Assessment of Natural Radioactivity Levels and Radiological Hazards for Tigris River Basin

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ABSTRACT

Activity concentrations of ^{226}Ra (of ^{238}U series), (^{232}Th) and (^{40}K) in some soil samples along Tigris River basin were determined and evaluated. The measurements were carried out using high purity germanium (HPGe) detector. The mean activity concentrations in soil samples were 18.2, 16.4 and 375 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K, respectively. The absorbed dose rates (D), mean annual effective dose equivalent (AEDE), radium equivalent activity (Ra_{eq}), external and internal hazard indices (H_{ex} and H_{in}) were evaluated to be 34.2 nGy/h, 0.042 mSv/y, 71 Bq/kg, 0.19 and 0.24, respectively, well within the relevant permissible limits of 59nGy/h for D, 1 mSv/y for AEDE, 370 Bq/kg for Ra_{eq}, and 1 for H_{ex} and H_{in}. Accordingly, it is concluded that the natural radioactivity levels for Tigris River basin in Baghdad city satisfy safety radiation dose limit for.

Keywords: Natural Radioactivity; Radiological Hazards; Tigris River

تقييم مستويات النشاط الاشعاعي الطبيعي والمخاطر الاشعاعية في حوض نهر دجلة

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الخلاصة

الهدف من هذه الدراسة هو تقييم تراكيز نظير الراديوم ^{226}Ra (من سلسلة اليورانيوم ^{238}U) ، و سلسلة الثوريوم ^{232}Th ونظير البوتاسيوم ^{40}K في نماذج تربة منتخبة من حوض نهر دجلة في بغداد. استخدم كاشف الجرمانيوم عالي النقاوة HPGe في مختبر القياسات والتحاليل في وزارة العلوم والتكنلوجيا – مديرية السلامة الاشعاعية والنووية لقياس تراكيز النظائر المشعة في نماذج التربة ، وكانت معدلات التراكيز (375,16.4,18.2 بكريل /كغم) لنظائر الراديوم ^{226}Ra، ^{232}Th والبوتاسيوم ^{40}K على التوالي وتم حساب معدل الجرع الأشعاعية الفعالة الممتصه(D) وكانت بحدود 34.2(nGy/h) ، معدل الجرعه السنوية الفعالة (AEDE) كانت بحدود 0.04 mSv/y , مؤشر مكافيء الفعالية للراديوم Ra_{eq} هو 71Bq/kg ، مؤشرات الخطورة الخارجية هو 0.19 والداخلية وكانت بحدود 0.24 وهي تعتبر ضمن الحدود المسموح بها بالمقارنة بالحدود المسموح بها عالميا والتي هي(59(nGy/h، 1mSv/y، Bq/kg 370 و 1 لل D,AEDE، Ra_{eq}، H_{ex}وH_{in}على التوالي. وتبين من نتائج هذه الدراسة ان مستويات النشاط الاشعاعي الطبيعي لحوض نهر دجلة في بغداد ضمن الحدود المسموح بها عالميا لتعرض عامة السكان.

الكلمات المفتاحية : النشاط الاشعاعي الطبيعي ، المخاطر الأشعاعية، نهر دجلة.

Introduction

Human beings are exposed to ionizing radiation from natural sources throughout their lifetime, and sometime from man-made sources [1]. Therefore, the knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmologenic sources. Natural sources of radiation constitute almost 80% of the collective radiation exposure of the World's population [2]. Terrestrial background radiation represents the main external source of irradiation of the human body. Human beings are exposed also naturally from sources outside their bodies; mainly cosmic rays and gamma rays emitters in soil, building materials, water, food and air [1]. Significant amount of manmade Radionuclides ^{137}Cs, ^{131}I and ^{90}Sr may also present in the environment as a result of testing of nuclear weapons in the atmosphere, accidents such as the Chernobyl accident and the Japan nuclear power plant disaster, and the routine discharge of radionuclides from nuclear installations [3]. Once present in the environment, these Radionuclides whether natural or man-made are available for uptake by plants and animals and find their way into human body through the food chain [4]. The aim of this study is to assess the environmental natural radioactivity level in surface soils and sediments collected along Tigris River basin in Baghdad city, Iraq. This area falls within the agricultural, industrial and urban communities and tourist area which makes this study worthy. It also aims to establish a data baseline for the area under investigation.

