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# Radiation Hazard Indices in Some Soil Samples from Uranium Mine in Abuskair, Iraq Using HPGe Detector

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The specific activity of natural radioactive nuclei in 37 samples of soil taken from different sites around the uranium mine in Najaf province, Iraq, were studied. The experimental data were obtained using a high purity germanium (HPGe) detecting system. A standard source of γ-ray (Eu-152) was used to calibrate the HPGe system. The detection time of the soil samples was 10,000 sec. Accordingly, the specific activity of the soil samples ranged from 27.4 to 920 Bq/kg for $^{238}U$, 5.1 to 14.5 Bq/kg for $^{232}Th$ and 124 to 598 Bq/kg for $^{40}K$, with mean values of 88.849 Bq/kg, 9.79 Bq/kg and 284.65 Bq/kg, respectively. In order to assess the radiation hazards of the natural radioactivity, the radium equivalent activity ($Ra_{eq}$), the γ-ray absorbed dose (D), the annual effective dose, the internal hazard index ($H_{in}$) and the external hazard index ($H_{ex}$) were calculated and then compared with the standard published values for safe use (OECD, 1979) together with the world average values of UNSCEAR.

**Keywords: Radioactivity, Uranium mine, Highpurity germanium detector, Gamma ray spectroscopy.**

## INTRODUCTION

Naturally occurring radioactive material (NORM) in nuclear sciences indicates for materials containing radioactive elements of natural origin together with those nuclides formed by natural processes [1]. Additionally, the International Atomic Energy Agency (IAEA) has defined the NORM as "radioactive materials, which are containing no significant amounts of radionuclide other than naturally occurring radionuclides" [2]. Natural radioactivity, in general, arises from primordial radioactive nuclei (*i.e.* $^{40}K$, $^{232}Th$ and $^{238}U$ series) and their decay products, which occur at trace levels of the ground [3]. Examples for the NORM include rocks, mineral ores and soil that involve natural radioactivity, which can also be dissolved into ground water [1]. Determination of radioactivity is a key element for the assessment of radiation hazard and determining changes in natural radiation background. This therefore provides the appropriate protection for human beings. Natural radioactivity assessment is also important since NORM can serve as biochemical and geochemical indicators in case of geological events such as earthquakes and eruptions of volcano [4]. The soil is one of the major contributors to background radiation. It is very interesting to identify the radioactivity level of the soil throughout the world. The natural radioactive nuclei have been considered as essential elements of the earth during its creation. In fact, the natural radioactivity in soil originated from $^{238}U$ and $^{232}Th$ series as well as natural $^{40}K$. The emission of γ-rays from these naturally occurring radionuclides represents the major source (*i.e.* external) of irradiation of the human body, while the internal exposure is resulted from the inhalation of radon and their decay products. The mean specific activity of $^{238}U$, $^{232}Th$ and $^{40}K$ is around 32, 45 and 400 Bq/kg [5]. It is generally accepted that the natural radioactivity and the corresponding radiation exposure due to γ-irradiation depend primarily on the geographical and geological conditions and appear at various levels of radionuclides in the soils of each specific region in the world [6]. Many studies have been achieved to determine concentrations of radionuclide in building materials across different countries [7-11]. This work was undertaken for the purpose of measuring the natural radioactivity caused by $^{238}U$, $^{232}Th$ and $^{40}K$ in thirty seven soil samples which were collected from places situated around the uranium mine within the district of Abu Skair at Najaf governorate. The radium equivalent activity, absorbed dose rate, annual indoor and outdoor effective dose and internal and external radiation hazard were determined so as to be compared with the recommended limits.

**Area of study:** The current study is focusing on an area located in the south west of Najaf city in Iraq. It is located at around 18 km from Najaf and 2 km from west of Al-Heera town within the district of Abu Skair. The area of the study is called Hor Al-Jebssa, it is in between Al-Zejrey and Alsaneen villages [12]. The area is located within the southern part of sea of Najaf. The surface of the area is semi plane of recent deposit quaternary age which contains a mixture of soft sands and clays along with vegetal organic materials resulted from remnants of grass, plants and trees. This deposit has black colour in some areas specifically in Hor Al-Jebsaa. Such black deposits has been seen in other locations mixed with gypsum materials [13]. The uranium deposits of Abu Skhair consist of non-uniform gray to dark gray manly limestone layer of variable thickness (0.2-4.7 m) rich with organic materials and broken fossil shells geologically. Belong to Euphrates formation of L. Miocene age (14) under about (50-70) m below the earth surface in the study area. A part of distinguishable radioactivity can be markedly recognized by sharp colour range from the underlying limestone rock bed of orange to yellow colour [14].

