# Estimation of Natural Radioactivity in Surface Soil Samples from Baghdad, Nahrain and Al-Mustansiriyah Universities Using Gamma-Ray Spectroscopy

**Ali Abdulwahab Ridha*** **Mahdi M. Mutter****
**Manar Dheyaa Salim*****

*** AL-Mustansiriyah University/ College of Science/ Physics Department**
**dr.aliabdulwahab@yahoo.com**
**** Ministry of Science and Technology, Physics Application Center, Nuclear Application Department**
*****Thi-Qar University/ College of Science/ Physics Department**

**Abstract:**

The study of natural radioactivity in public universities surface soil sample is very important because of containing a large numbers of students and personnel in small areas and for long periodic times, especially the centers and gathering student's areas. So it was chosen the most important Universities in Baghdad city according to the student's density, which is Baghdad and Nahrain University in Al-Jadriyah region in addition to Al-Mustansiriyah University in Palestine street region. Sixteen surface soil samples collected from these regions to estimate the radiological impact to the dweller, the concentrations of $^{238}$U, $^{232}$Th and $^{40}$K present in the soil samples were analyzed using NaI(Tl) detector as Gamma-spectrometry. The results showed that the averages radioactivity of $^{238}$U are (38.264, 24.785 and 10.291) Bq/kg, for $^{232}$Th are equal to (32.498, 21.933 and 8.147) Bq/kg and for $^{40}$K are (268.543, 394.397 and 216.558) Bq/kg for Baghdad, Nahrain and Al-Mustansiriyah Universities respectively. Thus, the values of specific activity of $^{238}$U, $^{232}$Th and $^{40}$K for all soil samples are in the ranges of the worldwide average. The maximum value for $Ra_{eq}$ is (119.727 Bq/kg) recorded in the College of Physical Education - Baghdad University (sample B2), with an average value of all soil samples (76.535 Bq/kg), which below the global and European permissibility limit (370 and 247) Bq/kg respectively. In addition to radium equivalent, the absorbed gamma dose rate ($D_{\gamma}$), outdoor annual effective dose and hazard indices (internal and external) are calculated in this work and show low values compared with permissible limits.

**Keywords:** Natural activity, Environment, Gamma spectroscopy.

# تقدير النشاط الإشعاعي الطبيعي في عينات تربة سطحية من جامعات بغداد، النهرين والمستنصرية باستخدام مطيافية اشعة كاما

علي عبد الوهاب رضا* مهدي محمود مطر** منار ضياء سالم***

* الجامعة المستنصرية/ كلية العلوم/ قسم الفيزياء
** وزارة العلوم والتكنولوجيا/ مركز الفيزياء التطبيقية/ قسم التطبيقات النووية
*** جامعة ذي قار/ كلية العلوم/ قسم الفيزياء

**الخلاصة:**

ان دراسة النشاط الإشعاعي الطبيعي في نماذج تربة سطحية من الجامعات مهم جدا بسبب كونها تحتوي على أعداد كبيرة من الطلاب والموظفين في مساحات صغيرة ولأوقات طويلة نسبيا، وخاصة في مناطق الساحات المركزية ومناطق تجمع الطلاب. لذلك تم اختيار ثلاث جامعات مهمة في مدينة بغداد وفقا لكثافة الطلاب، والتي تمثل جامعة بغداد والنهرين في منطقة الجادرية بالإضافة إلى الجامعة المستنصرية في منطقة المستنصرية. تم اخذ ١٦ عينة تربة سطحية لهذه الجامعات وذلك لتقدير الأثر الإشعاعي للطلاب والعاملين هناك، وقد حللت تراكيز نشاط النويدات المشعة الطبيعية ($^{238}U$, $^{232}Th$, $^{40}K$) الموجودة باستخدام كاشف NaI(Tl) كمحلل لاشعة كاما. أظهرت النتائج أن معدلات تراكيز الـ $^{238}U$ كانت Bq/kg(٣٨,٢٦٤، ٢٤,٧٨٥ و ١٠,٢٩١)، وللـ $^{232}Th$ Bq/kg (٣٢,٤٩٨، ٢١,٩٣٣ و ٨,١٤٧) بينما كانت معدلات الـ $^{40}K$ هو Bq/kg (٢٦٨,٥٤٣، ٣٩٤,٥٤٣ و ٢١٦,٥٥٨) بالنسبة لجامعات بغداد، النهرين والمستنصرية على التوالي. ولذا فإن قيم تراكيز العناصر المشع الطبيعية لجميع عينات التربة هو ضمن من المعدلات العالمية.

