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# Evaluation of Natural Radioactivity Levels and Radiological Hazards in Soil Samples of Sarıkamış Province, Kars, Turkey

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**Abstract:** In this study, the activity concentrations of 121 soil samples gathered from diverse places of Sarıkamış of Kars were found out employing NaI (Tl) gamma spectrometry. It was monitored that the concentration of the natural radionuclides $^{40}$K, $^{226}$Ra and $^{232}$Th in the soil samples altered from 148.0±31.2 to 909.2±38.4 Bqkg$^{-1}$, BDL to 38.1±8.9 Bqkg$^{-1}$ and 7.6±0.7 to 53.0±7.4 Bqkg$^{-1}$, respectively. Also relatively low deposits of $^{137}$Cs were found in the investigated area, where the activity concentrations ranged from BDL to 21.0±1.1 Bqkg$^{-1}$. The determined average values of activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K were employed to work out the radiation hazard indices in soil samples. The total observed dose rate in the working area varied from 18.4 to 87.7 nGyh$^{-1}$ with the mean value of 46.9 nGyh$^{-1}$ and also the annual effective dose ranged between 22.6 and 107.5 µSv with the average value of 57.7 µSv. It was observed that the values established whenever compared to the world values allowed are under the standard limits for the environment.

**Keywords:** Radioactivity Concentration, Soil, Gamma Spectrometry, Radiation Hazard Indices

## 1. Introduction

The greatest contribution to environmental radioactivity is comes from radioactive substances such as uranium, thorium and potassium that are naturally found in the air, water and soil of our earth. Humans are exposed to both internal and external radiation caused by both natural and artificial radiation sources [1, 2]. The level of radioactivity from natural radionuclides depends on the amount of radioactive material in the environment and is entitled as the terrestrial background radiation and contributes to the total radiation dose that people are exposed to. The amount of natural environmental radioactivity and therefore the amount of gamma dose to which it is exposed depends on geological and geographical conditions and varies for dissimilar soil types in each region of the world [2, 3]. While activity levels of naturally occurring radionuclides are generally low, the activity concentrations of the natural radionuclides in the soil can reach high levels with industrial activities [4]. In order to determine whether the region people live in is healthy in terms of the natural radionuclides concentrations in the environment, the radionuclides in the soil and the effects of radiation on human health must be known. Therefore, researches are being conducted to determine the type of radiation and the amount of radiation hazard doses caused by environmental sources and to assess the radiological risks to which humans are exposed [5-8]. In addition, assessment of natural radioactivity levels in the soil is crucial for analyzing the changing in the terrestrial background as a result of any radioactive release. The aim of this work is to determine the concentrations of natural and artificial radioactivity in soil samples and to assess human exposure dose rates and health risks.

## 2. Materials and Methods

Soil samples were taken from 24 different uncultivated fields where are undamaged by rain water and stream water away from the residential areas (Figure 1). Samples of approximately 2 kg were taken from 4-6 different sampling points and at different depths ranging from 0-15 cm in each station to provide better sampling in the studied area. The location of the Sarıkamış district in the Eastern Anatolia region is 40 ° 18 'North and 42 ° 31' East. Sarıkamış has a surface area of 1751 $km^2$ and an altitude of 2225 meters. The people of the region mostly live in livestock because of the wide availability of meadows and pastures in the surrounding area. The position of each field sampled by the samples is measured by the GPS device.