Materials and Methods

1. Preparation of Samples and Samples Analysis

Twenty four soil samples were collected from different locations along Tigris River basin for radiometric analysis as show in figure 1. The twenty four samples each about 1 kg in weight, were ground, homogenized and sieved to about 1 mm mesh size by a crushing machine. The soil samples were air dried and kept in oven for 24 hours at 110°C. Weighed samples were placed and stored in polyethylene Marnillie beakers of 500 ml volume for at least one month to measurement to achieve the secular equilibrium between ^{226}Ra and ^{232}Th and their progeny and then the gamma ray spectrum was accumulated to 3600 sec. The collected samples were analyzed in the Laboratories of Ministry of Science and Technology/ Radiation and Nuclear Safety Directorate using High purity germanium detector HPGe [5] with detector efficiency of 40%and (3"x3") crystal dimension Genie 2000 software was used to analyze the spectrum. The Gamma-energy lines of 351.9(37.2%) keV from ^{214}Pb and 609.3(46.3%) keV, 1120.3(15.1%) keV and 1764.5(16%) keV from ^{214} Bi were used to represent ^{226}Ra.While 238.6(44.6%) keV from ^{212}Pb, 338.4(12%) keV and 911.2(29%) keV from ^{228}Ac were used to represent ^{232}Th series and 1460.8(10.67%) keV was used to represent ^{40}K. The activity concentrations of the radionuclides of concern were calculated using equation below [6]:

$$A_C = \frac{A_{net}}{I_\gamma(E_\gamma) \times E_{ff}(E_\gamma) \times T \times M}$$

Where Anet is the A_c is the net peak counts (detector background subtracted). Iγ (Eγ) is the absolute gamma decay intensity (emission probability) for the specific energy peak, also known as abundance at energy Eγ. E_{ff} (Eγ) is the efficiency of the detector at energy Eγ. T is the counting time (3600 sec). M is the mass of the sample in kg.

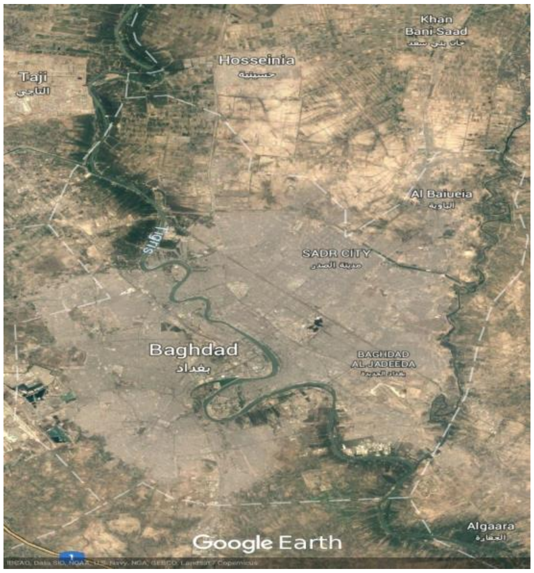

Figure (1) Location of selected samples from Tigris River in Baghdad

2. Radiological Hazards Assessment

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K measured in each of the analyzed samples indicate the quantity of radioactivity present but do not provide a measure of radiation hazard. The hazard associated with radioactivity in samples is assessed through hazard indices. A hazard index is a parameter that is represented by a single value that takes into account the measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the sample. The various types of radiological hazard indices are the radium equivalent activity, external and internal hazard indices, annual effective dose and total absorbed dose rate.

3. Radium equivalent activity index (Ra_{eq})

To represent the activity levels of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced [7]. This Index is called Radium equivalent (Ra_{eq}) activity and is mathematically defined by [2] [8]:

$$Raeq = C_{Ra} + 1.43C_{Th} + 0.077C_{K}$$

Where C_{Ra}, C_{Th} and C_{K} are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively. In the above relation, it has been assumed that 10 Bq/kg of ^{226}Ra, 7 Bq/kg of ^{232}Th and 130 Bq/kg of ^{40}K produce equal gamma dose. The maximum value of Ra_{eq} in soil must be less than 370 Bq/kg.