ان اعلى قيمة لمكافئ الراديوم ($Ra_{eq}$) هي (119.727 Bq/kg) سجلت في كلية التربية الرياضية – جامعة بغداد (العينة B2) وبمعدل (76.535 Bq/kg) لجميع العينات حيث كان مكافئ الراديوم لجميع العينات اقل من الحد المسموح به عالمياً (370 Bq/kg) بالاضافة الى الحد الاوربي (247Bq/kg). تم ايضا حساب معدل الجرعة الممتصة ($D_\gamma$)، الجرعة الفعالة السنوية ($E_\gamma$)، ومعاملي الخطورة (الداخلي والخارجي) وقد ظهرت اعلى القيم عند العينة (B2) والتي كانت واطئة مقارنة مع الحدود المسموح بها عالميا.

***Introduction***

People are exposed to nuclear radiation every day in their lives. Some of this radiation is from natural sources, and others are from artificial sources.[1] One of the scientific subjects that attract most public attention is human exposure to ionizing radiation. Since radiation of natural origin is responsible for most of the total radiation exposure of the human population [2].

The naturally occurring radionuclides on earth are therefore those with relatively long half-lives, and these can be divided into those which occur singly and those which are components of three distinct decay series. Of the former the most important is $^{40}$K, with a half-live of $1.27\times10^{9}$ years [3]. Natural occurring radionuclides materials (NORMs) are known to be present in rocks and soils. These radionuclides such as $^{238}$U and $^{232}$Th or their progenies and also $^{40}$K can be originated in the primordial era. Since their half-lives are very long (up to $10^{10}$ years), their presence in soils and rocks can simply be considered as permanent. Human activity such as mining and oil exploration can further increase the originally low concentration, to a more noticeable level (TENORM) [4]. Naturally occurring radionuclides of terrestrial origin primordial radionuclides are present in various degrees in all media of the environment, including the human body himself. Only those radionuclides with half-lives comparable to the age of the earth, and their decay products, exist in significant quantities in these materials.

Irradiation of the human body from external sources is mainly by γ-radiation from radionuclides in the $^{238}$U and $^{232}$Th series and from $^{40}$K. These radionuclides are also present in the human body from ingestion and inhalation, and irradiate the various organs with α- and β-particles, as well as γ-rays. Some other terrestrial radionuclides, including those of the $^{235}$U series, $^{87}$Rb, $^{138}$La, $^{147}$Sm and $^{176}$Lu, exist in nature but at such low levels that their contributions to the dose in humans are small [5]. External exposure outdoors arise from terrestrial radionuclides present at trace levels in all soils depending on the types of rock from which the soils originate. Gamma-spectrometric measurements indicate that the three components of the external radiation field, i.e. from the γ-emitting radionuclides in the $^{238}$U and $^{232}$Th series and $^{40}$K, make approximately equal contributions to the externally incident γ-radiation dose to individuals in typical situations both outdoors and indoors. The activity concentration of $^{40}$K in soils is an order of magnitude higher than that of $^{238}$U or $^{232}$Th series. UNSCEAR suggested median values for $^{238}$U, $^{232}$Th and $^{40}$K of (35, 30 and 400) Bq/kg respectively, based on corresponding dose coefficients of (0.0417, 0.462 and 0.604) nGy/h per Bq/kg[6].

***Theoretical Basis***

1- ***Specific activity ($A_i$)***

The activity concentration of each radionuclide was calculated by the following equation[7]:

$$A_i = \frac{N}{I_\gamma . \varepsilon . m . t} \qquad \ldots(1)$$

Where $A_i$ the activity concentration of the i radionuclides (Bq/kg), N is the net peak area at the specific energy, $I_\gamma$ the absolute transition probability of gamma decay, ε the detector efficiency for the specific gamma-ray energy, m the mass of sample (kg) and t is the time of measurement in second.

