*DOI: 10.24996/ijs.2021.62.9.10*

**ISSN: 0067-2904**

# Measurement of Specific Activity of Natural Radioactive Materials and Cs-137 in Soil Samples for Some Areas in Al-Doura City in Baghdad Governorate

**Basim Khalaf Rejah, Farah Faris Kaddoori*, Sala Sami Hamza, Karima Saber Wadi[1]**

College of Science for Women, University of Baghdad, Baghdad, Iraq

Received: 23/8/2020 Accepted: 25/2/2021

**Abstract**

In the present work, radium ($^{226}$Ra), thorium ($^{232}$Th), potassium ($^{40}$ K), and cesium ($^{137}$Cs) (Bq/kg) was measured for 24 soil samples of some districts of Al-Doura city in Baghdad governorate. The gamma spectrometry method with NaI (Tl) detector was used for radiometric measurements. The average values of specific activity for $^{226}$Ra, $^{232}$Th, $^{40}$K and $^{137}$Cs in soil samples were 38.03, 42.48, 16.34 and 2.76 Bq/kg, respectively. The radiation indicators were measured and the average values recorded were 100 Bq/kg, 44.6 nGy/h, 0.27 Bq/kg, 0.373 Bq/kg, 0.219 mSv/y, 0.055 mSv/y and 0.689 Bq/kg for the parameters of radium equivalent activity (Raeq), the absorbed dose rate (D), the external hazard index (Hex), the internal risk index (Hin), and the annual effective equivalent dose for the indoor (In $E_{ff.}$), outdoor annual effective dose equivalent (Out $E_{ff.}$) and representative gamma index (Iγr), respectively. All the health hazard indices were well below their recommended limits, except in one soil sampling site (AL-Eskan site) which were found to be 0.495 Hex and 0.668 Hin.

**Keywords:** Natural radioactivity, activity concentration, hazardous indices, NaI (Tl) Detector.

# قياس النشاط النوعي للمواد المشعة الطبيعية و السيزيوم -137 في عينات التربة لبعض المناطق في مدينة الدورة بمحافظة بغداد

**باسم خلف رجه, فرح فارس قدوري*, سلا سامي حمزه، كريمة صبر وادي**

الفيزياء، كلية العلوم للبنات، جامعة بغداد، بغداد، العراق

**الخلاصة**

في العمل الحالي تم قياس تركيز نشاط معين للراديوم- 226 والثوريوم -232 والبوتاسيوم -40 والسيزيوم -137 في بيكريل/كغم في 24 عينة تربة في بعض مناطق الدورة في محافظة بغداد . تم استخدام طريقه قياس طيف جاما باستخدام كاشف NaI(Tl) للقياسات الاشعاعية . متوسط قيمة الراديوم - 226 والثوريوم -232 والبوتاسيوم -40 والسيزيوم -137 لتركيز نشاط معين في عينات التربة هو 38.03 و 42.48 و16.34 و 2.76 بيكرل/كغم على التوالي حيث تم قياس مؤشرات الاشعاع لعينات

*Email: farahfaris84@gmail.com

من التربة وكانت متوسط القيم الواردة هي من عينات التربة هي 100 بيكرل/كغم و 44.6 نانوكري/ساعه و 0.27 بيكريل/كغم و 0.373 بيكريل /كغم و 0.219ملي سيفرت/سنة و0.055 ملي سيفرت/سنة 0.689 بيكريل /كغم كنشاط مكافئ للراديوم Raeq و معدل الجرعة الممتصة (D) ومؤشر المخاطر الخارجية Hex و مؤشر المخاطر الداخلية Hin و الجرعة السنوية الفعالة المكافئة للداخل In Eff و الجرعة الفعالة السنوية الخارجية المكافئة Out Eff و مؤشر جاما التمثيلي IYr على التوالي . جميع مؤشرات المخاطر الصحية اقل بكثير من الحدود الموصي بها باستثناء مواقع اخذ عينات التربة التي تم العثور عليها في منطقة الاسكان Hex 0.495 و 0.668Hin .