4. Absorbed dose rate (D)

in outdoor (D) due to gamma radiations in air at 1m 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 [2]. The conversion factors used to compute absorbed dose rate (D) in air per unit activity concentration in Bq/kg (dry-weight) corresponds to 0.462 nGy/h for ^{226}Ra (of U- series), 0.621 nGy/h for ^{232}Th and 0.0417 nGy/h for ^{40}K [2]; [8-10]:

$D\ (nGy/h) = 0.462\ C_{Ra} + 0.621\ C_{Th} + 0.0417\ C_{K}$. The recommended limit for the absorbed dose rate is 59 nGy/h [2].

5. Annual effective dose equivalent (AEDE)

To estimate the annual effective dose rates outdoor, one has to take into account the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv/Gy) and outdoor occupancy factor (0.2) proposed by [2]. Therefore, the annual effective dose rate (mSv/y) was calculated by the formula [2], [7-9]:

$$\text{Effective dose rate (mSv/y)} = D\ (nGy/h) \times 8760\ (h/y) \times 0.7\ (Sv/Gy) \times 0.2 \times 10\text{-}6 \qquad (3)$$

6. External hazard index (H_{ex})

A widely used hazard Index (reflecting the external exposure) called the external hazard index H_{ex} is defined as follows [2], [7-8]:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (4)$$

7. Internal hazard index (H_{in})

In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter progenies is quantified by the internal hazard index H_{in}, which is given by the equation [2][11]:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (5)$$

The values of the indices (H_{ex}, H_{in}) must be less than unity for the radiation hazard to be acceptable [8]

Results and Discussion

Analyzing the samples of Tigris River basin, the activity concentrations for the measured. Radionuclides of ^{226}Ra, ^{232}Th and ^{40}K are obtained (table 1). The activity concentration values of ^{226}Ra, ^{232}Th and ^{40}K are varied from 12.2 to 28.6, 9.12 to 22.62, and 269 to 428 Bq/kg, respectively. The mean activity concentrations of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K are 0.51, 0.54 and 1.07 times of the world wide average concentrations of these Radionuclides of 35, 30 and 400 Bq/kg, respectively (UNSCEAR 2000).

Table 1 gives the radium equivalent (Ra_{eq}) in (Bq/kg), external H_{ex} and internal H_{in} hazard indices, dose rate in (nGy/h), and annual effective dose equivalent in (mSv/y). The calculated values of radium equivalent index (Ra_{eq}) ranged from 50 to 84 Bq/kg, which are lower than the recommended limit of 370 Bq/kg (UNSCEAR 2000). The calculated values of external and internal hazard indices are ranged from 0.13 to 0.23 and from 0.17 to 0.30, respectively. Both are lower than unity that keeps the radiation hazard acceptable.

The values of absorbed dose rate are ranged from 24.1 to 40.7 nGy/h which is lower than the recommended limit (59 nGy/h) (UNSCEAR 2000). Table 1 also presents the estimated annual effective dose equivalent range from 0.03 to 0.05 mSv/y, which is lower than the world wide average annual effective dose approximately 0.5 mSv/y [2]. Figures 2, 3 and 4 show that the evaluated radiological hazard indices are much less than the relevant permissible limits.

Table (1) Average activity concentrations of (^{226}Ra, ^{232}Th and ^{40}K) Bq/kg, absorbed dose rate in (nGy/h), annual effective dose equivalent (AEDE) in (mSv/y), radium equivalent index in (Bq/kg), external and internal hazard indices (H_{ex} and H_{in})