2- ***Radium equivalent activity ($Ra_{eq}$)***

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 in Bq/kg unit, to compare the specific activity of materials containing different amounts of $^{226}Ra$, $^{232}Th$ and $^{40}K$. The radium equivalent activity was considered as [8]:

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \qquad \ldots (2)$$

Where, $A_U$, $A_{Th}$ and $A_K$ are the activities of $^{238}U$, $^{232}Th$ and $^{40}K$ respectively. The global maximum dose $Ra_{eq}$ in soil must be less than 370 Bq/kg for safe use [8].

***3- Absorbed gamma dose ($D_\gamma$)***

The absorbed dose rates due to γ-radiation in air at 1m above the ground surface for a uniform distribution of the naturally occurring radionuclides ($^{238}U$, $^{232}Th$ and $^{40}K$) were calculated. We assumed that the contributions from other naturally occurring radionuclides to actual dose rates were insignificant. The absorbed gamma dose $D_\gamma$ in air was calculated using the expression below [8]:

$$D_\gamma = 0.462A_U + 0.604A_{Th} + 0.0417A_K \qquad \ldots (3)$$

***4- External annual effective dose ($E_\gamma$)***

The annual effective dose rates ($E_\gamma$) is an important parameter in order to judge the health effects of the absorbed dose. To estimate the effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv/Gy) proposed by (UNSCEAR 2000 and 2008 reports)[6,9] are used. For outdoor occupancy factor (0.2) proposed in ref. (Veiga et al., 2006) [10], the annual effective dose rates ($E_\gamma$) has been obtained [11]:

$$E_\gamma \,(mSv/y) = D_\gamma \,(nGy/h) \times 10^{-6} \times 8760\ h/y \times 0.2 \times 0.7\ Sv/Gy \qquad \ldots (4)$$

***5- Internal hazard index ($H_{in}$)***

The internal exposure to ${}^{222}_{86}Rn_{136}$ and its radioactive progeny is controlled by the interned hazard index ($H_{in}$)[7].

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad \ldots(5)$$

***6- External hazard index ($H_{ex}$)***

To limit the annual external gamma-ray dose to 1.5mSv/y (UNSCEAR, 2000)[6], the external hazard index ($H_{ex}$) is given by the following equation[7]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad \ldots(6)$$

For the safety, the maximum values of ($H_{in}$ and $H_{ex}$) should be less than unity[7].

***<u>Experimental</u>***

Thirteen soil samples were collected from the surface of different sites of Baghdad and Nahrain University in Al-Jadriya region in addition to Al-Mustansiriyah University in Al-Mustansiriyah region, which are big Universities in Baghdad city-Iraq. 6 samples denoted by (B) for Baghdad University, 2 samples (N) for Nahrain University and 5 samples (M) for Al-Mustansiriyah University as shown in Figures (1 and 2). The location, longitude and latitude of each sample were be found by using Global Positioning System (GPS) method as listed in Table (1).

The samples were grounded into a fine powder with a particle size less than 600μm and then dried in a temperature-controlled furnace at 150 $^{o}$C for 4 h to remove moisture. Each sample of volume 1 L stored in a sealed polyethylene marinelli beaker for 30 days to achieve the secular equilibrium. This marinelli beaker was used as sampling and measuring container. Before use, the containers were washed with hydrochloric acid and rinsed with distilled water.

The activities of radionuclides $^{238}U$, $^{232}Th$ and $^{40}K$ for surface soil samples were determined by using gamma rays spectrometry NaI(Tl) detector system which is an order of International Atomic Energy Agency (IAEA), Germany origin, the details of this system is as follow:

1- SCIONIX model 51S51, 2"x2" NaI(Tl) detector
2- Bright SPEC model bMCA (plug-on multichannel analyzer)
3- Laptop PC Fujitsu Lifebook N532 HD+AB

4- SODIGAM, software for high-precision analyzer, USB-Hardlock SC2

The determination of $^{238}U$, $^{232}Th$ and $^{40}K$ activity in soil samples is based upon the detection of 1765, 2614 and 1460 keV gamma rays emitted by $^{214}Bi$, $^{208}Tl$ and $^{40}K$, respectively.