## Introduction

Terrestrial background radiation is a gamma radiation emitted from naturally occurring radioactive materials (NORMs) like uranium-238 ($^{238}U$), thorium-232 ($^{232}Th$),
and potassium-40 ($^{40}K$), which is the major external source for irradiation of the human body [1, 2]. In addition, humanity may be exposed to radiation from other sources called synthetic radioactive sources such as cesium137 ($^{137}Cs$) in the Earth's environment that may result from nuclear weapon tests or the nuclear effects of nuclear technology [3]. the presence of naturally occurring radioactive materials (NORMs) in the soil mostly arose from crumbling rocks that are transported by rain and flows into the soil. The contrast in the background of ground radiation zones is influenced by geological features, locations, elevation, and geochemical influences [4, 5]. Therefore, it was found that the activity for radionuclide in granite positions is higher than that found in mud, sandstone and travertine soil [6, 7]. So that, measurements of natural radioactivity in soil provides us with knowledge of the levels of radionuclide activity in the environment and important information about environmental radioactivity monitoring [8]. Over the last two decades, it has been conceded that the existing of NORMs in the environment with a specific activity concentration higher than the reference radioactivity levels established by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) will pose a risk to living creatures [9]. Radiation survey is important for every country in order to build a basic database of radiation levels for environmental purposes, as well as to know future changes in the level of radiation for one reason or another. Externally, natural radioactive elements represent a hazard of exposure due to their gamma-ray releases, while inside, radon and its progeny release alpha particles, posing a risk of exposure [10]. This research was dedicated to determine the activity levels of the natural radionuclides (238 U, 232 Th, 40 K) and radionuclides of the substance (137 cc) present in soil samples collected from different districts. These data are fundamental for the establishment of baseline values for radionuclides in the soil samples of Al-Doura region. In addition, the research is aiming to estimate a collection of health indicators of the presence of risk, such as radium equivalent activity, absorbed dose rate index, external and internal risk indicators, representative range index, as well as gamma radiation dose rate using a gamma spectrophotometer and a NaI (Tl) detector.

## Materials and Methods

This study was conducted on soil samples taken from some districts (AL-Mahdia1, AL-Mahdia2, AL-Eskan, AL-Moalimen, AL-Wadi, AL-Tuama, AL-Shurta, AboTayra and AL-Jameaa) in Al-Doura region in Baghdad Governorate, as shown in Figure-1.

