.50
K3	12.46±0.61	8.69±0.31	312.56±3.17	333.71	0.57
K4	13.80±0.64	7.17±0.28	325.62±3.24	346.59	0.64
K5	12.49±0.61	5.60±0.25	346.32±3.34	364.41	0.58
K6	17.04±0.71	11.26±0.35	360.03±3.41	388.33	0.79
K7	11.23±0.58	7.51±0.29	440.26±3.77	459	0.52
K8	17.70±0.73	9.66±0.32	319.49±3.21	346.85	0.82
K9	12.46±0.61	8.21±0.30	401.50±3.60	422.17	0.57
K10	10.04±0.55	5.54±0.25	318.85±3.21	334.43	0.46
K11	11.38±0.58	6.22±0.26	347.55±3.35	365.15	0.52
K12	5.87±0.42	9.44±0.32	320.78±3.22	336.09	0.27
K13	12.93±0.62	8.64±0.31	343.32±3.33	364.89	0.60
K14	17.79±0.73	4.15±0.21	290.60±3.06	312.54	0.82
K15	3.16±0.31	8.58±0.31	339.45±3.31	351.19	0.15
K16	9.68±0.54	3.58±0.20	171.50±2.35	184.76	0.45
K17	10.16±0.55	9.73±0.33	285.15±3.03	305.04	0.47
K18	9.59±0.53	5.89±0.25	263.35±2.91	278.83	0.44
K19	6.59±0.44	2.41±0.16	193.72±2.50	202.72	0.30
K20	12.34±0.61	11.23±0.35	298.21±3.10	321.75	0.57
K21	10.46±0.56	9.34±0.32	475.93±3.92	495.73	0.48
K22	15.20±0.67	9.37±0.32	367.51±3.44	392.08	0.70
K23	18.65±0.75	8.65±0.31	377.70±3.49	405	0.86
K24	15.11±0.67	10.50±0.34	402.95±3.60	428.56	0.70
K25	25.33±0.87	14.30±0.39	442.55±3.78	482.18	1.17
K26	12.96±0.62	10.42±0.34	465.81±3.88	489.19	0.60
K27	27.75±0.84	12.66±0.35	416.81±3.40	457.22	1.28
K28	33.33±0.92	11.48±0.33	476.84±3.64	521.65	1.54
K29	14.98±0.62	8.83±0.29	310.89±2.94	334.7	0.69
K30	13.50±0.59	7.32±0.26	217.10±2.46	237.92	0.62
K31	14.88±0.62	12.38±0.34	461.65±3.58	488.91	0.69
K32	21.48±0.74	12.07±0.34	430.25±3.46	463.8	0.99
K33	22.73±0.76	12.39±0.34	388.96±3.29	424.08	1.05
K34	24.23±0.79	13.39±0.36	412.12±3.38	449.74	1.12
K35	13.76±0.59	14.10±0.36	425.14±3.44	453	0.63
K36	23.77±0.78	15.53±0.38	461.29±3.58	500.59	1.10
K37	21.71±0.74	11.35±0.33	395.77±3.31	428.83	1.00
K38	20.28±0.72	15.92±0.39	454.60±3.55	490.8	0.93
K39	21.07±0.73	12.69±0.35	412.79±3.39	446.55	0.97
K40	23.80±0.78	10.24±0.31	263.46±2.70	297.5	1.10
K41	25.45±0.81	11.73±0.33	345.23±3.10	382.41	1.17
K42	15.42±0.63	10.46±0.31	385.22±3.27	411.1	0.71
K43	19.26±0.70	10.23±0.31	496.78±3.71	526.27	0.89
K44	20.31±0.72	9.64±0.30	421.45±3.42	451.4	0.94
K45	16.84±0.66	8.77±0.29	403.18±3.35	428.79	0.78
K46	27.49±0.84	9.11±0.29	388.41±3.28	425.01	1.27
Mean ± S.E.	16.47±0.94	9.72±0.43	367.95±11.13	394.15±11.90	0.76±0.043

