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Assessment of Natural Radioactivity Levels and Radiation Hazards of Soils from Erbil Governorate, Iraqi Kurdistan

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***Abstract*—In this work, the activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in soil samples from Erbil Governorate, Iraqi Kurdistan were investigated by a gamma-spectroscopy system based on high-purity germanium detector. This is to assess the dose of radionuclides exposure to the population, knowing the health risks and to have a baseline for future changes in the environmental radioactivity. It was found that the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K were ranged from 14.6 ± 1.6 to 38.2 ± 2.8 Bq/kg, 4.5 ± 1.4 to 52.4 ± 5.8 Bq/kg, and 302.8 ± 12.6 to 388.6 ± 12.8 Bq/kg, respectively. The measured activity concentrations for these radionuclides were compared with the reported data of other countries and with the worldwide average activity of soil. Radium equivalent activities, absorbed dose rate, excess lifetime cancer risk, and the values of hazard indices were calculated for the measured samples to assess the radiation hazard of the natural radioactivity in all samples to the people. It was concluded that the radium equivalent activities of the studied samples are below the internationally accepted values. These results show that annual effective dose absorbed through occupant from activity construction of soil samples used in the under place is below 1.0 mSv/y. It is concluded that the assessment radioactivity of soil is within acceptable levels and does not pose any health hazard to the population.**

***Index Terms*—Gamma-ray spectroscopy, Radioactivity, Soil, Erbil Governorate.**

I. Introduction

The natural radioactivity present in the environment is the main source of radiation exposure of humans and constitutes the background radiation level (Amrani and Tahtat, 2001). The principle characteristic supporters of outer introduction from gamma beams are ^{226}Ra, ^{232}Th, and ^{40}K. Since these radionuclides are not consistently disseminated, the information of their dispersion in soil assumes a critical part in radiation security (Aziz et al., 2014). Natural radionuclides in soil represent the significant component of population background exposure. The specific levels of terrestrial environmental radiation are related to the geological composition of each lithological separated area, and to the content of natural radionuclides in rocks from which the soils originate in each area (Snežana et al., 2012). The relatively more abundant naturally occurring radionuclides belong to uranium and thorium decay series (Zakariya et al., 2013). Humans are exposed to both internal and external radiation from the natural sources. Internal exposure occurs through the intake of terrestrial radionuclides through inhalation or ingestion. Inhalation exposure dose results from the existence of dust particles in air, including radionuclides from ^{238}U and ^{232}Th decay series (Hammood and Khalifa, 2011). The radioactivity concentrations in soil give information on both natural and manmade sources which are important in radiological monitoring and assessment of radiation dose for public (Eissa, et al., 2010).

Also literature showed that studies on radionuclide concentrations in mines have been extensively in national studies (Hussein, 2018; Azeez et al., 2018; Ahmed and Samad, 2014; Dashty and Ali, 2013; Makki et al., 2014; Hussain and Hussain, 2011; Hussain and Abbas, 2010; Ali, 2011; Kamal et al., 2015). Mining activities have not been subjected to radiological regulatory control and so there is generally little or no awareness and knowledge of the radiological hazards. In addition, ^{137}Cs is the most important fission product released to the environment as a result of nuclear activities, because this radionuclide rapidly passes through soil to vegetables and creates a dose effect (Hammood and Khalifa, 2011. p. 22). Several studies have been measured and evaluated values for the level of natural radioactivity in worldwide national studies; such as, in Malaysia (Alzubaidi et al., 2016; Salih, 2018), India (Sureshgandhi et al., 2014; Punniyakotti and Ponnusamy, 2017), Nigeria (Fasae, 2013: Jibiri and Biere, 2014), Brazil (Veiga et al., 2006), Egypt (Darwish et al., 2015), and Saudi Arabia (El-Taher and Abdelhalim, 2013: Al-Zahrani, 2012).

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Natural occurring radioactive material when the is processed, the concentration of the radionuclides became higher in the wastes, so the radionuclides have a very long half-life, when concerning about the public safety (Hassan et al., 2013).