Background activities for the three selected energies were subtracted from the sample's readings in order to assess the true activities of each isotope. To reduce the background effect the detector was enveloped by 5cm thickness layer of lead covering. The measurement time for each sample was 14400 s.


Figure (1): A satellite map of Baghdad and Nahrain Universities, Showing the points which samples were collected from.

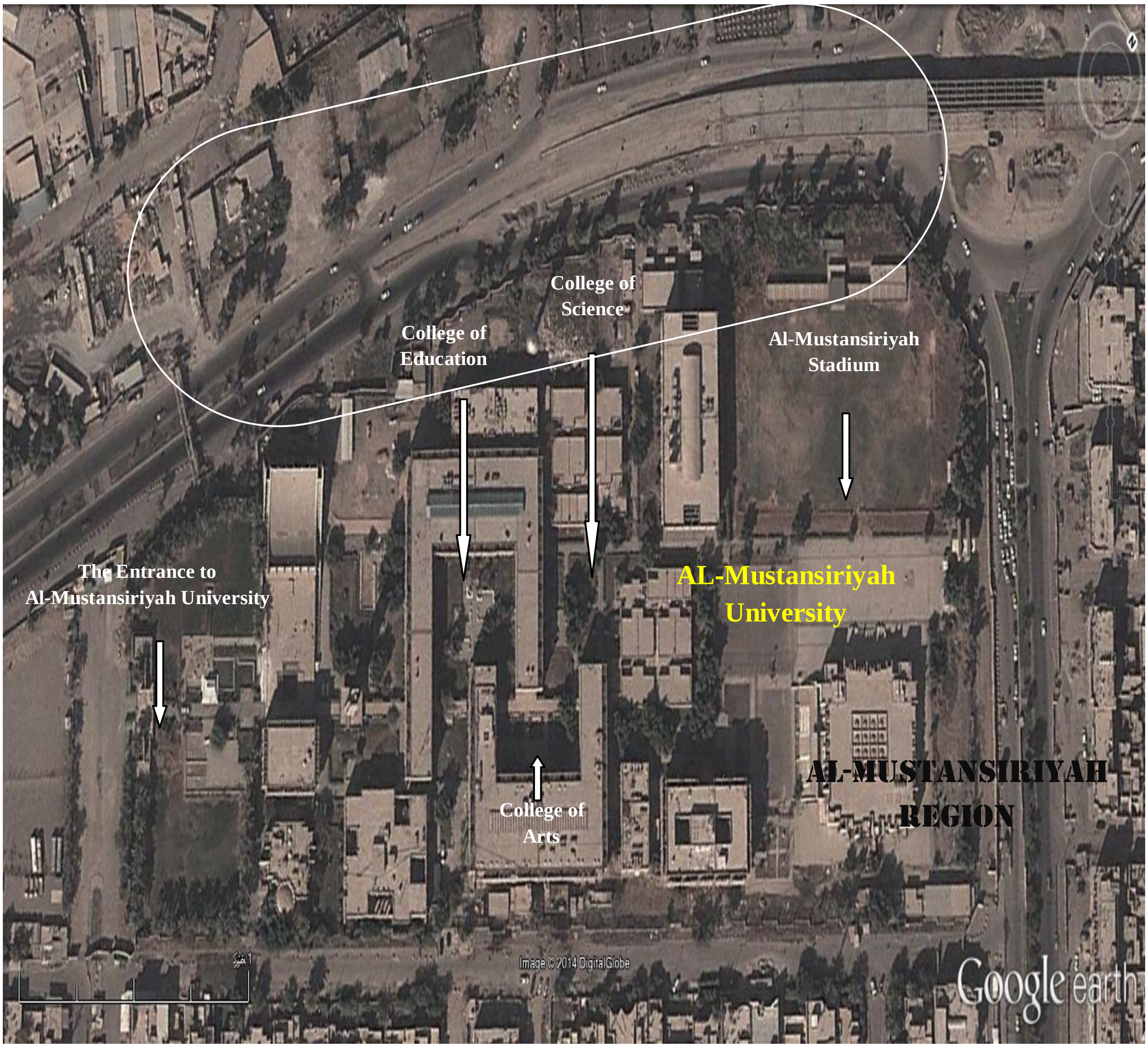


Figure (2): A satellite map of Al-Mustansiriyah University, Showing the points which samples were collected from.

***Results and discussion***

The measured range and average values of specific activity for $^{238}U$, $^{232}Th$ and $^{40}K$ radioactivity to Baghdad, Nahrain and Al-Mustansiriyah Universities of surface soil samples are given in Table (1). It can be seen that the specific activity for all samples to $^{238}U$ ranges from below detection limit (B.D.L.) in sample (M5) to 57.145±7.56 Bq/kg in sample (B2), with an average value of 26.312±5.13 Bq/kg, the specific activity of $^{232}Th$ varies from (B.D.L.) in (M1 and M3) to 44.247±6.65 Bq/kg in sample (B5), with an average value of 23.507±4.85Bq/kg and for $^{40}K$ lies between 89.412±9.46 Bq/kg in (M5) to 658.682±25.66Bq/kg in (N3), with an average of 291.627±17.08 Bq/kg. Thus, the average value of specific activity of $^{238}U$, $^{232}Th$ and $^{40}K$ for all soil samples lie in the range of the worldwide average 35, 30 and 400 Bq/kg respectively [6].

Figure (3) shows the specific activity for all soil samples to comparing with the recommended average values of each radionuclide represented by the dot line (red for U-238, blue for Th-232 and green for K-40). It is clear that the maximum value of $^{238}U$ lie in the College of Physical Education/ Baghdad University (B2) sample, for $^{232}Th$ lie in College of Science for Women/ Baghdad University (B5) sample, while the maximum value of $^{40}K$ was in College of Science/ Nahrain University (N3) sample.

