Evaluation of Natural Terrestrial Gamma Radiation Dose in Baghdad City

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ABSTRACT

Evaluation of the activity concentration for natural terrestrial radiation in the Baghdad city has been achieved in this study, Gamma ray activities of radionuclides ^{226}Ra,^{232}Th and also the long-lived naturally occurring radionuclide ^{40}K have been determined in soil samples for selected regions in Baghdad city by using gamma spectrometry(which contains High- purity Germanium Detector) with a efficiency of 40% and resolution 2 keV for Energy, 1.33Mev gamma ray photo peak of ^{60}Co ,collection, preparations and tests of 25 soil samples were all done according to IAEA, The measuring time of all soil samples is 3600 seconds. It was found that, the soil specific activity ranges from(20.07 ± 1.86) to (41.10 ± 2.12) Bq/kg for (^{226}Ra), (17.21 ±1.95) to (38.19 ±2.42) Bq/kg for (^{232}Th) and (346.12± 8.19) to (613.97 ±10.00) Bq/kg for (^{40}K) with mean values of (27.94)Bq/kg,(25.24)Bq/kg and (476.65) Bq/kg**,** respectively in AL KARKH side, while the soil specific activity ranges from (16.23 ± 1.25) to (35.52 ± 1.21) Bq/kg for (^{226}Ra), (19.02 ± 2.8) to (30.57 ± 2.7**)** Bq/kg for (^{232}Th) and (308.99 ± 9.92) to (593.74 ±11.90) Bq/kg for (^{40}K) with mean values of **(**22.51) Bq/kg,(24.77) Bq/kg and (464.20) Bq/kg**,** respectively in AL RASAFAH side

The average of radium equivalent activity (Ra_{eq}), the gamma absorbed dose rate (D) in air, the annual effective dose rate, and the rate of external hazard index have been calculated, the results were 95.84 (Bq/kg), 46.41 (nGy/h), 56.91x10^{-6} (Sv), 0.25 respectively in AL KARKH side, and 92.84 (Bq/kg),44.81 (nGy/h),54.96x10^{-6} (Sv), 0.24 in AL RASAFAH side respectively.

Finally the results have been compared with the acceptable world average values (UNSCEAR, 2000).and According to results of this study we can regard the Baghdad city within the regions of normal background radiation which includes cosmic radiation arise in outer space and radionuclides in the earth's crust.

1- Introduction

Studies on radiation levels and radionuclide distribution in the environment provide vital radiological baseline information, Such information is essential in understanding human exposure from natural and man-made sources of radiation and necessary in establishing rules and regulations relating to radiation protection .

Natural radioactivity arises mainly from primordial radionuclides, such as ^{40}K and the isotopes in the ^{238}U, ^{235}U and ^{232}Th decay series which are present in at least trace amounts in all ground formations. Concentrations and distributions of the radionuclides in natural materials are of interest since they provide information on environmental radioactivity. Gamma radiation emitted from naturally-occurring radioisotopes, also called terrestrial background radiation, represents the main source of irradiation external to the human body. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on geological and geographical conditions and appear in different amounts in each region of the world [1].

A significant part of the total dose from of natural sources comes from terrestrial gamma emitting radionuclides. Only nuclides with half-lives comparable to the age of the earth in terrestrial materials are of interest. Large accretions of uranium and its decay products in rocks and soils and thorium in monazite sands are the important sources of high natural background in several areas of the world ,systematic and accurate measurements of the radioactivity level in soils are essential for understanding changes in the natural radiation background as a function of geographical location and time ,Therefore it is important to monitor the concentration of radionuclides in soil and to assess the radiation exposure to the people. Most of the developed and developing countries in the world are carrying out nation-wide surveys to assess the amount of radioactivity in order to establish possible radiological hazards and to take safety measures if necessary[2].

2- THEORETICAL PART

2-1 Behavior of long-lived radionuclides in soil

The concentration of naturally occurring radionuclides in soil depends on the rock type from which the soil is formed .The soil is contaminated either by radionuclide deposition originally discharged into the atmosphere, or on the land surface by direct discharge of wastes.

The concentration of radionuclides in soil increases by adsorption with soil particles and their precipitation on soil. The concentration decreases by leaching process and also dilutes when the organic matter and soil water content

increases behavior of radionuclides in soil on site characteristics, rate and amount of rain –fall and soil drainage [3].