## EXPERIMENTAL

Thirty-seven samples of soil were collected from places located around the uranium mine. We used a systematic circular sampling system involving 9 radial line, each line has a 30 degree difference from the previous line and each of them consists of 4 samples, the taken distance between the sampling locations was around 50 m and each sample's depth was around 60 cm from the ground surface, as seen in Fig. 1.

The soil samples were first cleaned of the stones and vegetation. All these samples were dried up at room temperature, sieved, placed in the plastic 400 $cm^3$ containers and left up to 4 weeks to reach radioactive equilibrium. The resulted spectra were analyzed using GENIE 2000 software. The $^{226}Ra$ and $^{232}Th$ specific activities were determined depending on their decay products (*i.e.* $^{214}Bi$, 609 keV; and $^{228}Ac$, 911 keV respectively). The activity of $^{40}K$ was determined from its 1460 keV gamma-line. The adopted counting time interval in this study was 10,000 seconds. The background spectrum was immediately recorded after or before the sample counting.

The distribution of $^{226}Ra$, $^{232}Th$ and $^{40}K$s' in soil is not uniform. Uniformity of exposure to radiation was determined in terms of radium equivalent activity ($Ra_{eq}$) in Bq/kg to have the chance of comparing the specific activity of materials including various amounts of $^{226}Ra$, $^{232}Th$ and $^{40}K$. This was calculated using the following equation [15,16]:

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K \quad (1)$$

where $C_{Ra}$, $C_{Th}$ and $C_K$ are the activities of each of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg, respectively. Given that $Ra_{eq}$ activity determined according to eqn. 1, it was assumed that 370 Bq/kg of $^{226}Ra$ or 259 Bq/kg of $^{232}Th$ or 4810 Bq/kg of $^{40}K$ produce a similar γ-ray absorbed dose.

The γ-absorbed dose in the air at 1 m above ground level was determined according to the measured activities of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the soil considering that the other radionuclides, such as $^{137}Cs$, $^{90}Sr$ and the $^{235}U$ series could be neglected since they contribute very little to the overall dose from environmental background [17-19]. The calculations were performed using the following equation [5]:

$$D = 0.462C_{Ra} + 0.604C_{Th} + 0.042C_K \quad (2)$$

where D is the dose rate in unit of nGy/h and $C_{Ra}$, $C_{Th}$ and $C_K$ are the specific activities (Bq/kg) of $^{226}Ra$, $^{232}Th$ and $^{40}K$,