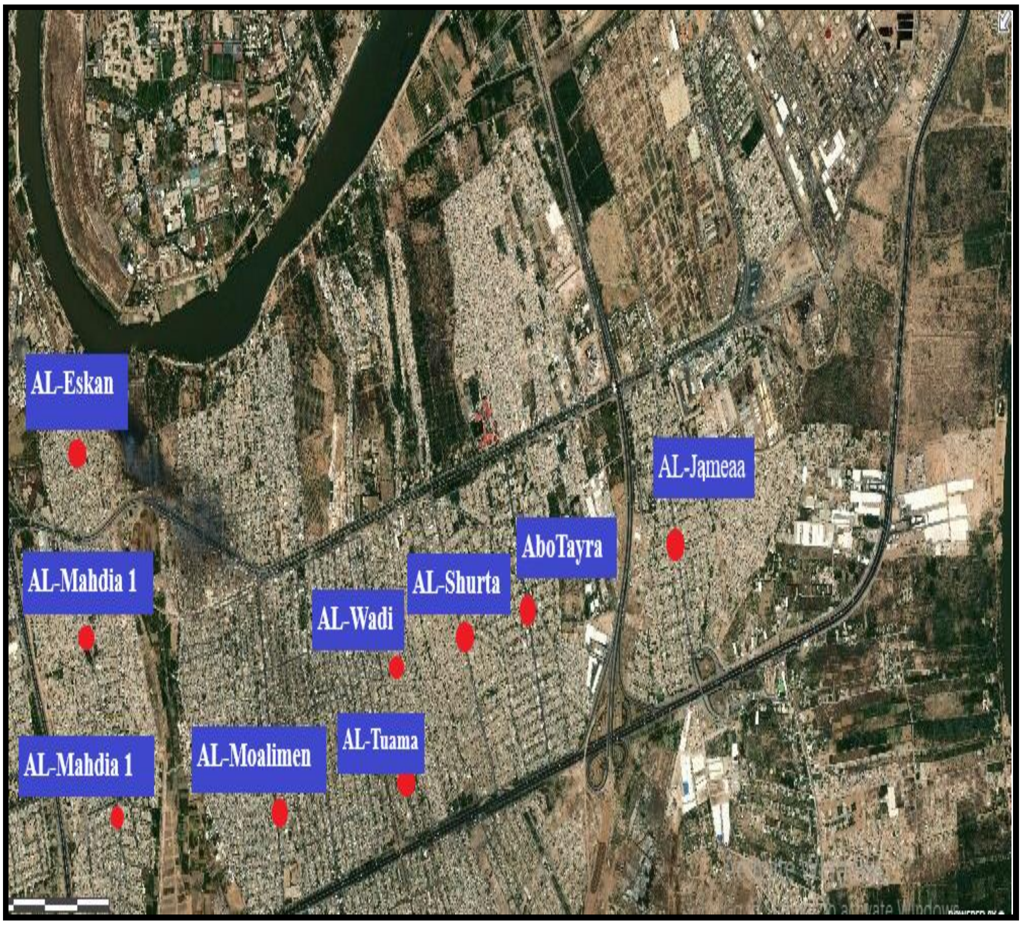


**Figure 1-**Map of the studied area.

The soil samples (1 kg each) were taken from a depth of 30 cm, with three samples from each district. These samples were milled, dried, crushed, and sieved by 2- A mm net. All sample containers were tightly closed, and the samples were stored for 28 days before counting, which allows to establish a secular balance between 238U and 232Th, which have long half-life values, and the decomposing products. To determine the radioactivity of a particular element, the samples were tested with a 3x3 NaI (Tl) detector with Canberra Inc circuits and its spectrum was stored in a PC-based multichannel analyzer (MCA) [11]. The sensor was shielded by a 100 mm thick lead castle in this experiment. Because to its high densities and huge atomic size, it forms an excellent protective material. Radiological measurements were performed in order to qualitatively and quantitatively determine the radionuclides present in the soil. The specific activity of the sample is the activity per unit mass Bq/kg. Since the NaI (Tl) detector has poor efficiency in energy analysis, the daughter radionuclide was chosen to determine the radioactivity of a specific activity of two chains of 238U and 232Th. A nuclide 226Ra was chosen to denote the radioactivity of a chain of 238U, which contains the radioisotope 214Pb (352 kV). Moreover, a series of $^{232}$Th was determined through the radioactive isotopes of $^{212}$Pb (238.6 keV) and $^{228}$Ac (911.1 keV) . With regard to $^{40}$K (1460.8 keV), it could be detected directly by the detector, which was also the case for $^{137}$Cs (661.60 keV) [12]. In this study, the specific activity for each sample was calculated from the following equation [13, 14]:

$A = \frac{Activty}{m}$, where A is the activity and m is the mass of the sample.

The activity values in the samples were obtained using the following equation [15]:

$$Activity = \frac{C}{m.I.\varepsilon.t}$$

where the activity of radionuclides is expressed in Bq/kg, C is the net area under the curve (count), *m* is the mass of the sample (kg), I is the intensity, ε is the absolute efficiency at energy E, and *t* is the measuring time (sec.).

**Radiation Hazard Indices**

In recent studies, different analyses for radiation health risk indicators have been used to reach accurate results and support safety measures with regard to the health status of people and the environment [16].