The radium equivalent activities of soil samples are calculated and listed in Table (2). The minimum value is 19.703 Bq/kg noted in sample (M5) and the maximum value is 119.727 Bq/kg recorded in sample (B2), with an average value of 76.535 Bq/kg. All soil samples has $Ra_{eq}$ value lower than 247Bq/kg or 370Bq/kg (European and global permissibility limit) respectively, which is due to low content of $^{238}U$, $^{232}Th$ and $^{40}K$ in the samples[9].

Table (2) also includes the absorbed dose rate, annual outdoor effective dose, and hazard indices. The absorbed dose rate is found to vary from 9.143 to 54.656 nGy/h, with an average value of 35.981 nGy/h which is lower than the worldwide average (55 nGy/h) [6].

The calculated annual outdoor effective doses range from 0.011 to 0.067 mSv/y with average value of 0.044mSv/y; all values of annual outdoor effective dose are less than the global limit (1mSv/y). While the internal and external hazard index varies from 0.053 to 0.478 and 0.053 to 0.323, with an average of 0.273 and 0.207 respectively, all of them are less than unity (the permissibility value). Figure (4) contents a comparison of $Ra_{eq}$, $D_{\square}$, outdoor annual effective dose and hazard indices with the permissible limits or average of each one represented by the dot line (red for global limits of ($E_{\gamma}$, $H_{in}$ and $H_{ex}$), blue for worldwide average of $D_{\gamma}$ and green for European limit for $Ra_{eq}$).

***Conclusions***

The soil samples from the three Universities have low concentrations of natural radionuclides; this is reflecting the nature of Iraqi geological surface which has been in agreement with the most researches in this field. In general, it is clear that Baghdad and Nahrain Universities soil has higher concentration than Al-Mustansiriyah University and this may be due to the nearest from Daurah Refinery (INOC) and Tigris river, but although of these reasons, all soil samples of the three Universities were in the range of the worldwide average and it is safe for any students and peoples working there because of, all the hazard indices have lower values compared with the global permissibility limit.