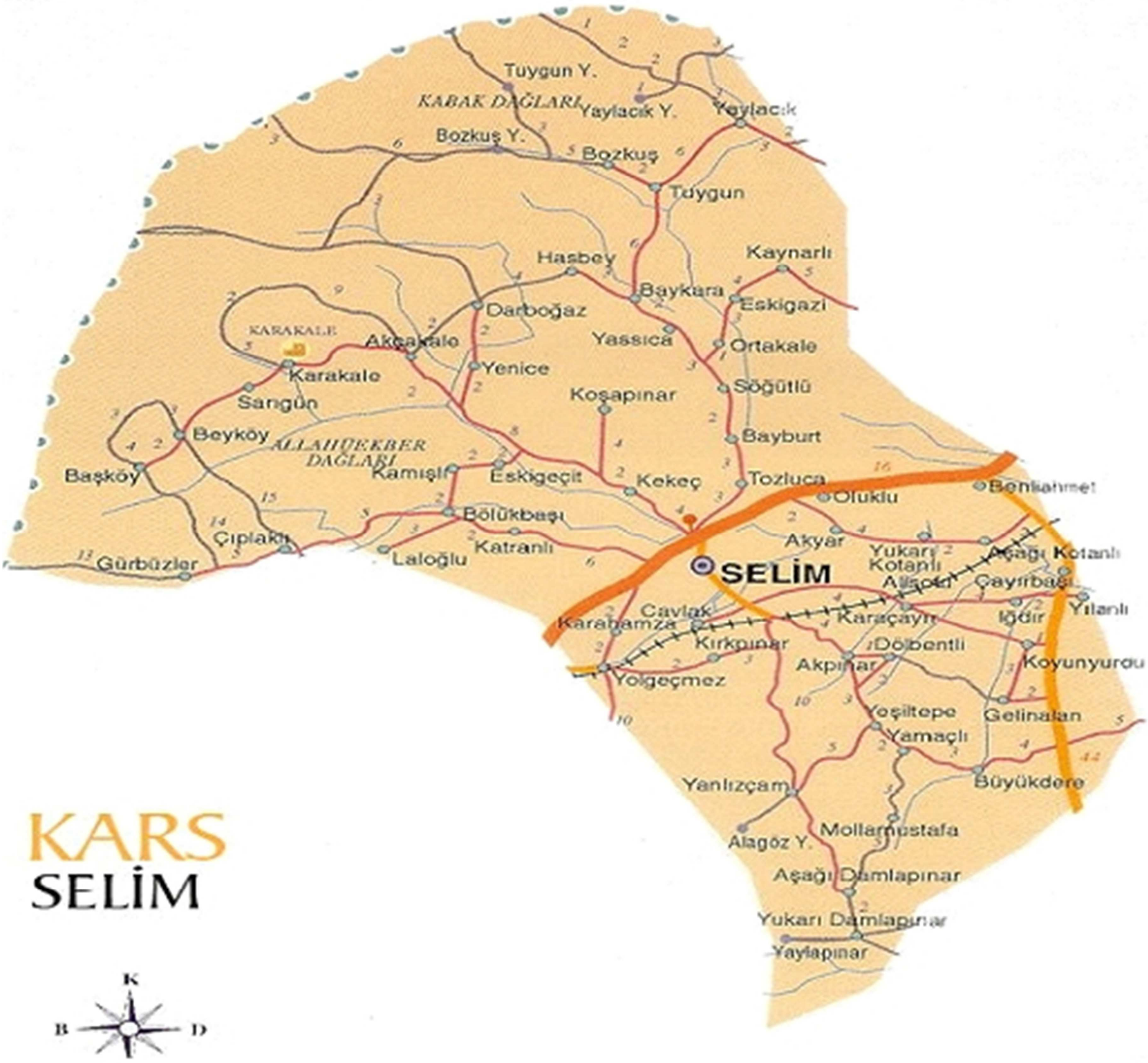


***Figure 1.*** *Map of Sarıkamış showing the area surveyed during the investigation.*

In the laboratory, stones, plant roots, etc. in soil samples were removed and homogenized by crushing and sieved with a 2 mm mesh sieve. To provide radioactive equilibrium and short-lived degradation products between radium and thorium, the weighed samples were stored in cylindrical plastic containers for 40 days. Natural radioactivity concentrations of each sample collected were calculated by counting approximately 24 hours using NaI (Tl) scintillation detector based on a gamma spectrometer system. In general, a gamma spectrometer system with a 3" x 3" NaI (Tl) detector, a NaI (Tl) scintillation detector (D), a preamplifier (PA), a high power supply (HV), an analogue digital converter (ADC), a multi-channel analyzer (MCA), and a personal computer (PC). Ortec Maestro software was used for analyzing the gamma-ray spectra. At the base and side surfaces of the detector, 5 cm thick lead layers were used to minimize the contribution of building materials and the surrounding radiation. The energy calibration and the relative efficiency calibration of the gamma spectrometer were determined with standard calibration material (IAEA-375). Activity concentrations, corresponding photopeaks at various energies were taken into account and the relevant area (ROI) regions were selected for each peak. $^{226}Ra$ concentration was determined by measuring the 609.3, 1120.3 and 1764.5 keV gamma-rays from $^{214}Bi$. In a similar way, 583 keV and 2614.5 keV from $^{208}Tl$ were employed to specify the activity concentration of $^{232}Th$. In order to calculation of the activity concentrations of $^{40}K$ and $^{137}Cs$, the 1460.8 keV and 661.7 keV gamma lines analyzed, respectively.

## 3. Gamma Radiation Parameters

### *3.1. Evaluation of Radium Equivalent ($Ra_{eq}$)*

The major purpose of assessing radioactivity is to predict the possible radiation dose to be transmitted to living organisms. Exposure to radiation can be explained by various parameters. Radium equivalent activity ($Ra_{eq}$) is a commonly utilized hazard marker. Using equation (1), computed presuming that 370 Bq $kg^{-1}$ of $^{226}Ra$, 259 Bq $kg^{-1}$ of $^{232}Th$ and 4810 Bq $kg^{-1}$ of $^{40}K$ generate equal gamma dose rate [9].

$$R_{aeq}\ (Bq\ kg^{-1}) = C_{Ra226} + 1.43C_{Th232} + 0.077C_{K40} \quad (1)$$

where $C_{Ra\text{-}226}$, $C_{Th\text{-}232}$ and $C_{K\text{-}40}$ are the activity concentration of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in $Bqkg^{-1}$, respectively. The average $Ra_{eq}$ outcomes of all studied samples examined in column 2 of Table 2 are outlined.