The goal of this study decides the concentration of activity ^{226}Ra, ^{232}Th, and ^{40}K in the soil from Erbil Governorate, Iraq. Assessment of natural radioactivity of the soil samples for some regions in Kurdistan region considers as the main objective of this research. The radium equivalent activity (Ra_{eq}), absorbed gamma dose rate (D), external hazard (H_{ex}), internal hazard (H_{in}), gamma radiation representative level index (I_{γ}), and the outdoor and indoor annual effective dose rate annual effective dose equivalent (AEDE) were calculated and compared with the standard values and other references values.

II. Research Methodology

A. Study Area

Erbil Governorate is the capital of Kurdistan Region Government – Iraq, the oldest city with continuous residentially. This city is regarded as one of the most deep-rooted Governorates in the area. The Erbil Governorate is located at the height of 418 m from sea level. The geographic area of the study place is located northwest to Sulaymaniyah Governorate and it is only 350 km from Baghdad. The city is surrounded by Nineveh from West, and Kirkuk city from East, and Iran and Turkey from North. The total area of the Erbil Governorate is 15214 Km^2 (Kamal and Ali, 2004), as shown in Fig. 1.

B. Sample Collection and Preparation

In the current study, 54 soil samples taken from top soil to a depth of 15 cm were collected from 15 different locations in Erbil Governorate. The samples had been desiccated in an

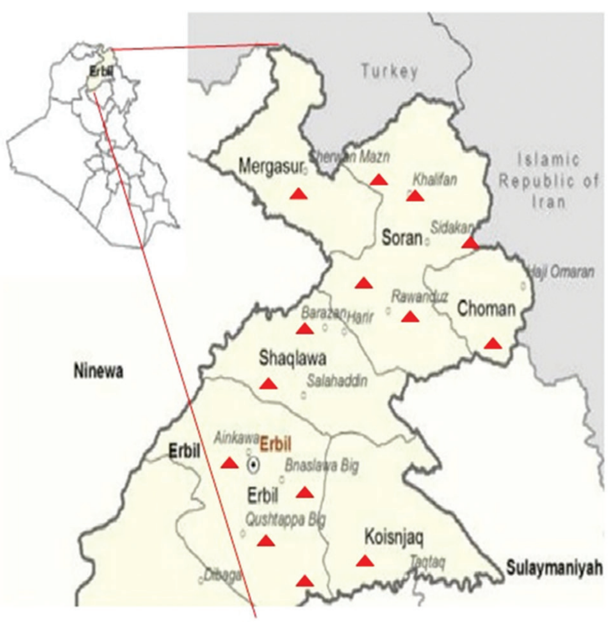

Fig. 1. Map of samples location samples in study area.

oven at about 100°C for 24 h to remove the moisture content material then pulverized and closely sealed in cylindrical plastic chambers (13 cm diameter and 14 cm height). The samples have been saved for 30 days before counting so as to confirm up to expectation^{238}U attains radioactive equilibrium including their daughters. In average 500 g of soil is used per each sample (Jayasheelan et al., 2013).

C. Gamma-ray Spectrometry

The activity natural radionuclides concentration of ^{226}Ra, ^{232}Th, and ^{40}K in soil was found using gamma-ray spectrometer system at the Biophysics Laboratory, Physics Department, USM-Malaysia. After the equipoise, the sample was kept on up of the germanium detector and calculated for a duration of 54,000 s. In the present work, we are used^{152}Eu,^{137}Cs, and^{60}Co standard sources and ^{226}Ra standard source and its progenies were used in energy calibration. The concentration of radium-226 was determined from photopeak 609.3 keV of a^{214}Bi peak, whereas the 911.2 keV photopeak of^{228}Ac peak and 583.4 keV of^{208}TI applied to fined. Thorium-232 and photopeak at 1461.6 keV were used to fine the concentration of potassium-40. To determine radionuclide concentrations for each soil sample, the total net counts below the chosen photopeaks after subtracting convenient background counts were used and by applying convenient factors for photopeak effectiveness (Kumar et al., 2001).

D. Calculation of Radiological Parameters

The gamma-ray radiation risks due to the particular radionuclides ^{226}Ra, ^{232}Th, and ^{40}K were estimated through various points. The activity concentrations of the samples have been calculated using the net area below photopeaks by (Lu and Xiaolan, 2006).

$$A_s\,(Bq/kg)=C_a/\varepsilon P_\tau\, M_s \quad (1)$$

Where A_s is the radio nucleus activity concentration of the sample, C_a is the net count rate below the corresponding peak, P_τ is the absolute transition probability of the specific ɣ ray, M_s is the mass of the sample (kg), and ε is the detector efficiency at the specific ɣ ray energy.