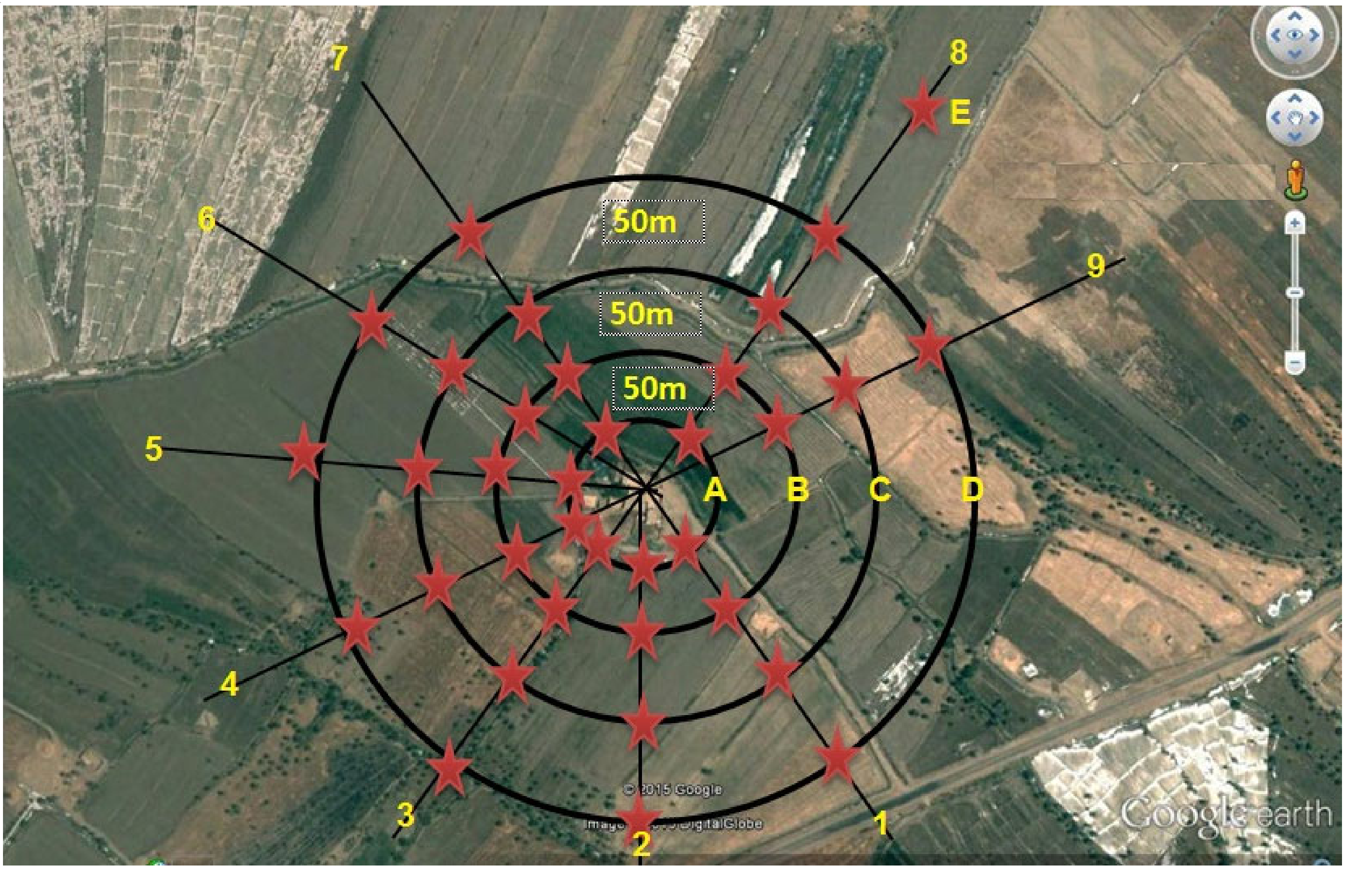


Fig. 1. Schematic diagram of systematic circular sampling system

respectively. In eqn. 2, it is assumed that all decay products of $^{226}$Ra and $^{232}$Th are in radioactive equilibrium with their parents.

In order to estimate the annual effective dose, the following measures must be considered: (a) the conversion coefficient of absorbed dose in air to effective dose and (b) the indoor occupancy factor. Accordingly, adopting the conversion factor of 0.7 Sv/Gy [5] to convert the absorbed dose rate in air to effective dose received by adults spent 20 %, on the average, of their time outdoors [5], the annual effective doses were calculated using the following equation:

$$\text{Annual effective dose (Sv)} = D \times 24 \times 365 \times 0.7 \times 0.2 \quad (3)$$

The external hazard index ($H_{ex}$) can be determined as follows [15]:

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

where $C_{Ra}$, $C_{Th}$ and $C_K$ represent the specific activity (Bq/kg) of each 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 to population insignificant. The maximum value of $H_{ex}$ that equal to unity corresponds to the upper limit of (370 Bq/kg) of radium equivalent activity.

The internal hazard index represents a criterion of radiation hazard index. In addition to this, $^{222}$Rn is a well-known contributor to internal exposure in a room. Effectively, the radio toxicity of $^{238}$U is increased by a factor of two to allow for the contribution from $^{222}$Rn and its short lived progeny. The internal exposure due to radon and its daughter products was estimated using the internal hazard index $H_{in}$, which was defined as shown below [15]:

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

The internal hazard index is calculated in order to reduce the acceptable maximum concentration of $^{238}$U to half the value appropriate to external exposures alone [15].