the high activity concentration of Ra_{aq} is still in the range of the permissible level. The results of H_{ex}, H_{in}, $I_{\gamma r}$ and I_{α} (see Table 3) ranged from 0.067 to 0.234 with an average value of 0.1586 ±0.00546, from 0.085 to 0.239 with an average 0.2032 ±0.00768, from 0.197 to 0.655 with an average 0.4523±0.0151 and from 0.167 to 0.016 with an average 0.08237 ±0.0046 respectively. The results of hazard indexes (H_{ex}, H_{in}, $I_{\gamma r}$ and I_{α}) of all values for all the samples studied in this work are less than one which is the maximum value of the permissible safety limit recommended (EC1999). The results of exposure rate ($\dot{X}$), absorbed dose rate in air (D_r), annual gonadal equivalent dose (AGED), annual effective dose equivalent indoor, outdoor and total ($AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$), excess lifetime cancer risk (ELCR) are listed in Table 4. The $\dot{X}$ found is the minimum values in sample K19 1.46 μR/h and the maximum values in sample K28 4.89 μR/h, with an average value of 3.367 ±0.113μR/h. The results of D_r ranges from 12.58nGy/h to 42.217nGy/h with an average value of 28.8309 ±0.968nGy/h. The values of D_r were smaller than the value of the world average, which is equal to 55 nGy/h according to UNSCEAR (2000). The values of AGED as given in Table 4 have ranged from 91.26 mSv/y to 300.70 mSv/y with an average of 207.1078 ±6.86mSv/y. The annual gonadal equivalent dose values are lower than when compared with the world average permissible limit of ≤ 300 mSv/y, as relates to radiation (Okogbue & Nweke 2018), except sample k28. The calculated values of $AEDE_{indoor}$, $AEDE_{outdoor}$ and $AEDE_{total}$ in this study ranged from 0.062mSv/y to 0.207mSv/y, with an average of 0.1415 ±0.00475mSv/y, from 0.015mSv/y to 0.052mSv/y with an average of 0.03541 ±0.00119mSv/y and from 0.077mSv/y to 0.259mSv/y with an average of 0.177 ±0.00594mSv/y respectively. Since, all the values of $AEDE_{indoor}$, $AEDE_{outdoor}$ and $AEDE_{total}$ are lower than the corresponding worldwide values of 0.42, 0.08 and 0.50 mSv/y respectively (ICRP 1993). The calculated excess lifetime cancer risk of this location is given in Table 4. These values vary from 0.270×10^{-3} to 0.907×10^{-3} with an average of $0.465\pm0.019\times10^{-3}$. According to these results, the values of ELCR are very less, therefore, it may be decided that the risk of cancer is negligible. The results of specific activity in natural radionuclides for the studied samples were lower than the world's average according to UNSCEAR (2008). As well as, the average specific activity of ^{238}U, ^{232}Th and ^{40}K in soil samples in Baghdad governorate (Karakh side) were compared with those from similar investigations in other countries and summary results are given in Table 5.

CONCLUSION

Geostatistical tools of ArcGIS software analysed terrestrial gamma radiation in soil samples at Baghdad Governorate (Karakh Side) pollution by element mapping. It was

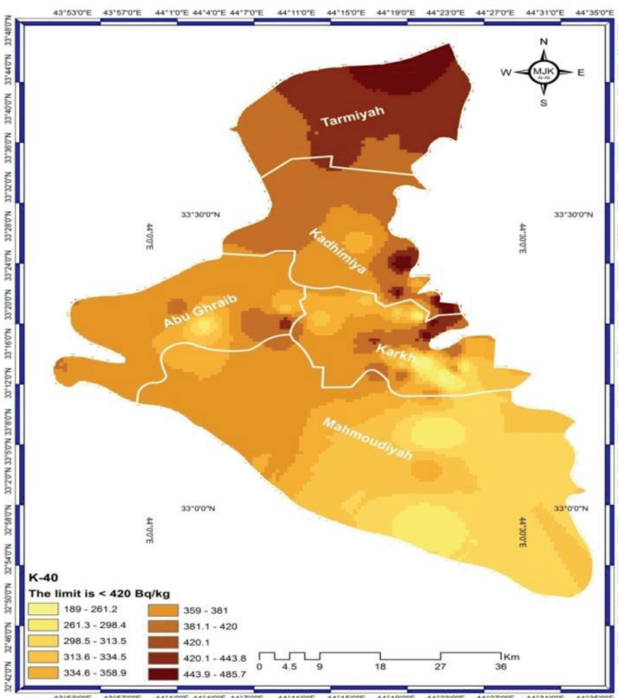

Fig. 4: The choropleth maps of the values of specific activity of ^{40}K and comparison of the results with word average activity UNSCEAR (2008).