Table (1): Sample code, location, longitude and latitude of soil samples, in addition to the specific activity of $^{238}U$, $^{232}Th$ and $^{40}K$ radionuclides.

| No. | Sample code | Location | Longitude (East) | Latitude (North) | $^{238}U$ (Bq/kg) | $^{232}Th$ (Bq/kg) | $^{40}K$ (Bq/kg) |
|---|---|---|---|---|---|---|---|
| 1 | B1 | The entrance to Baghdad University | 44°23'8.28" | 33°16'47.50" | 37.742±6.14 | 24.978±5.00 | 277.921±16.67 |
| 2 | B2 | College of Physical Education | 44°23'3.38" | 33°16'31.04" | 57.145±7.56 | 33.072±5.75 | 198.553±14.09 |
| 3 | B3 | College of Science | 44°22'46.49" | 33°16'30.11" | 31.846±5.64 | 28.138±5.30 | 412.134±20.30 |
| 4 | B4 | College of Engineering | 44°22'30.40" | 33°16'26.93" | 26.995±5.20 | 24.188±4.92 | 260.475±16.14 |
| 5 | B5 | College of Science for Women | 44°22'55.83" | 33°16'17.03" | 39.112±6.25 | 44.247±6.65 | 144.850±12.04 |
| 6 | B6 | College of Political Science | 44°22'35.90" | 33°16'11.81" | 36.746±6.06 | 40.367±6.35 | 317.324±17.81 |
| Average of Baghdad University Soil Samples | | | | | 38.264±6.186 | 32.498±5.70 | 268.543±16.39 |
| 7 | N1 | The entrance to Nahrain University | 44°22'38.97" | 33°16'35.86" | 29.839±5.46 | 12.558±3.54 | 245.016±15.65 |
| 8 | N2 | College of Engineering | 44°22'31.77" | 33°16'46.49" | 21.774±4.67 | 30.073±5.48 | 465.447±21.57 |
| 9 | N3 | College of Science | 44°22'32.34" | 33°16'38.82" | 22.627±4.76 | 23.957±4.89 | 658.682±25.66 |
| 10 | N4 | Garden of Al-Salam Auditorium | 44°22'28.08" | 33°16'36.44" | 31.440±5.61 | 25.190±5.02 | 255.833±15.99 |
| 11 | N5 | Graduation Garden | 44°22'37.95" | 33°16'38.96" | 18.245±4.27 | 17.887±4.23 | 347.005±18.63 |
| Average of Nahrain University Soil Samples | | | | | 24.785±4.98 | 21.933±4.68 | 394.397±19.86 |
| 12 | M1 | The entrance to Al-Mustansiriyah University | 44°24'3.66" | 33°21'55.60" | 17.569±4.20 | B.D.L. | 134.821±11.61 |
| 13 | M2 | College of Education | 44°24'6.89" | 33°22'0.72" | 4.151±2.04 | 1.874±1.37 | 312.645±17.68 |
| 14 | M3 | College of Arts | 44°24'9.80" | 33°22'0.44" | 7.843±2.80 | B.D.L. | 288.907±17.00 |
| 15 | M4 | College of Science | 44°24'8.94" | 33°22'2.48" | 11.599±3.41 | 13.604±3.69 | 257.006±16.03 |
| 16 | M5 | Al-Mustansiriyah Stadium | 44°24'12.18" | 33°22'6.40" | B.D.L. | 8.964±2.99 | 89.412±9.46 |
| Average of Al-Mustansiriyah University Soil Samples | | | | | 10.291±3.21 | 8.147±2.85 | 216.558±14.72 |
| Minimum | | | | | B.D.L. | B.D.L. | 89.412±9.46 |
| Maximum | | | | | 57.145±7.56 | 44.247±6.65 | 658.682±25.66 |
| Average | | | | | 26.312±5.13 | 23.507±4.85 | 291.627±17.08 |