## RESULTS AND DISCUSSION

The specific activity of $^{226}$Ra, $^{232}$Th and $^{40}$K radionuclides of 37 soil samples are presented in Table-1. It is ranged from 27.4 to 920 Bq/kg for $^{226}$Ra, 5.1 to 14.5 Bq/kg for $^{232}$Th and from 124 to 598 Bq/kg for $^{40}$K. The results are comparable to the worldwide average that recommended by UNSCEAR (2000), which are 32, 35 and 400 Bq/kg for each of $^{226}$Ra, $^{232}$Th and $^{40}$K [5]. It was found that all values of $^{226}$Ra's specific activities are higher than the expected worldwide average for the samples of (B2, C1, C4 and C9), where the maximum specific activity value is found in sample (E) and the minimum value was found in (D6). By comparison, the UNSCEAR 2000 report indicates that the maximum value of uranium is greater than the worldwide average (*i.e.* 32 Bq/kg) by approximately 34 times. The values of $^{232}$Th specific activities are less than the worldwide average (*i.e.* 35 Bq/kg). With regard to $^{40}$K, it is clear that the specific activities, except (A3, D8 and E) samples, were found to be higher than worldwide average, whereas the maximum specific activity value was calculated in sample (E) and the minimum value was seen in sample A1. The distribution of anomalous area with uranium around the site was attribution to the heterogeneous of the extracted rock contain uranium. The values of radium equivalent activity, dose rate, annual

TABLE-1
SPECIFIC ACTIVITIES OF RADIONUCLIDES IN SOIL SAMPLES OF DIFFERENT SITES IN THE MUNICIPAL AREA AROUND THE URANIUM MINE AT ABU-SKHAIR IN NAJAF GOVERNORATE

| Samples | Specific activity of radionuclides (Bq/kg) | | |
|---|---|---|---|
| | $^{226}$Ra | $^{232}$Th | $^{40}$K |
| A1 | 41.5 ± 4.04 | 7.7 ± 3.56 | 124 ± 12.62 |
| A2 | 153.2 ± 4.98 | 8.7 ± 4.47 | 379 ± 14.82 |
| A3 | 432.4 ± 4.86 | 5.8 ± 4.83 | 434 ± 15.67 |
| A4 | 46.5 ± 5.71 | 10.1 ± 4.92 | 253 ± 15.72 |
| A5 | 93.3 ± 3.57 | 17.2 ± 3.47 | 348 ± 16.06 |
| A6 | 144.2 ± 4.40 | 8.0 ± 3.91 | 289 ± 17.68 |
| A7 | 61.7 ± 4.00 | 7.5 ± 3.59 | 327 ± 11.91 |
| A8 | 119.2 ± 4.51 | 8.3 ± 3.18 | 394 ± 16.70 |
| A9 | 60.2 ± 4.11 | 10.0 ± 4.04 | 309 ± 15.07 |
| B1 | 40.5 ± 4.10 | 12.7 ± 2.97 | 131 ± 10.56 |
| B2 | 29.8 ± 3.82 | 6.5 ± 2.64 | 221 ± 10.39 |
| B3 | 37.1 ± 4.81 | 12.3 ± 4.32 | 234 ± 14.31 |
| B4 | 45.8 ± 3.55 | 12.0 ± 2.98 | 273 ± 13.78 |
| B5 | 38.4 ± 5.31 | 12.3 ± 3.42 | 339 ± 14.57 |
| B6 | 44.5 ± 5.07 | 14.5 ± 4.36 | 269 ± 14.45 |
| B7 | 67.2 ± 4.27 | 9.3 ± 3.48 | 336 ± 15.20 |
| B8 | 39.4± 4.79 | 5.3 ± 4.33 | 217± 15.35 |
| B9 | 47.3 ± 3.06 | 12.2 ± 3.12 | 309 ± 10.37 |
| C1 | 29.2 ± 4.40 | 5.2 ± 3.95 | 165 ± 9.82 |
| C2 | 52.9 ± 3.42 | 12.3 ± 3.28 | 283 ± 13.77 |
| C3 | 33.6 ± 4.81 | 5.9 ± 3.97 | 193 ± 13.70 |
| C4 | 30.6 ± 3.93 | 7.9 ± 3.26 | 286 ± 11.21 |
| C5 | 41.7 ± 4.02 | 7.0 ± 3.54 | 311 ± 9.27 |
| C6 | 42.1 ± 3.90 | 9.3 ± 3.50 | 179 ± 14.49 |
| C7 | 48.4 ± 5.07 | 12.4 ± 4.45 | 352 ± 16.66 |
| C8 | 40.5 ± 4.43 | 7.1 ± 4.55 | 217 ± 17.56 |
| C9 | 30.2 ± 3.97 | 7.0 ± 2.05 | 284 ± 11.30 |
| D1 | 37.9 ± 4.60 | 10.1 ± 4.32 | 217 ± 10.13 |
| D2 | 53.7 ± 7.22 | 10.8 ± 5.39 | 190 ± 11.58 |
| D3 | 46.2 ± 5.20 | 10.1 ± 4.71 | 253 ± 14.19 |
| D4 | 37.9 ± 6.34 | 11.7 ± 5.06 | 175 ± 26.57 |
| D5 | 35.4 ± 5.33 | 13.2 ± 4.40 | 314 ± 11.55 |
| D6 | 27.4 ± 4.66 | 9.0 ± 4.68 | 271 ± 11.76 |
| D7 | 35.8 ± 4.31 | 14.3 ± 4.44 | 365 ± 15.52 |
| D8 | 172 ± 5.33 | 11.3 ± 4.40 | 409 ± 11.55 |
| D9 | 29.7 ± 4.66 | 12.0 ± 4.68 | 284 ± 11.76 |
| E | 920 ± 4.31 | 5.1 ± 4.44 | 598 ± 15.52 |
| Average | 88.849 | 9.79 | 284.65 |