2-2 Dose assessment;

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq/kg to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K. It is calculated using the following relation [4]:

$$\mathbf{Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K} \quad \text{……………..(1)}$$

The absorbed dose rates (D) due to gamma radiation in air at 1 m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guidelines provided by UNSCEAR 2000.we assumed that the contributions from other naturally occurring radionuclides were insignificant, such as ^{137}Cs, ^{90}Sr and the ^{235}U series. The calculations were performed according to the following equation [4]:

$$\mathbf{D(nGy.h^{-1}) = 0.462A_{Ra} + 0.621\ A_{Th} + 0.0417\ A_K} \quad \text{…………(2)}$$

Where A_{Ra}, A_{Th}, A_K are the activity concentrations of ^{226}Ra, ^{232Th} and ^{40}K respectively.

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose ($0.7Sv.Gy^{-1}$) and outdoor occupancy factor (0.2)

proposed by UNSCEAR 2000 are used .Therefore ,the annual effective dose rate ($mSv.yr^{-1}$) was calculated by the following formula[4] ;

Effective dose rate ($mSv.yr^{-1}$) =

$$\mathbf{D(nGy.h^{-1}) x8760\ h.\ yr^{-1} x0.7x(10^3 mSv/10^9)\ nGy\ x0.2} \quad \text{…….(3)}$$

The external hazard index, H_{ex}, is defined as [4]:

$$\mathbf{H_{ex} = C_{Ra} / 370 + C_{Th} / 259 + C_K / 4810} \quad \text{……….(4)}$$

where C_{Ra}, C_{Th} and C_K are the specific activities (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The value of this index must be less than unity in order to keep the radiation hazard insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of radium equivalent activity (370 Bq/kg).

3- EXPERIMENTAL PART

3-1 Sample collection and preparation;

Soil samples were collected from 25 locations in the Baghdad city (thirteen in Al KARKH side, and twelve in AL RASAFAH side) , three samples from each location, enclosing nearly an area of 100 m^2, were collected, thoroughly mixed, and homogenized as a representative sample for each location, the soil samples measured at 5-15 cm depth level were collected from

sampling points. Stones were manually eliminated from the samples, which were then sieved in their locations, using a 2 mm sieve. the samples were dried in open air dry place for 24 hours to ensure that any significant moisture was removed from the samples[6]. The final sample preparation and all the gamma-ray measurements to determine the sample radioactivities were all done according to IAEA[5] .

3-2 Radiometric measurements;

The two families of radionuclide originate with ^{238}U and ^{232}Th account for much of the natural radioactivity to which human is exposed, a third family originate with ^{235}U is also present but does not contribute significant radiation dose[5].

About 750-1000 g from each sample was packed in a plastic container, sealed well and stored for about 30 days before analysis. This allowed the in-growth of uranium and thorium decay products prevent the escape of radiogenic gases ^{222}Rn and ^{220}Rn and allowed secular equilibrium between ^{238}U, ^{232}Th and their decay products. After attainment of secular equilibrium, each of the prepared samples was measured in the laboratory using gamma spectrometry which contains High- purity Germanium Detector with a efficiency of 40% and resolution 2 keV for Energy, 1.33Mev gamma ray photo peak of ^{60}Co , each sample was counted for 3600 sec[6] . Since uranium and thorium are not γ-emitters, they were measured indirectly through the γ-ray photons emitted from their decay products,^{214}Pb (351 keV)or^{214}Bi(609keV)for ^{226}Ra ^{228}Ac (911 keV) or Ti(583 keV)for ^{232}Th whereas potassium was measured directly from the γ-ray photon emitted by ^{40}K (1460 keV. The spectra were analyzed using the program GENIE 2000[6][7].

4- RESULTS AND DISCUSSION

Calculations of count rates for each detected photo-peak and radiological concentrations (activity per mass unit or specific activity) of detected radionuclides depend on the establishment of secular equilibrium in the samples, the lab tests were conducted using a High Purity Germanium Spectrometry.

4-1 AL KARKH side :

The results of the variation in the activity concentration (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K radionuclides for 13 soil samples collected at various areas in AL KARKH side of the Baghdad city are shown in Table 1 .