**Table (2): Radium equivalent, absorbed dose rate, external annual effective dose and hazard indices of soil samples.**

| No. | Sample Code | $Ra_{eq}$ (Bq/kg) | D□ (nGy/h) | E□ (mSv/y) | $H_{in}$ | $H_{ex}$ |
|---|---|---|---|---|---|---|
| 1 | B1 | 94.860 | 44.113 | 0.054 | 0.358 | 0.256 |
| 2 | B2 | 119.727 | 54.656 | 0.067 | 0.478 | 0.323 |
| 3 | B3 | 103.818 | 48.894 | 0.060 | 0.366 | 0.280 |
| 4 | B4 | 81.640 | 37.943 | 0.047 | 0.293 | 0.221 |
| 5 | B5 | 113.539 | 50.835 | 0.062 | 0.412 | 0.307 |
| 6 | B6 | 118.905 | 54.591 | 0.067 | 0.420 | 0.321 |
| **Average** | | **105.415** | **48.505** | **0.060** | **0.388** | **0.285** |
| 7 | N1 | 66.663 | 31.588 | 0.039 | 0.261 | 0.180 |
| 8 | N2 | 100.618 | 47.633 | 0.058 | 0.331 | 0.272 |
| 9 | N3 | 107.604 | 52.391 | 0.064 | 0.352 | 0.291 |
| 10 | N4 | 87.161 | 40.408 | 0.050 | 0.320 | 0.235 |
| 11 | N5 | 70.543 | 33.703 | 0.041 | 0.240 | 0.191 |
| **Average** | | **86.518** | **41.145** | **0.050** | **0.301** | **0.234** |
| 12 | M1 | 27.950 | 13.739 | 0.017 | 0.123 | 0.076 |
| 13 | M2 | 30.904 | 16.087 | 0.020 | 0.095 | 0.083 |
| 14 | M3 | 30.089 | 15.671 | 0.019 | 0.102 | 0.081 |
| 15 | M4 | 50.842 | 24.293 | 0.030 | 0.169 | 0.137 |
| 16 | M5 | 19.703 | 9.143 | 0.011 | 0.053 | 0.053 |
| **Average** | | **31.898** | **15.787** | **0.019** | **0.108** | **0.086** |
| **Minimum** | | **19.703** | **9.143** | **0.011** | **0.053** | **0.053** |
| **Maximum** | | **119.727** | **54.656** | **0.067** | **0.478** | **0.323** |
| **Average** | | **76.535** | **35.981** | **0.044** | **0.273** | **0.207** |