1. *Radium Equivalent Activity ($Ra_{eq}$)*

The radium equivalent activity is a balanced average of the activities of the radioisotopes indicated previously, and is predicated on the assumption of 1Bq/kg of 226Ra, 0.7 Bq/kg of 232Th, and 13 Bq/kg of 40K have about the equivalent dose of radiation levels. The radium equivalents activity level (REAI) is calculated as follows:

$$Ra_{eq}\left({}^{Bq}/_{kg}\right) = A_{Ra} + (1.43 \times A_{Th}) + (0.077 \times A_K \quad (1)$$

where the elements $A_{Ra}$, $A_{Th}$, and $A_K$ represent the specific radioactivity of $^{226}$Ra, $^{232}$Th and $^{40}$K [16, 17].

2. *External Hazard Index ($H_{ex}$)*

The principal primordial radionuclides of activities of the natural radionuclides are $^{226}$Ra, $^{232}$Th and $^{40}$K that produce significant human exposure, as given in eq. 2 [17].

$$H_{ex}\left({}^{Bq}/_{kg}\right) = \frac{A_{Ra}}{370} + \frac{A_{Th}}{260} + \frac{A_K}{4810} \quad (2)$$

3. *Internal Hazard Index ($H_{in}$)*

The internal risk indicator is found as follows:

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

4. *Representative Gamma Index (Iγr)*

The gamma index has been employed to assess the γ- radiation hazard associated with physical radionuclides. The representative gamma index is given in eq. 4 [16]:

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (4)$$

5. *The absorbed gamma dose rate*

By using conversion factors, the rate of absorbed gamma dose (D) in air is calculated per unit specific activity (in 1Bq /kg), as follows:

$$D(\frac{nGy}{h}) = [0.604 \times A_{Th} + 0.462 \times A_{Ra} + 0.0417 \times A_K] \quad (5)$$

where: $A_{Ra}$, $A_{Th}$, $A_K$ are the radioactivity values of $^{226}$Ra, $^{232}$Th, and $^{40}$K, respectively [13, 17].

6. *Equivalent annual effective dose*

The conversion factors from average absorbed dose in air to effective dose (0.7 Sv Gy-1), external occupancy factor (0.2), and internal occupancy factor (0.8) [17] were used. The equivalent effective dose rate, in units of millisievert per year, is calculated from the following equations:

$$Out\ Eff\ \left(\frac{mSv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 8766\frac{h}{y} \times 0.7\ \left(\frac{Sv}{Gy}\right) \times 0.2 \times 10^{-3} \quad (6)$$

$$In\ Eff\ \left(\frac{mSv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 8766\frac{h}{y} \times 0.7\ \left(\frac{Sv}{Gy}\right) \times 0.8 \times 10^{-3} \quad (7)$$

**Results and Discussion**

The specific activity (Bq/m3) of 226Ra, 228Ac (a series of 232Th through a radioactive isotope 212Pb; 238.6 keV), and 228Ac (911.1 keV, 40 K) were identified. The specific activity values of 137 scores in all sites are listed in Table-1.

**Table 1** -The specific activity of $^{226}$Ra, $^{228}$Ac, $^{40}$K. and $^{137}$Cs (Bq/m$^3$) in all locations.

| **Locations** | **$^{226}$Ra (Bq /kg)** | **$^{228}$Ac (B q/kg)** | **$^{40}$K (B q/kg)** | **$^{137}$Cs (Bq/kg)** |
|---|---|---|---|---|
| **AL-Mahdia 1** | 38.50 | 45.20 | 15.76 | 1.05 |
| **AL-Mahdia 2** | 54.60 | 68.08 | 11.45 | 2.40 |
| **AL-Eskan** | 64.03 | 82.07 | 22.10 | 3.02 |

| | | | | |
|---|---|---|---|---|
| **AL-Moalimen** | 26.54 | 56.70 | 7.60 | 3.41 |
| **AL-Wadi** | 61.10 | 6.40 | 26.01 | 0.50 |
| **AL-Tuama** | 8.88 | 30.30 | 31.60 | 4.44 |
| **AL-Shurta** | 49.90 | 51.60 | 6.02 | 5.06 |
| **AboTayra** | 14.06 | 22.90 | 23.30 | 2.03 |
| **AL-Jameaa** | 24.70 | 19.03 | 3.25 | 2.90 |
| **Average** | 38.03 | 42.48 | 16.34 | 2.76 |