Table (1): specific activities of the three radionuclides in soil samples at various areas in AL KARKH side

Specific activity of radionuclides (Bq/kg)					
NO.	Location	Samples Code	Ra-226	Th-232	K-40
1	AL TAJI	SO TA	41.10 ± 2.12*	38.19 ±2.42*	605.74 ± 10.39
2	AL KAZIMAYAH	SO KA	20.07 ± 1.86*	20.32± 1.73	425 ± 7.60
3	AL HURRIYAH	SO HU	33.16 ± 1.80	28.54 ± 2.09	556.24 ± 8.85
4	AL SHULAH	SO SH	25.56 ± 2.16	23.61 ± 1.02	469.53 ± 8.69
5	HAYY AL KHADRA	SO KH	38.06 ± 2.14	34.04 ± 2.36	613.97 ±10.00*
6	AL AMIRIYAH	SO AM	23.15 ± 1.51	20.79 ± 1.61	406.19± 7.27
7	AL JAHID	SO JA	24.08 ± 1.88	17.21 ±1.95*	409.30 ± 7.99
8	AL AALAM	SO AA	21.19 ± 1.82	23.46 ± 1.97	403.41 ± 8.23
9	AL YARMUK	SO YA	27.10± 1.79	19.12 ± 1.87	346.12± 8.19*
10	AL MAMUN	SO MAM	24.22± 1.43	21.08± 1.40	406.48 ± 7.19
11	AL MANSUR	SO MA	33.17 ± 1.81	28.42 ± 1.42	573.55 ± 9.39
12	ALAWI AL HILLA	SO AL	26.42 ± 1.74	26.75 ± 2.05	487.04 ± 9.18
13	HAYFA STREET	SO HA	26.01 ± 1.09	22.24 ± 1.99	493.91 ± 8.47
AVERAGE			27.94	25.24	476.65

*The bold characters represent the minimum and maximum values.

From Table (1) the specific activity of the radionuclides in Bq/kg ranged between(20.07 ± 1.86) and (41.10 ± 2.12)for ^{226}Ra, (17.21 ± 1.95)and (38.19 ± 2.42) for ^{232}Th and from (346.12± 8.19) and (613.97 ± 10.00) for ^{40}K.

By applying equations.1,2,3,and 4 ,the Radium equivalent activity, dose rate, annual effective dose and external hazard index were calculated in the Table 2.

Table(2): Radium equivalent activity, dose rate, annual effective dose and external hazard index at different locations in AL KARKH side

Samples Code	Radium equivalent activity (Bq/kg)	Dose rate (nGy/h)	Annual effective dose (10^{-6} Sv)	External hazard index
SO TA	**142.35***	**67.94***	**83.32***	**0.37***
SO KA	81.84	39.60	48.56	0.20
SO HU	116.17	56.22	68.94	0.30
SO SH	95.47	46.03	56.45	0.24
SO KH	134.00	64.31	78.86	0.35
SO AM	84.14	40.66	49.86	0.22
SO JA	**80.20***	**38.61***	**47.35***	**0.20***
SO AA	85.79	41.16	50.47	0.22
SO YA	81.09	38.82	47.60	0.21
SO MAM	85.65	41.22	50.55	0.22
SO MA	117.97	56.87	69.74	0.29
SO AL	102.17	49.15	60.27	0.27
SO HA	95.84	46.41	56.91	0.25
Range	**80.20 - 142.35**	**38.61 - 67.94**	**47.35 - 83.32**	**0.20 - 0.37**
Average	100.20	48.23	59.14	0.25

*The bold characters represent the minimum and maximum value

The values obtained from Table 2, the radium equivalent activity (Ra_{eq}) values for the soil samples varied from 80.20(AL JAHID region)to 142.35 (AL TAJI region) Bq/kg ,These values are less than 370 Bq/kg, which are acceptable for safe use [4].The mean absorbed gamma dose in air was calculated as average 48.23 nGy/h (min. 38.61 nGy/h and max. 67.94 nGy/h) and found to be comparable to the world average of 57 nGy/h [4]. The calculated values of external hazard index obtained range from 0.20 to 0.37, since these values are lower than unity, we can say that the radiation hazard is low. The calculated values of annual effective dose range from 0.04 to 0.08 mSv with a mean value of 0.059 mSv, which is lower than the world average of 0.48 mSv [4].