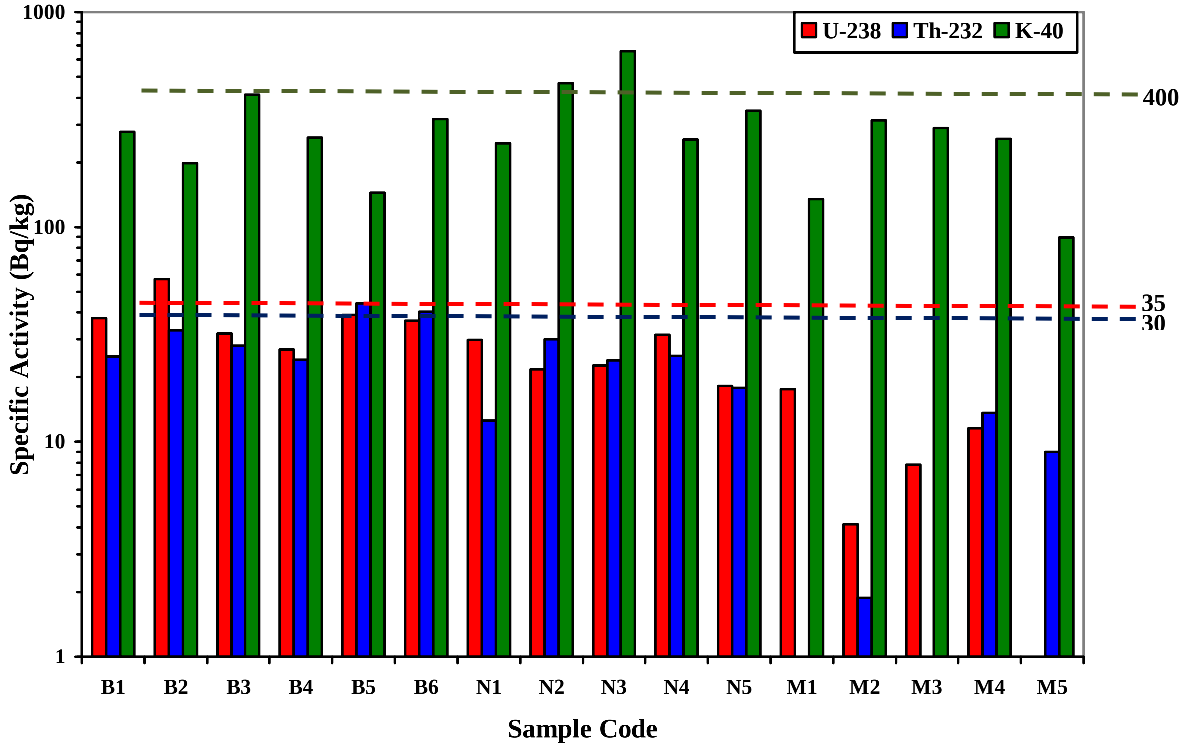


**Figure (3): Specific activity of $^{238}U$, $^{232}Th$ and $^{40}K$ radioactivity for soil samples.**

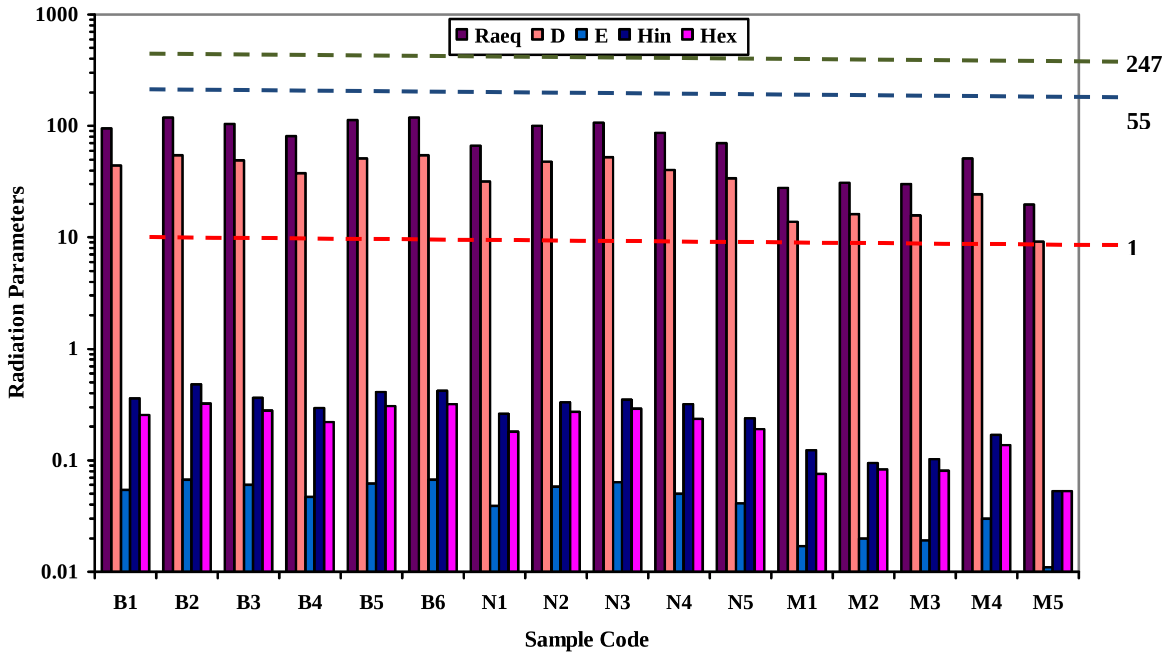


**Figure (4): A comparison of hazard indices with the worldwide average and permissible limit for soil samples.**

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