The ultimate widely available used radiation hazard index Ra_{eq} is called the radium equivalent activity Ra_{eq}. Radium equivalent activity is a weighted sum of activities of the up three radionuclides primary based on the determination that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th, and 4810 Bq/kg of ^{40}K produce the same γ-ray dose rates. Ra_{eq} is given through formula (Aziz et al., 2014).

$$Ra_{eq}=A_{Ra}+(A_{Th}\times 1.43)+(A_K\times 0.077) \quad (2)$$

Where A_k, A_{Th}, and A_{Ra} are the activity concentrations of ^{40}K, ^{232}Th, and ^{226}Ra, in Bq/kg, respectively. The equation is based on the presumption that 370 Bq/kg, 259 Bq/kg, and 4810 Bq/kg of ^{226}Ra, ^{232}Th, and ^{40}K, respectively, make the same gamma-ray dose rate.

To limit the outer gamma-radiation dose from the soil sample, an extensively used hazard index, the internal hazard index (H_{in}) and the external hazard index (H_{ex}) and were determined by the formula (Eissa et al., 2010).

$$H_{in}=A_{Ra}/185+A_{Th}/259+A_K/4810 \quad (3)$$

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$$H_{ex}=A_{Ra}/370+A_{Th}/259+A_K/4810 \quad (4)$$

Where A_{Ra}, A_{Th}, and A_k the activities of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/Kg.

Radiation risks related with the natural radionuclides of soil samples were estimated through radioactivity level index, $I_{\gamma r}$. The following formula was used to determine $I_{\gamma r}$ for soil below realization (Hussein, 2011).

$$I_{\gamma r}=(C_{Ra}/150)+(C_{Th}/100)+(C_K/1500) \quad (5)$$

Where C_{Ra}, C_{Th}, and C_K are the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/kg, respectively.

To determine average absorbed gamma dose in air D_R (nG/h) at 1 m above the ground for regular distribution of radionuclides using the formula provided through UNSCEAR (UNSCEAR, 2000).

$$D_R\ (nG/h)=0.427C_{Ra}+0.623C_{Th}+0.043C_K \quad (6)$$

Where 0.427, 0.623, and 0.043 activities to indoor dose rate diversion factors in nG/h/Bq/kg for, ^{226}Ra, ^{232}Th, and ^{40}K, respectively. The absorbed dose rate expresses the received dose in the open air from the radiation emitted from radionuclides concentration in environmental materials. The absorbed dose used to calculate the AEDE by applying the occupancy factor of 0.2 for outdoor and 0.8 for indoor with an dose conversion factor of 0.7 Sv/Gy (Al-Hamarneh, and Awadallah, 2009).

$$(AEDE)_{outdoor}=D\ (nG/h)\times 8760\ (h/y)\times 0.7 \times (103\ mSv/nGy\ 10^9)\times 0.2 \quad (7)$$

$$(AEDE)_{indoor}=D\ (nG/h)\times 8760\ (h/y)\times 0.7 \times (103\ mSv/nGy\ 10^9)\times 0.8 \quad (8)$$

III. Results and Discussion

The results of the present work on the three types of samples are abridged in the following parts.

A. Activity Concentration in Active Soil Samples

The activity concentration of the natural radionuclides of the ^{226}Ra, ^{232}Th, and ^{40}K has been calculated in the soil samples from Erbil Governorate using gamma-ray spectrometer. The measured specific activities of ^{238}U, ^{232}Th, and ^{40}K in Becquerel per kilogram in soil samples were determined by Equation (1) and the results for the same are shown in Table I. The activity of ^{226}Ra in the soil ranged from 14.6 ± 1.6 Bq/kg (Erbil Central) to 38.2 ± 2.8 Bq/kg (Choman) with a mean of 25.61 Bq/kg, ^{232}Th ranged from 4.5 ± 1.4 Bq/kg (Erbil Central) to 38.2 ± 4.5 Bq/kg (Shaqlawa) with a mean of 20.15 Bq/kg, and ^{40}K ranged from 302.8 ± 12.6 Bq/kg (Erbil Central) to 388.6 ± 12.8 Bq/kg (Mergasur) with a mean of 326.64 Bq/kg.