From this table, it can be observed that the average value for the activity of $^{137}$Cs in all locations was 2.76 Bq/kg. The highest value of specific activity was 5.06 Bq/kg in AL-Tuama district. The lowest value of specific activity was 0.50 Bq/kg in AL-Wadi district. Figure-2 explains the relationship between specific activity values for $^{137}$Cs in all locations studied.
Moreover, the average values of the specific activity for $^{226}$Ra, $^{228}$Ac and $^{40}$K in all locations studied were 38.03, 42.48 and 16.34 Bq/kg, respectively. The highest values of specific activity for $^{226}$Ra and $^{228}$Ac were 64.03 and 82.07 Bq/kg, respectively, in AL-Eskan district, while for $^{40}$K the highest value was 23.30 Bq/kg in AboTayra district. The lowest values of specific activity for $^{226}$Ra was 8.88 Bq/kg in AL-Tuama district, while for $^{228}$Ac it was 6.40 Bq/kg in AL-Wadi district, and for $^{40}$K it was 3.25 Bq/kg in AL-Jameaa district. The results obtained showed that the specific activity values of 238U (226Ra), 228Ac (232Th) and 40K in all soil samples were below the recommended limits from UNSCEAR 2017, which are 35, 30 and 400 Bq.kg$^{-1}$, respectively [18].
The results of the calculations of radiation hazard indices are listed in Table-2. The radiation indices had maximum values in AL-Eskan district samples, which showed H-external and H-internal values of > 1. This indicates higher pollution in the region which is very crowded with inhabitants are dealing with oil derivatives in abundance. The minimum value of radiation hazard indices was recorded in samples from AboTayra district because it is an open area with agricultural areas and gardens.

**Table 2-** Results of Radiological indices in soil samples of Al-Doura region

| Location | $Ra_{eq}$ | D (nGy/h) | H-external | H-internal | In Eff (mSv/y) | out Eff (mSv/y) | Iγr |
|---|---|---|---|---|---|---|---|
| **AL-Mahdia 1** | 104.3 | 46.5 | 0.282 | 0.386 | 0.228 | 0.057 | 0.719 |
| **AL-Mahdia 2** | 152.8 | 68.0 | 0.413 | 0.560 | 0.333 | 0.083 | 1.052 |
| **AL-Eskan** | 183.1 | 81.5 | 0.495 | 0.668 | 0.400 | 0.100 | 1.262 |
| **AL-Moalimen** | 108.2 | 47.8 | 0.292 | 0.364 | 0.234 | 0.059 | 0.749 |
| **AL-Wadi** | 72.3 | 33.3 | 0.195 | 0.360 | 0.163 | 0.041 | 0.489 |
| **AL-Tuama** | 54.6 | 24.2 | 0.148 | 0.172 | 0.119 | 0.030 | 0.383 |
| **AL-Shurta** | 124.2 | 55.3 | 0.335 | 0.470 | 0.272 | 0.068 | 0.853 |
| **AboTayra** | 48.6 | 21.7 | 0.131 | 0.169 | 0.106 | 0.027 | 0.338 |
| **AL-Jameaa** | 52.2 | 23.4 | 0.141 | 0.208 | 0.115 | 0.029 | 0.357 |
| **Average** | 100.0 | 44.6 | 0.270 | 0.373 | 0.219 | 0.055 | 0.689 |

The results of Radium Equivalent Activity ($Ra_{eq}$) in all locations are explained in Figure-3. This activity, as well as the representative gamma index (Iγr), was found at all sites, which are considered as a function of the rate of the absorbed gamma dose (Figure- 4). From the figure, one can obtain the following relationships:

$$Ra_{eq}\left({}^{Bq}/_{kg}\right) = 2.2469\, D\left({}^{nGy}/_{h}\right) - 0.4894$$
$$I_{\gamma r} = 0.0154\, D\left({}^{nGy}/_{h}\right) - 0.0007$$