effective dose, external hazard index and internal hazard index are presented in Table-2. Table-2 showed that the radium equivalent activity ($Ra_{eq}$) for the soil samples were varied from 48.186 to 969.153Bq/kg. All these values are lower than 370 Bq/kg [20] except sample (E), but the mean value are acceptable for safe use [1]. The average dose rate was calculated to be a 58.914 nGy/h and this is comparable to the world average of 57 nGy/h [5]. The values of annual effective dose ranged from 28.895to 555.849 µSv, with a mean value of 72.252 µSv, which is lower than the world average of 0.48 mSv [5] except sample (E). The calculated values of external hazard index and internal hazard index in this study were ranged from 0.113 to 2.63 and from 0.252 to 5.11 respectively. Given that certain values were higher than the unity, thus suggested that the radiation hazard is high.

The results revealed that in the sites located around the uranium mine at Abu-Skhair in Najaf governorate are comparable to another studies that determined the natural

TABLE-2
RADIUM EQUIVALENT ACTIVITY, DOSE RATE, ANNUAL EFFECTIVE DOSE AND EXTERNAL HAZARD INDEX OF DIFFERENT SITES AROUND THE URANIUM MINE AT ABU-SKHAIR IN NAJAF GOVERNORATE

| Samples | Radium equivalent activity (Bq/kg) | Dose rate (nGy/h) | Annual effective dose ($10^{-6}$ Sv) | External hazard index | Internal hazard index |
|---|---|---|---|---|---|
| A1 | 61.191 | 29.0318 | 35.60459952 | 0.167671518 | 0.27983368 |
| A2 | 192.171 | 91.9512 | 112.7689517 | 0.526438966 | 0.94049302 |
| A3 | 471.074 | 221.5 | 271.6476 | 1.281271161 | 2.44991981 |
| A4 | 78.653 | 38.2094 | 46.86000816 | 0.217270567 | 0.342946243 |
| A5 | 142.256 | 68.1094 | 83.52936816 | 0.390920701 | 0.643082863 |
| A6 | 175.87 | 83.5904 | 102.5152666 | 0.480700921 | 0.87043065 |
| A7 | 95.315 | 46.7694 | 57.35799216 | 0.263697654 | 0.43045441 |
| A8 | 158.649 | 76.6316 | 93.98099424 | 0.436121176 | 0.758283338 |
| A9 | 96.13 | 46.8304 | 57.43280256 | 0.265553906 | 0.428256608 |
| B1 | 67.831 | 31.8838 | 39.10229232 | 0.185729136 | 0.295188595 |
| B2 | 54.565 | 26.9756 | 33.08287584 | 0.151583012 | 0.232123552 |
| B3 | 71.069 | 34.3974 | 42.18497136 | 0.196409266 | 0.296679537 |
| B4 | 82.07 | 39.8736 | 48.90098304 | 0.226872587 | 0.350656371 |
| B5 | 79.719 | 39.408 | 48.3299712 | 0.221752302 | 0.325536086 |
| B6 | 84.065 | 40.615 | 49.810236 | 0.232179982 | 0.352450252 |
| B7 | 104.019 | 50.7756 | 62.27119584 | 0.287383427 | 0.469005049 |
| B8 | 62.169 | 30.518 | 37.4272752 | 0.172064152 | 0.278550639 |