The appointed activity due to ^{40}K is the biggest contributor to the total activity for all the samples. The mean activity concentration values of ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples from different locations in Erbil Governorate, are shown in Fig. 2.

Table II shows the comparison for different regions of soil samples of the mean activity concentrations values. The difference in the radioactivity concentrations in the soil of the different area of the world, depending to the range of fertilizer utilized to the soil and geological status of the area (SEAM, 2005, Azeez et al., 2018).

TABLE I
The Average Activity Concentrations of Radionuclides in Soil used in Erbil Governorate

Location	Number of samples	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
Erbil central	5	14.6±1.6	4.5±1.4	302.8±12.6
Koya	5	20.8±1.5	22.8±2.3	319.5±14.2
Soran	5	29.6±2.2	45 6±2.8	320.2±11.2
Rawanduz	4	30.8±2.2	26.2±2.5	322.4±12.6
Xabat	4	19.2±1.4	52.4±5.8	317.2±12.8
Shaqlawa	4	28.6±2.1	38.2±4.5	325.6±14.5
Choman	4	38.2±2.8	25.6±2.7	364.2±14.8
Khalifan	4	26.8±1.8	16.4±1.5	318.6±12.2
Hiran	4	24.5±1.7	8.6±4.2	316.4±15.6
Mergasur	3	34.5±2.9	18.5±2.4	388.6±12.8
Salahaddin	3	18.6±1.5	9.2±1.6	308.4±14.2
Sidakan	3	32.6±2.4	21.8±2.6	342.8±11.6
Bnslawa	3	17.2±1.2	11.6±1.4	310.4±12.5
Dibaga	3	22.6±1.7	6.2±2.6	315.9±11.7

TABLE II
Comparison of Activity Concentration of ^{226}Ra, ^{232}Th, and ^{40}K with Other Countries and Present Study

Country	Mean activity concentration (Bq/kg)			References
	^{226}Ra	^{232}Th	^{40}K	
Turkey	37	40	667	(Tufan and Disci, 2013)
Syria	23	20	270	(UNSCEAR, 2000)
Iran	28	22	640	(UNSCEAR, 2000)
Qatar	23.2	45.2	127.1	(UNSCEAR, 2000)
Jordan	49	27	291	(Al-Hamarneh and Awdallah, 2009)
Oman	29.7	15.9	225	(Goddard, 2001)
India	32.4	48.2	312.5	(Jayasheelan, et al., 2013)
Japan	29	28	310	(UNSCEAR, 2000)
China	38.5	54.6	584	(Lu and Xiaolan, 2006)
Pakistan	25.8	49.2	561.6	(Aziz et al., 2014)
Sweden	34	42	680	(UNSCEAR, 2000)
United State	40	35	370	(UNSCEAR, 2000)
Iraq	25.61	20.1`5	326.64	Present study

B. Radiological Indices

Estimate the health risks, the radium equivalent activity (Ra_{eq}), internal hazard index (H_{in}), external hazard index (H_{ex}), and representative level index ($I_{\gamma r}$), have been measured from the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K by Equations (2), (3), (4), and (5), respectively, and the values are shown in Table III.

The results are shown in Table III describe that the radium equivalent activity varied from 86.4 to 188.2 Bq/kg with an average value of 141.4 Bq/kg. However, all the values for radium equivalent activity obtained here away under the limit of 370 Bq/kg (IAEA, 1989).

The internal radiation hazard index (H_{in}) ranged from 0.32 to 0.62 with an average value of 0.45 for external radiation hazard index (H_{ex}) ranged from 0.22 to 0.53 with an average value of 0.376, which all values are under the critical value of unity. Thus, established on these results of external hazard

TABLE III
Average Radiological Hazards (H_{EX}, H_{IN}, $I_{\gamma r}$, and Ra_{eq}) in Soil from Erbil Governorate Iraqi Kurdistan