Sample No.	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	D (nGy/h)	AEDE (mSv/y)	Ra_{eq}	Hazard indices	
							H_{ex}	H_{in}
1	18.14±0.81	14.62±0.69	379.45±14.76	33.3	0.041	68	0.18	0.23
2	19.23±0.84	22.62±0.91	426.03±16.47	40.7	0.050	84	0.23	0.28
3	18.04±0.75	16.95±0.92	400.10±16.37	35.5	0.044	73	0.20	0.25
4	21.46±0.91	18.31±0.80	407.69±15.14	38.3	0.047	79	0.21	0.27
5	15.89±0.65	14.90±0.69	344.12±14.64	30.9	0.038	64	0.17	0.21
6	16.21±0.71	16.93±0.79	423.35±16.97	35.6	0.044	73	0.20	0.24
7	17.52±0.61	17.40±0.93	356.17±14.87	33.7	0.041	70	0.19	0.24
8	18.74±0.50	15.69±0.82	397.05±15.49	35.0	0.043	72	0.19	0.24
9	17.42±0.12	16.76±0.83	353.97±14.24	33.2	0.041	69	0.19	0.23
10	19.04±0.51	17.28±1.03	376.54±17.99	35.2	0.043	73	0.20	0.25
11	19.94±0.53	16.55±0.69	340.03±12.91	33.7	0.041	70	0.19	0.24
12	15.21±0.41	15.16±0.70	330.89±13.33	30.2	0.037	62	0.17	0.21
13	12.24±0.32	11.68±0.57	269.33±10.85	24.1	0.030	50	0.13	0.17
14	16.24±0.51	18.62±0.83	341.93±13.90	33.3	0.041	69	0.19	0.23
15	17.23±0.41	16.32±0.87	386.22±15.23	34.2	0.042	70	0.19	0.24
16	18.24±0.77	20.79±0.93	381.82±15.52	37.2	0.046	77	0.21	0.26
17	19.48±0.49	15.56±0.71	356.21±12.44	33.5	0.041	69	0.19	0.24
18	18.54±0.59	17.64±0.96	360.58±13.14	34.5	0.042	71	0.19	0.24
19	15.51±0.64	12.26±0.62	382.99±13.90	30.7	0.038	62	0.17	0.21
20	17.64±0.75	15.44±0.74	428.97±16.18	35.6	0.044	73	0.20	0.24
21	18.53±0.74	17.44±0.80	389.08±15.01	35.6	0.044	73	0.20	0.25
22	21.41±0.82	18.54±0.86	419.80±17.58	38.9	0.048	80	0.22	0.27
23	16.21±0.78	9.12±0.59	378.37±13.47	28.9	0.035	58	0.16	0.20
24	28.64±0.95	16.60±0.84	382.12±14.59	39.5	0.048	82	0.22	0.30
Mean	18.20±0.63	16.40±0.79	375.44±14.79	34.2	0.042	71	0.19	0.24
Minimum	12.24±0.32	9.12±0.59	269.33±10.85	24.1	0.030	50	0.13	0.17
Maximum	28.64±0.95	22.62±0.91	428.97±16.18	40.7	0.050	84	0.23	0.30

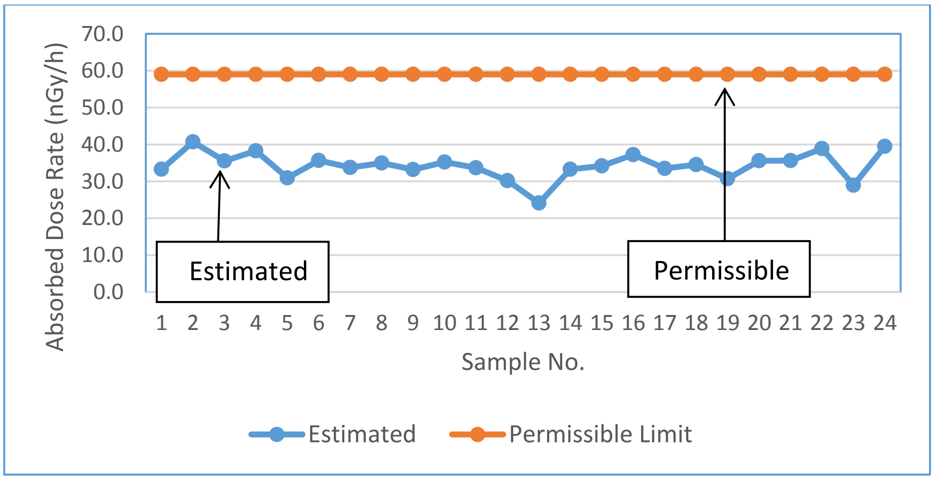

Figure (2) Comparison between the estimated absorbed dose rate with the relevant permissible limit