| B9 | 86.376 | 42.1994 | 51.75334416 | 0.239183249 | 0.367021087 |
| C1 | 48.186 | 23.5612 | 28.89545568 | 0.133299673 | 0.212218592 |
| C2 | 90.299 | 43.755 | 53.661132 | 0.249299079 | 0.392272052 |
| C3 | 55.547 | 27.1928 | 33.34924992 | 0.153715474 | 0.244526285 |
| C4 | 61.917 | 30.9208 | 37.92126912 | 0.172664093 | 0.255366795 |
| C5 | 73.48 | 36.5554 | 44.83154256 | 0.204386694 | 0.317089397 |
| C6 | 67.929 | 32.5854 | 39.96273456 | 0.186905257 | 0.300689041 |
| C7 | 90.772 | 44.6344 | 54.73962816 | 0.251868132 | 0.382678943 |
| C8 | 65.843 | 32.1134 | 39.38387376 | 0.181986932 | 0.291446391 |
| C9 | 60.09 | 30.1084 | 36.92494176 | 0.167692308 | 0.249313929 |
| D1 | 67.533 | 32.7242 | 40.13295888 | 0.186542917 | 0.288975349 |
| D2 | 82.444 | 39.3126 | 48.21297264 | 0.226335016 | 0.371470151 |
| D3 | 78.353 | 38.0708 | 46.69002912 | 0.216459756 | 0.341324621 |
| D4 | 66.881 | 31.9266 | 39.15478224 | 0.183988714 | 0.286421146 |
| D5 | 76.256 | 37.5156 | 46.00913184 | 0.211921592 | 0.307597268 |
| D6 | 59.24 | 29.4768 | 36.15034752 | 0.165144045 | 0.239198099 |
| D7 | 81.799 | 40.5068 | 49.67753952 | 0.227852688 | 0.324609445 |
| D8 | 216.789 | 103.4672 | 126.8921741 | 0.593525394 | 1.058390258 |
| D9 | 66.74 | 32.8974 | 40.34537136 | 0.185645976 | 0.265916246 |
| E | 969.153 | 453.2364 | 555.849121 | 2.630501931 | 5.116988417 |
| Average | 122.7687297 | 58.91435676 | 72.25256713 | 0.337095658 | 0.577227141 |

radiation level of ($^{226}$Ra, $^{232}$Th, $^{40}$K) in soil of another locations in Najaf governorate such as, Madhloom [21] and Alrahban [22] regions which indicated that the average natural radiation level ($^{226}$U, $^{232}$Th, $^{40}$K) were lower than worldwide average levels. We found that our location have natural radiation levels highest than other region also it has a highest levels from the worldwide average levels, we can identified it as high background radiation areas [23].

## Conclusion

All the values of radium equivalent activity are less than 370 Bq/kg, which are acceptable for safe use OECD 1979 except the location of sample (E). The average value of dose rate obtained in this study (58.9 nGy/h) is closer to the world average (57 nGy/h). The calculated annual effective dose (average value) was 0.0722 mSv, which is lower than the worldwide average limit. The mean values of external hazard index and internal hazard index obtained in this study were 0.337 and 0.577 respectively, which means that the radiation hazard is insignificant for those population living in the investigated area.

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