Location	Number of samples	Radium equivalent activity Ra_{eq} (Bq/kg)	External hazard index H_{ex}	Internal hazard index H_{in}	Representative level index $I_{\gamma r}$
Erbil central	5	86.4	0.22	0.32	0.54
Koya	5	134.5	0.32	0.43	1.14
Soran	5	158.4	0.42	0.52	1.46
Rawanduz	4	168.4	0.44	0.54	1.48
Xabat	4	128.6	0.32	0.42	1.16
Shaqlawa	4	124.8	0.29	0.38	0.56
Choman	4	172.6	0.46	0.55	1.51
Khalifan	4	145.7	0.39	0.48	1.21
Hiran	4	138.2	0.35	0.44	1.17
Mergasur	3	188.2	0.52	0.62	1.88
Salahaddin	3	128.6	0.32	0.39	0.58
Sidakan	3	176.8	0.48	0.56	1.54
Bnslawa	3	115.8	0.28	0.36	0.57
Dibaga	3	112.8	0.26	0.34	0.55
	Minimum	86.4	0.22	0.32	0.54
	Maximum	188.2	0.52	0.62	1.88
	Average	141.4	0.36313	0.455625	1.110625

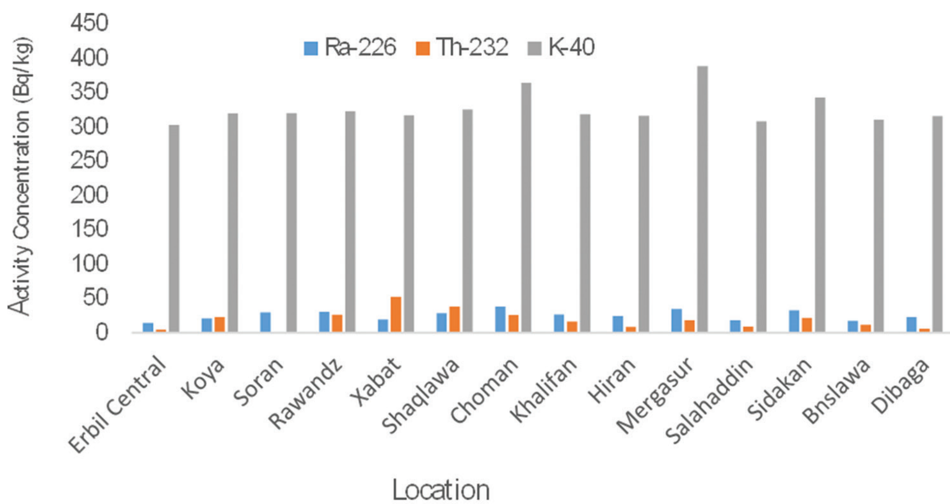

Fig. 2. Average activity of radionuclides in soil from different locations in Erbil Governorate, Iraqi Kurdistan.

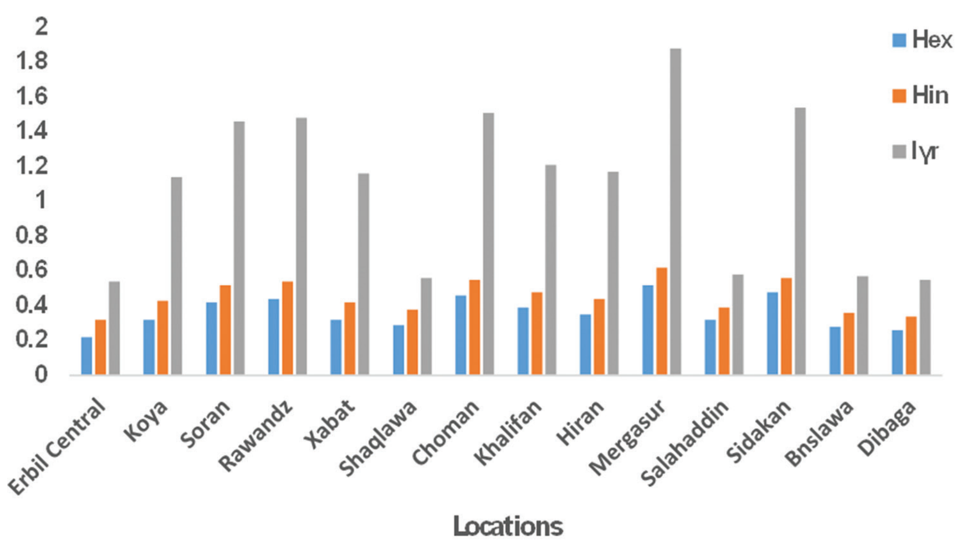

Fig. 3. The main representative level index, $I_{\gamma}r$ and hazard index (H_{ex}, H_{in}).