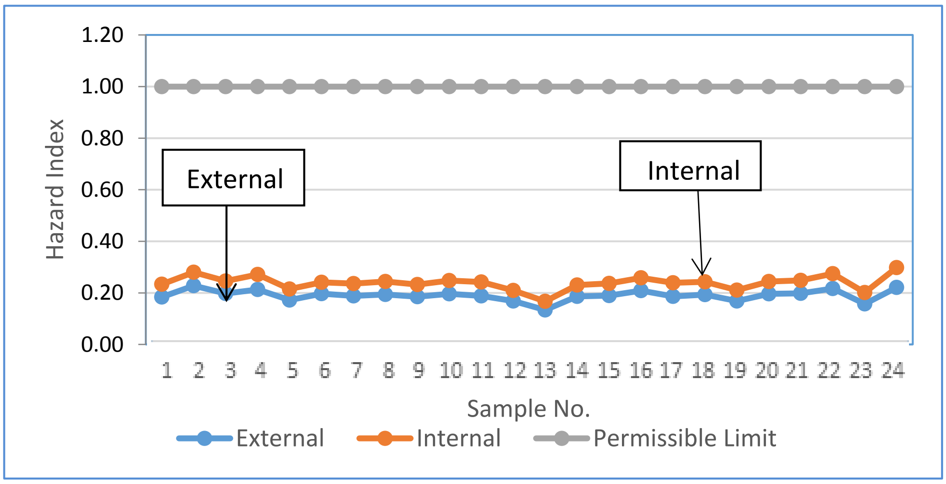

Figure (3) Comparison between the estimated internal and external hazard indices with the relevant permissible limit

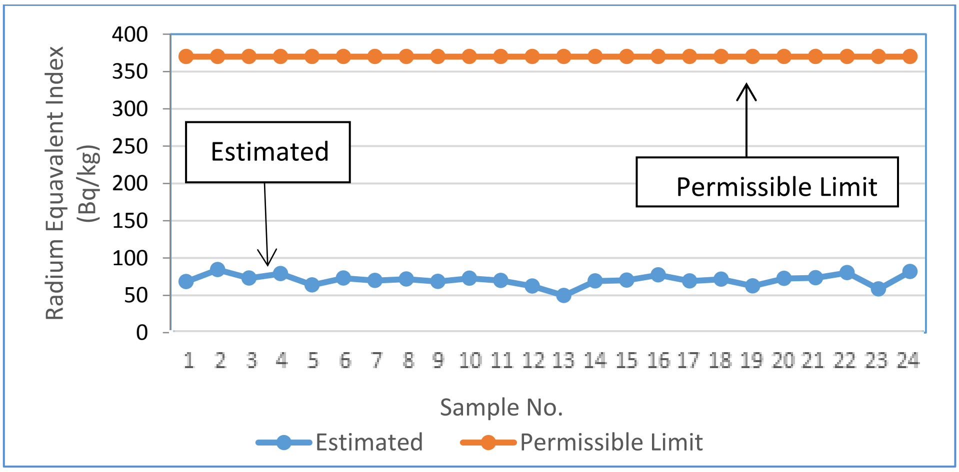

Figure (4) Comparison between the estimated radium equivalent index with the relevant permissible limit

Conclusions

The levels of naturally occurring radioactivity in surface soil and sediments samples collected from Tigris River basin in Baghdad was evaluated using HPGe spectrometry. The results show that the mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soils and sediments of Tigris River basin are comparable to reported world-wide range and mean values identified in UNSCEAR 2000 report. For ^{40}K, the mean measured activity concentrations (375 Bq/kg) is low compared to the worldwide mean value (420 Bq/kg). The use of fertilizers in large extent in agricultural soils has not affected radionuclides concentration (especially potassium containing fertilizers are one of the causes of presence of high activity of ^{40}K in soil). Also, the results can be useful in the assessment of the radium equivalent index (Ra_{eq}), external (H_{ex}) and internal (H_{in}) hazard indices, absorbed dose rate (D) and annual effective dose equivalent (AEDE).The mean annual effective dose equivalent (AEDE), radium equivalent activity (Ra_{eq}), external and internal hazard index (H_{ex} and H_{in}) were evaluated, well within the relevant permissible limits of 1 mSv/y for AEDE, 370 Bq/kg for Ra_{eq}, and 1 for H_{ex} and H_{in}. Accordingly, it is concluded that the natural radioactivity levels for Tigris River basin satisfy safety radiation dose limit for public exposure.

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