In Figure- 5, the results of indoor and outdoor effective dose equivalent rate (mSv/y) as a function of the absorbed gamma dose rate are demonstrated for all locations. From this figure, one can obtain the following relationships:

$$In\ Eff\ \left(\frac{mSv}{y}\right) = 0.0049\ \times D\left(\frac{nGy}{h}\right)$$
$$Out\ Eff\ \left(\frac{mSv}{y}\right) = 0.0012 \times D\left(\frac{nGy}{h}\right)$$

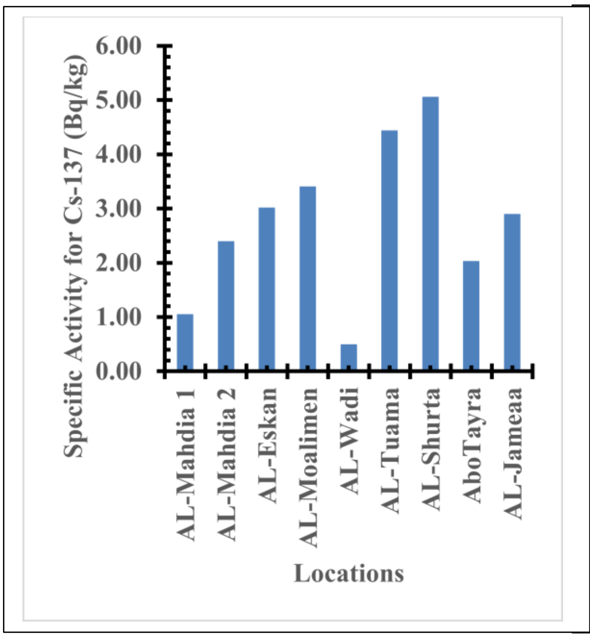


**Figure 2-**Specific activity for $^{137}$Cs in all locations.

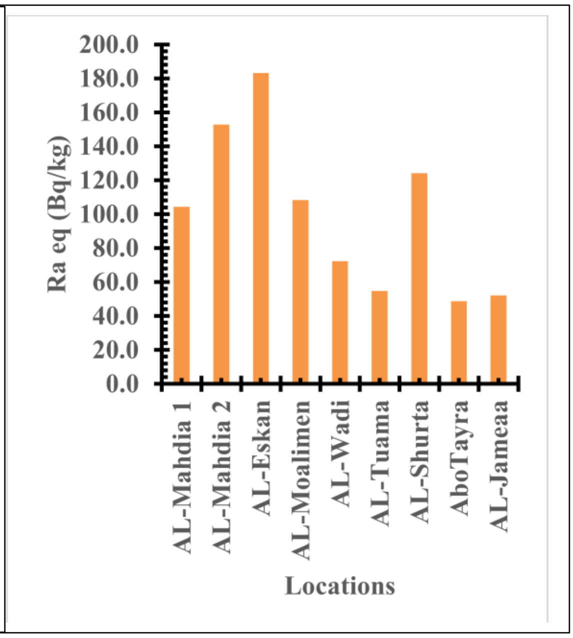


**Figure 3-**Radium Equivalent Activity ($Ra_{eq}$) in all locations.

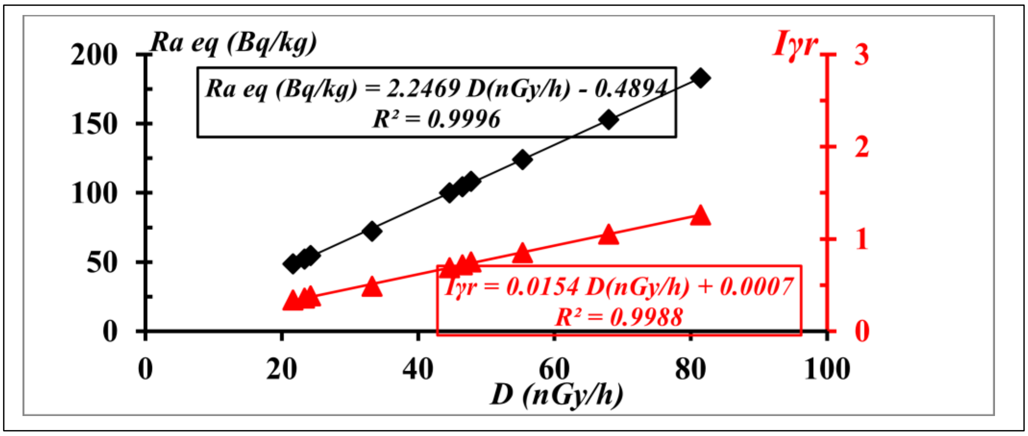


**Figure 4-**The activity of radium equivalent (Raeq) and the representative gamma index (Iγr) at all sites, as a function of the rate of the absorbed gamma dose.

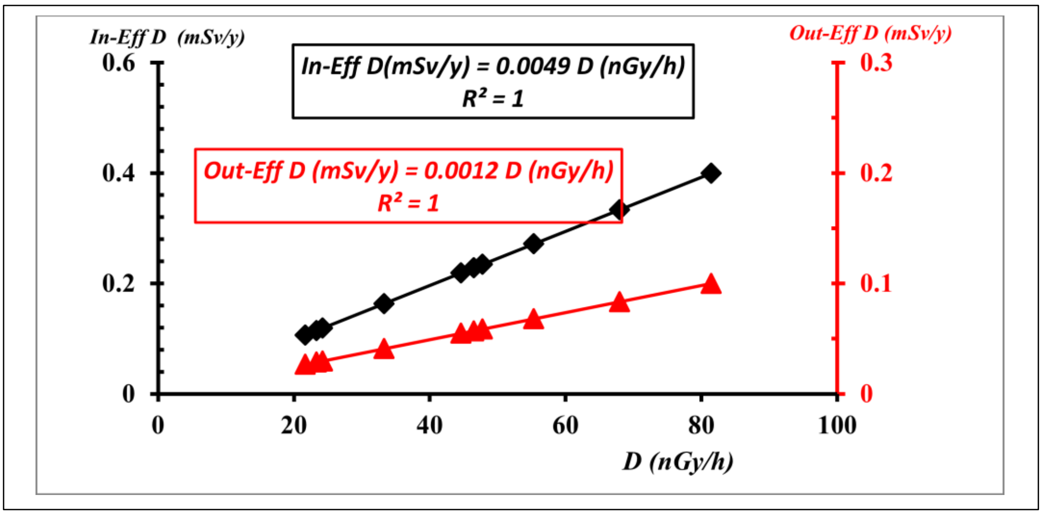


**Figure 5-**Indoor and outdoor effective dose equivalent rate (mSv/y) in all locations as a function of the absorbed gamma dose rate.

**Conclusions**

The levels of radioactivity and the values of the radiation hazard indices for soil samples in some districts of Al-Doura city in Baghdad governorate were studied in this research. The average values of the specific activity of $^{226}$Ra, $^{228}$Ac, $^{40}$K and $^{137}$Cs in all locations were 38.03, 42.48, 16.34 and 2.76 Bq/kg respectively, which were found to be lower than the permissible limits, reflecting no pollution in the study area. The average R aeq value was 100 Becquerel / kg (within a range of 48.6 to 183.1 Bq/kg), which is lower than the recommended maximum level of radium equivalent in soil (370 Bq/kg). The radiation indices had maximum values in AL-Eskan district samples, which showed H-external and H-internal values of > 1, which could indicate higher pollution in the region. The minimum value of radiation hazard indices was recorded in AboTayra district samples. This study established baseline information on the natural radioactivity and $^{137}$Cs status of Al-Doura region in Baghdad governorate, which will serve as a reference for future studies.