Table 3: Results of Ra_{eq}, H_{ex}, H_{in}, $I_{\gamma r}$ and I_{α} in the present study.

Sample code	Ra eq (Bq/kg)	H_{ex}	H_{in}	$I_{\gamma r}$	$I_{\alpha\gamma}$
K1	65.15	0.176	0.231	0.496	0.102
K2	53.96	0.146	0.175	0.422	0.055
K3	48.95	0.132	0.166	0.378	0.062
K4	49.13	0.133	0.170	0.381	0.069
K5	47.16	0.127	0.161	0.370	0.062
K6	60.86	0.164	0.210	0.466	0.085
K7	55.87	0.151	0.181	0.443	0.056
K8	56.11	0.152	0.199	0.428	0.089
K9	55.12	0.149	0.183	0.433	0.062
K10	42.51	0.115	0.142	0.335	0.050
K11	47.04	0.127	0.158	0.370	0.057
K12	44.07	0.119	0.135	0.347	0.029
K13	51.72	0.140	0.175	0.401	0.065
K14	46.10	0.125	0.173	0.354	0.089
K15	41.57	0.112	0.121	0.333	0.016
K16	28.00	0.076	0.102	0.215	0.048
K17	46.03	0.124	0.152	0.355	0.051
K18	38.29	0.103	0.129	0.298	0.048
K19	24.95	0.067	0.085	0.197	0.033
K20	51.36	0.139	0.172	0.393	0.062
K21	60.46	0.163	0.192	0.480	0.052
K22	56.90	0.154	0.195	0.440	0.076
K23	60.10	0.162	0.213	0.463	0.093
K24	61.15	0.165	0.206	0.474	0.076
K25	79.86	0.216	0.284	0.607	0.127
K26	63.73	0.172	0.207	0.501	0.065
K27	77.95	0.211	0.286	0.589	0.139
K28	86.46	0.234	0.324	0.655	0.167
K29	51.55	0.139	0.180	0.395	0.075
K30	40.68	0.110	0.146	0.308	0.068
K31	68.13	0.184	0.224	0.531	0.074
K32	71.87	0.194	0.252	0.551	0.107
K33	70.40	0.190	0.252	0.535	0.114
K34	75.11	0.203	0.268	0.570	0.121
K35	66.66	0.180	0.217	0.516	0.069
K36	81.50	0.220	0.284	0.621	0.119
K37	68.41	0.185	0.243	0.522	0.109
K38	78.05	0.211	0.266	0.597	0.101

Table cont....

Sample code	Ra eq (Bq/kg)	H_{ex}	H_{in}	$I_{\gamma r}$	$I_{\alpha\gamma}$
K39	71.00	0.192	0.249	0.543	0.105
K40	58.73	0.159	0.223	0.437	0.119
K41	68.81	0.186	0.255	0.517	0.127
K42	60.04	0.162	0.204	0.464	0.077
K43	72.14	0.195	0.247	0.562	0.096
K44	66.55	0.180	0.235	0.513	0.102
K45	60.43	0.163	0.209	0.469	0.084
K46	70.42	0.190	0.265	0.533	0.137
Mean ± S.E.	58.71 ±2.01	0.158 ±0.005	0.203 ±0.007	0.45 ±0.01	0.082 ±0.004

Table 4: Results of D_r, Exposure, AGED, $AEDE_{indoor}$, $AEDE_{outdoor}$, $AEDE_{total}$, ELCR in the present study.