TABLE IV
AIR-ABSORBED DOSE RATES AND ANNUAL EFFECTIVE DOSES IN SOIL SAMPLES OF ERBIL GOVERNORATE

Location	Number of samples	Absorbed dose (nGh^{-1})				Annual effective dose (mSv/y)	
		^{226}Ra	^{232}Th	^{40}K	Total	$(AEDE)_{outdoor}$	$(AEDE)_{indoor}$
Erbil Central	5	6.87	2.25	9.15	18.27	0.04	0.14
Koya	5	10.22	11.54	10.12	31.88	0.05	0.18
Soran	5	15.48	22.86	10.24	48.58	0.07	0.24
Rawanduz	4	18.46	14.24	10.82	43.52	0.08	0.25
Xabat	4	9.24	26.74	9.28	45.26	0.05	0.19
Shaqlawa	4	17.82	18.92	10.64	47.38	0.07	0.22
Choman	4	26.72	13.84	11.56	52.12	0.09	0.32
Khalifan	4	16.92	8.58	10.56	36.06	0.08	0.28
Hiran	4	13.54	4.56	10.42	28.52	0.06	0.16
Mergasur	3	25.66	9.64	11.48	46.78	0.08	0.24
Salahaddin	3	9.86	4.98	9.28	24.12	0.06	0.18
Sidakan	3	23.55	10.86	11.32	45.73	0.07	0.23
Bnslawa	3	8.94	5.78	9.15	23.87	0.05	0.18
Dibaga	3	12.48	3.46	10.28	26.22	0.06	0.17
Average		15.41	11.30	10.30	37.02	0.065	0.21

AEDE: Annual effective dose equivalent

indices and radium equivalent activity, one can conclude that there are no health risks from the soil in Erbil Governorate region. Representative level index ($I_{\gamma r}$) varies from 0.54 to 1.88 with an average value of 1.11 as shown in Table III. The main representative level index, $I_{\gamma r}$, and hazard index (H_{ex}, H_{in}) are shown in Fig. 3.

C. Absorbed Dose and Annual Effective Dose

Using Equations (6), (7), and (8) measured total absorbed gamma dose rates, AEDE for indoor and outdoor, respectively, and the values are shown in Table IV. It is spotted that the activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K from the absorbed dose rate varies from 6.87 to 26.72, 2.25 to 26.74, and 9.15 to 11.56 nGh^{-1}, respectively. The average dose absorbed in the work location range from 18.27 nGh^{-1} (Erbil Central) to 52.12 nGh^{-1} (Choman) a mean value 37.02 nGh^{-1}, which is lower than the limits recommended by ICRO report (ICRP, 1993).

The corresponding outdoor and indoor annual effective doses range from 0.04 to 0.09 mSv/y and 0.14 to 0.32 mSv/y, with an average value of 0.06 and 0.21 mSv/y, respectively. The worldwide mean annual effective dose is approximately 0.5 mSv/y, and the results for person countries are generally between the 0.3 and 0.6 mSv/y range for indoors recommended by UNSCEAR (UNSCEAR, 2000). Thus, the study area is still in the zones of simple radiation level which leaves the soil radioactivity there below a threat to the environment and body risks.

IV. CONCLUSION

Natural radioactivity levels in the soil samples for some locations in Erbil governorate have investigated using high pure germanium detector. It was found that the estimated levels were low compared with the standard levels. The mean value of total absorbed dose rate is 37.02 $nGyh^{-1}$, which is under than the world average value of 55 $nGyh^{-1}$ (ICRP, 1993). The determined average radium equivalent activity (Ra_{eq}) values for all the soil samples examined were lower than the recommended maximum level of radium equivalent of 370 Bq/kg^{-1}. The score obtained from internal and external hazard index are under than unity. The annual effective doses for indoor and outdoor are below than the action level of ICRP. The values obtained in the study are within the recommended safety limit, showing that the soil does not discompose any significant radiation risks.

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