**References**


1. M. K. a. W. F. M. Mohammed. **2014**. "Measurement of activity concentration levels of radionuclides in soil samples collected from Bethlehem Province, West Bank, Palestine," *Turkish Journal of Engineering & Environmental Sciences,* **38**: 13- 125.
2. UNSCEAR United Nations Scientific Committee on the effect of Atomic Radiation. **2000**. Sources, Effect, and Risks of Ionizing Radiation" Report to the general Assembly with Scientific Annexes, United Nations.
3. S. G. M. V. G. V. Ramasamy V. **2009**. "Evaluation of natural radionuclide content in river sediments and excess lifetime cancer risk due to gamma radioactivity.," *Journal Environmental Earth of Sciences Research,* **1**(1): 6-10.
4. K. M. A. P. T. A. H. S. K. G. Taskin H. **2009**. "Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli," *Turkey Journal Environmental Radiation,* **100**(1): 49-53.
5. United Nations Scientific Committee on the Effects of Atomic Radiation. **1993**. Exposure from natural sources of radiation, United Nations, New York.
6. R. H. M. F. R. M. R. S. R. M. Raque M. **2011**. " Assessment of radiological hazards due to soil and building materials used in Mirpur Azad Kashmir Pakistan.," *Iranian journal of Radiation Research,* **9**(2): 77-87.
7. M. Z. M. K. K. Khan H. **2012**. "Measurement of radionuclide's and absorbed dose rates in soil samples of Peshawar, Pakistan, using gamma ray spectrometry.," *Isotopes in Environmental and Health Studies,* **48**(2): 295-301.

**8.** A. A. **2008**. "Assessment of human exposures to natural sources of radiation in soil of Riyadh, Saudi Arabia.," *Turkish Journal of Engineering and Environmental Sciences,* **32**(4): 229-234.

**9.** D. T. M. o. N. R. i. S. S. f. B. K. R. I. Ali H. **2015**. *International Journal of Recent Research and Review,* **8**(4): 2277-8322.

**10.** Leena A. **2016**. "Natural Radioactivity and Hazard Indices of Soil Sample in Al-Dura thermal Power Plant in the Southern of Baghdad-Iraq,," *Iraqi Journal of Science,* **57**(1): 132-128.

A. H. B. B. D. Abdulrahman Kadum. **2013**. "Radioactivity Investigation of Sand from the Northern Region of Tlemcen-Algeria, Using Well- Shape NaI (Tl) Detector.," *Civil and Environmental Research,* **3**(12).

**11.** M. Abu-Samreh. **2006**. "Gamma radiation measurement and dose rates of naturally occurring radioactive samples from Hebron Province geological rocks," *Abhath AL-Yarmouk,* **15**(2): 1-9.

**12.** C. A. C. N. H. N. R. R. holkappian M. **2018**. "Determination of Radioactivity Levels and Radiation Hazards in Coastal Sediment Samples of Chennai Coast, Tamilnadu, India using Gamma Ray Spectrometry with Statistical Approach," *Journal Radiation and Nuclear Application ,* **3**(3): 171-182.

**13.** R. T. M. B. K. Wadhah M S. **2019**. "Detecting the possibility of soil pollution with Radon Emissions for an Area Located Within Baghdad University Campus-Al-Jadiriyah," *Iraqi Journal of Science,* **60**(9): 1985-1996.

**14.** L. G. Sozan T. **2007**. "Determination of specific activity of 226Ra, 232Th and 40K for assessment of radiation hazards from Turkish plumicesamples," *Journal of Environmental Radioactivity,* **2**(3): 122-130.

**15.** UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). **2008**. Exposures from Natural Radiation Sources. United Nations.

**16.** UNSCEAR United Nations Scientific Committee on the effect of Atomic Radiation. **2013**. Source, Effect, and Risks of Ionizing Radiation Report to the general Assembly with Scientific Annexes, United Nations ,New York.

**17.** UNSCEAR United Nations Scientific Committee on the effect of Atomic Radiation. **2017**. Source , Effect, and Risks of Ionizing Radiation Report to the general Assembly with Scientific Annexes, United Nations.