4-2 AL RASAFAH side:

The results of the variation in the activity concentration (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K radionuclides for 12 soil samples collected at various areas in AL RASAFAH side of the Baghdad city are shown in Table 3.

Table (3): specific activities of the three radionuclides in soil samples at different locations in AL RASAFAH side

Specific activity of radionuclides (Bq/kg)					
NO.	**Location**	**Samples Code**	**Ra-226**	**Th-232**	**K-40**
1	DIYLA BRIDGE	SO DI	**35.52 ± 1.21***	**30.57 ± 2.7***	527.22 ± 12.06
2	AL ZAFARANIYAH	SO ZA	28.93 ± 1.14	29.66 ± 1.8	526.38 ± 11.40
3	RASHEED MUASKIR	SO RA	21.1 ± 2.0	26.44 ± 2.8	387.42 ± 10.64
4	ZAYUNAH	SO ZAY	20.91 ± 1.09	21.48 ± 1.4	432.67 ± 10.05
5	AL MASHTAL	SOMA	18.81 ± 2.05	28.14 ± 1.9	585.85 ± 11.33
6	BALADEYAT	SO BA	22.39 ± 1.20	**19.02 ± 2.8***	366.99 ± 8.89
7	BEIRUT Sq.	SO BE	20.08 ± 1.81	23.80 ± 3.04	515.63 ± 10.46
8	MADINAT AL SADAR	SO SA	17.11± 1.04	24.41 ± 1.29	498.78 ± 11.34
9	HAYY AL QAHIRAH	SO QA	23.46 ± 2.19	27.51± 2.45	**593.74 ±11.90***
10	AL AZAMIYAH	SO AZ	**16.23 ± 1.25***	23.81 ± 1.70	346.92 ± 8.81
11	AL SULAYKH	SO SU	18.90 ± 1.32	23.14 ± 1.18	**308.99 ± 9.92***
12	AL KARRADAH	SO KA	26.70 ± 1.14	19.32 ± 1.6	479.86 ± 10.92
AVERAGE			22.51	24.77	464.20

*The bold characters represent the minimum and maximum values.

Table (3) indicate the specific activity of the radionuclides in Bq/kg ranged between 16.23 ± 1.25 and 35.52 ± 1.21 for ^{226}Ra, 19.02 ± 2.8 and 30.57 ± 2.7 for ^{232}Th and from 408.99 ± 9.92 and 693.74 ±11.90 for ^{40}K.

By applying equations.1,2,3,and 4 ,the Radium equivalent activity, dose rate, annual effective dose and external hazard index were calculated in the Table 4.

Table(4): Radium equivalent activity, dose rate, annual effective dose and external hazard index at different locations in AL RASAFAH side

Samples Code	Radium equivalent activity (Bq/kg)	Dose rate (nGy/h)	Annual effective dose (10^{-6} Sv)	External hazard index
SO DI	**119.82***	**57.37***	**70.35***	**0.32***
SO ZA	111.87	53.72	65.88	0.30
SO RA	88.73	42.30	51.87	0.23
SO ZAY	84.93	41.03	50.31	0.22
SOMA	104.16	50.58	62.03	0.27
SO BA	77.83	37.45	45.92	0.20
SO BE	93.81	45.54	55.85	0.25
SO SA	90.41	43.84	53.76	0.24
SO QA	108.50	52.66	64.58	0.29
SO AZ	76.98	36.73	45.04	0.20
SO SU	**75.78***	**35.97***	**44.11***	**0.20***
SO KA	91.26	44.33	54.36	0.24
Range	**75.78 - 119.82**	**35.97 - 57.37**	**44.11 -70.35**	**0.20 - 0.32**
Average	92.84	44.81	54.96	0.24

*The bold characters represent the minimum and maximum values.