Sample code	Exposure (μR/h)	D_r (nGy/h)	AGED (mSv/y)	$AEDE_{indoor}$ (mSv/y)	$AEDE_{outdoor}$ (mSv/y)	AEDE (mSv/y)	ELCR×10^{-3}
K1	3.70	31.70	226.53	0.156	0.039	0.195	0.681
K2	3.13	26.71	193.32	0.131	0.033	0.164	0.574
K3	2.81	24.04	172.97	0.118	0.030	0.148	0.516
K4	2.83	24.28	174.86	0.119	0.030	0.149	0.522
K5	2.74	23.59	170.75	0.116	0.029	0.145	0.507
K6	3.47	29.69	212.77	0.146	0.036	0.182	0.638
K7	3.28	28.08	204.33	0.138	0.034	0.172	0.603
K8	3.19	27.33	195.39	0.134	0.034	0.168	0.587
K9	3.21	27.46	198.89	0.135	0.034	0.168	0.590
K10	2.48	21.28	154.30	0.104	0.026	0.131	0.457
K11	2.74	23.51	170.29	0.115	0.029	0.144	0.505
K12	2.57	21.79	158.32	0.107	0.027	0.134	0.468
K13	2.98	25.51	183.87	0.125	0.031	0.157	0.548
K14	2.64	22.84	163.57	0.112	0.028	0.140	0.491
K15	2.46	20.80	152.22	0.102	0.026	0.128	0.447
K16	1.60	13.79	98.73	0.068	0.017	0.085	0.296
K17	2.64	22.46	161.60	0.110	0.028	0.138	0.482
K18	2.22	18.97	136.95	0.093	0.023	0.116	0.407
K19	1.46	12.58	91.26	0.062	0.015	0.077	0.270
K20	2.93	24.92	178.71	0.122	0.031	0.153	0.535
K21	3.55	30.32	220.80	0.149	0.037	0.186	0.651
K22	3.27	28.01	201.53	0.137	0.034	0.172	0.601
K23	3.44	29.59	212.38	0.145	0.036	0.182	0.636
K24	3.53	30.13	217.11	0.148	0.037	0.185	0.647
K25	4.53	38.79	277.00	0.190	0.048	0.238	0.833
K26	3.71	31.71	229.87	0.156	0.039	0.195	0.681

Table cont....

Sample code	Exposure (μR/h)	D_r (nGy/h)	AGED (mSv/y)	$AEDE_{indoor}$ (mSv/y)	$AEDE_{outdoor}$ (mSv/y)	AEDE (mSv/y)	ELCR×10^{-3}
K27	4.41	37.848	269.54	0.186	0.046	0.232	0.813
K28	4.89	42.217	300.70	0.207	0.052	0.259	0.907
K29	2.95	25.218	180.82	0.124	0.031	0.155	0.542
K30	2.30	19.711	140.48	0.097	0.024	0.121	0.423
K31	3.94	33.603	242.69	0.165	0.041	0.206	0.722
K32	4.10	35.155	251.92	0.173	0.043	0.216	0.755
K33	3.99	34.204	244.16	0.168	0.042	0.210	0.735
K34	4.26	36.467	260.25	0.179	0.045	0.224	0.783
K35	3.84	32.602	234.95	0.160	0.040	0.200	0.700
K36	4.64	39.598	283.21	0.194	0.049	0.243	0.850
K37	3.89	33.389	238.80	0.164	0.041	0.205	0.717
K38	4.45	37.942	271.96	0.186	0.047	0.233	0.815
K39	4.05	34.612	247.77	0.170	0.042	0.212	0.743
K40	3.28	28.167	199.07	0.138	0.035	0.173	0.605
K41	3.87	33.239	236.07	0.163	0.041	0.204	0.714
K42	3.45	29.506	212.33	0.145	0.036	0.181	0.634
K43	4.17	35.793	258.26	0.176	0.044	0.220	0.769
K44	3.82	32.780	235.39	0.161	0.040	0.201	0.704
K45	3.48	29.890	215.29	0.147	0.037	0.183	0.642
K46	3.99	34.400	244.98	0.169	0.042	0.211	0.739
Mean ± S.E.	3.36 ±0.11	28.83 ±0.96	207.1078 ±6.86	0.141 ±0.004	0.035 ±0.001	0.177 ±0.005	0.61 ±0.02

Table 5: Comparison of the specific activity of soil samples under investigation with other countries.

Country	specific activity in Bq/kg			Reference
	^{238}U	^{232}Th	^{40}K	
Egypt	27	31.4	427.5	(El Mamoney & Khater 2004)
Iran	23	31	453	(Saleh 2017)
Saudi Arabia	11.68	6.21	169.40	(El-Taher et al. 2018)
Libya	7.5	4.2	27.5	(El-Kameesy et al. 2008)
World average (soil)	33	45	420	(UNSCEAR 2008)
Iraq (Baghdad-Karakh side)	16.47	9.72	367.95	Present study

seen that terrestrial gamma radiation map resembled with uranium-238, thorium-232 and potassium-40 maps. The level of naturally occurring radioactivity in soil samples at Baghdad Governorate (Karakh Side) was evaluated using NaI(Tl) gamma-ray spectrometry. The obtained results revealed that the level of measured radioactivity could not pose any radiological threat to the people living near it, also the obtained values when compared to the worlds permissible values were below the acceptable value standard and hence risk of developing cancer by the people will be low.

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