The values obtained from Table 4, the radium equivalent activity (Ra_{eq}) values for the soil samples varied from 75.78 **(**AL SULAYKH region**)** to 119.82(DIYLA BRIDGE region)Bq/kg ,These values are less than 370 Bq/kg, which are acceptable for safe use [4].The mean absorbed gamma dose in air was calculated as 44.81 nGy/h (min. 35.97 nGy/h and max. 57.37nGy/h) and found to be comparable to the world average of 57 nGy/h [4]. The calculated values of external hazard index obtained range from 0.20 to 0.32, since these values are lower than unity, we can say that the radiation hazard is low. The calculated values of annual effective dose range from 0.04 to 0.07 mSv with a mean value of 0.054 mSv, which is lower than the world average of 0.48 mSv [4].

5- CONCLUSIONS

From lab tests, and all other gathered information, the following conclusions were drawn:

1- The measured level of the natural radiation background in the present study from the 25 investigated soil samples show that the Baghdad city have normal levels of background radiation

2- values for the Radium equivalent (Ra_{eq}), Radiation hazard index (H_{ex}) and Annual Effective dose equivalent were determined for each of the soil

samples. These indicate that the areas monitored can be regarded as having normal levels of natural background radiation.

3- Measurements of the concentration of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K revealed that the exposures in these regions are within the limits for the public. This permits the use of these soils as building materials in any probable development projects at this area.
4- There is no significant levels of radioactivity detected between the AL RASAFAH side and AL KARKH side

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تقدير جرعة أشعة كاما من النويدات المشعة ذات المنشأ الأرضي في مدينة بغداد

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الخلاصة

تقييم تركيز النشاط الإشعاع الطبيعي الأرضي في مدينة بغداد تم انجازه في هذه الدراسة،تم قياس فعالية أشعة كاما للنويدات المشعة ^{226}Ra، ^{232}Th وأيضا للنويدة المشعة طويلة العمر^{40}K في عينات التربة لمناطق مختارة في مدينة بغداد باستخدام منظومة تحليل أطياف كاما والتي تتألف من عداد الجرمانيوم عالي النقاوة ذو كفاءة 40% وقدرة فصل 2 keV للطاقة 1.33 MeV للقمة الضوئية لنظير ^{60}Co ،جمع ، تحضير وفحص لـ 25 نموذج تربة تم طبقا لتعليمات الوكالة الدولية للطاقة الذرية وكان زمن قياس النماذج 3600 ثانية. تراوح النشاط الإشعاعي النوعي من (20.07± 1.86) إلى (41.10± 2.12) بكرل/ كغم لـ Ra ^{226}، من (17.21± 1.95) إلى (38.19 ±2.42) بكرل/كغم لـ Th ^{232} و(346.12± 8.19) إلى (613.97 ±10.00) بكرل/كغم لـ ^{40}K ومتوسط القيم هي (27.94) بكرل/كغم، (25.24) بكرل/كغم و(476.65) بكرل/ كغم،على التوالي في جانب الكرخ، بينما تراوح النشاط الإشعاعي النوعي من (16.23± 1.25) إلى (35.52± 1.21) بكرل/ كغم لـ Ra ^{226}،(2.8 ±19.02) إلى (30.57 ±2.7) بكرل/ كغم لـ Th ^{232} و(308.99± 9.92) إلى (593.74 ±11.90) بكرل / كغم لـ ^{40}Kومتوسط القيم هي (22.51) بكرل/ كغم، (24.77) بكرل/ كغم و(464.20) بكرل/ كغم، على التوالي في جانب الرصافة .

تم حساب معدل مكافئ النشاط الإشعاعي لـ Ra_{eq} ، معدل الجرعة الممتصة لأشعة كاما في الهواء(D)، الجرعة السنوية الفعالة ودليل الخطر الإشعاعي الخارجي وكانت النتائج(95.84) بكرل/كغم، (46.41) نانو كري/ ساعة،(56.91×10^{-6}) سيفرت، (0.25) على التوالي في جانب الكرخ و(92.84) بكرل / كغم،(44.81) نانو كري/ ساعة، (54.96×10^{-6}) سيفرت، (0.24) في جانب الرصافة على التوالي.

أخيرا قورنت النتائج بالقيم المتوسطة العالمية المقبولة (UNSCEAR 2000)، وطبقا لنتائج هذه الدراسة يمكن أن نعتبر مدينة بغداد ضمن المناطق ذات الخلفية الإشعاعية الطبيعية والتي تشمل الأشعة الكونية المتأتية من الفضاء الخارجي والنويدات المشعة الموجودة في قشرة الأرض .