### *3.2. Absorbed Dose rate (ADR)*

Working out the dose rate is the principal move to assess health risk. Regarding biologic effects, the radiologic and clinical effects depend on the absorbed dose rate. The calculated activity concentrations of $^{226}Ra$, $^{232}Th$, and $^{40}K$ are turned into absorbed dose rate by utilizing 0.462, 0.604, and 0.0417 conversion factors for uranium, thorium, and potassium, respectively. These factors are exerted to work out the outdoor dose rate ($nGyh^{-1}$) using equation (2) [2];

$$ADR = 0.462\ C_{Ra} + 0.604\ C_{Th} + 0.0417\ C_K\ (nGyh^{-1}) \quad (2)$$

where $C_{Ra}$, $C_{Th}$ and $C_K$ are the activity concentrations ($Bqkg^{-1}$) for $^{226}Ra$, $^{232}Th$ and $^{40}K$ in soil samples, respectively. The values figured out for soil samples are presented in table 2.

### *3.3. Annual Effective Dose Equivalent (AED)*

The mean annual evaluated effective dose equivalent (AED) taken by a person was figured out employing a transformation factor of $7x10^{-1}$ $SvGy^{-1}$, which was used to transform the absorbed dose rate to humankind effective dose equivalent with an outdoor occupancy of 20% [2].

$$AED\ (outdoor)\ (\mu Sv/y) = ADR\ (nGy\ h^{-1}) \times 0.7\ Sv\ Gy^{-1} \times 8760\ hours \times 0.2 \times 10^{-3} \quad (3)$$

It is clear from the calculated values of the AED in table 2 that the average values of the outdoor AED for the soil samples in Sarıkamış are slightly greater than the world mean values (70 $\mu Svy^{-1}$).

### *3.4. Lifetime Cancer Risk (LCR)*

The lifetime cancer risk interests with the possibility of growing cancer over a certain exposure grade. LCR is given as equation 4, where AED is the annual effective dose, LS is the mean life span (approximately 70 years) and RF is the mortal cancer risk factor per Sievert [10, 11].

$$LCR = AED \times LS \times RF \quad (4)$$

For stochastic impacts, ICRP exploits RF as 0.05 for the community. The results are given in Table 2, which compatible the values to be the world's permissible standard of 0.29 x $10^{-3}$ [2].

## 4. Results and Discussion

The radioactivity concentration values of $^{226}Ra$, $^{232}Th$, $^{40}K$ and $^{137}Cs$ deliberated in 121 soil samples collected from 24 different sampling stations of Sarıkamış district are given in the columns 3, 4, 5 and 6 of Table 1. Average radioactivity concentration of $^{226}Ra$, $^{232}Th$, $^{40}K$ and $^{137}Cs$ were found to be 17.9±7.7, 30.7±6.8, 448.7±34.6 and 5.8±1.6, respectively. As clearly seen from Table 3, the values of the world mean radioactivity concentrations of $^{226}Ra$, $^{232}Th$, $^{40}K$ and $^{137}Cs$ are 35, 30, 400 and 14.8 $Bqkg^{-1}$, respectively [2]. According to our findings, the average activity concentration of $^{232}Th$, $^{226}Ra$ and $^{137}Cs$ are lower than the world's mean values but the average radioactivity concentration of $^{40}K$ is higher than the world average. Table 3 shows the comparison of radioactivity concentration of $^{226}Ra$, $^{232}Th$, $^{40}K$ and $^{137}Cs$ measured in Sarıkamış province with other studies in Turkey and around the world.

As a result of our studies, it was seen that the absorbed gamma dose rate values in air outdoors were varied between 18.4 nGy $h^{-1}$ (Köroğlu) and 87.7 nGy $h^{-1}$ (Karakurt) values and the mean value was 46.9 nGy $h^{-1}$. These values are given in the third column of Table 2. The calculated average value was found to be lower than Turkey and world mean value of 60.0 nGy $h^{-1}$ [1, 2]. It is also found that ADR values obtained in similar studies conducted in Turkey (Rize, Kırklareli, Adana, Mersin and Yalova) and in the world (Pakistan, Nigeria and Malaysia) is higher than our ADR values [6, 8, 11-16]. This value was found to be lower in Kars center and Palestine [5, 17]. In addition, the annual effective dose rates are given in the 4th column of Table 2, ranges from 22.6 μSv $y^{-1}$ to 107.05 μSv $y^{-1}$. The mean value of AED is found to be 57.5 μSv $y^{-1}$ which is lower than the average value of world and Turkey (70.0 μSv $y^{-1}$) [1, 2]. The calculated values of lifetime mortal cancer risk varies from $0.08x10^{-3}$ to $0.38x10^{-3}$ with the mean value of $0.20x10^{-3}$ were given in the 5th column of table 2. It was found to be lesser than the world average of $0.29x10^{-3}$ [2]. There is no sign of the possibility of developing cancer cases among people. The comparison of obtained values of LCR in this study with values reported in Turkey and also other countries of the world are given in Table 3. As can be seen Table 3, the average LCR values are much higher in Pakistan, Nigeria, Palestine and India than Sarıkamış Province [5, 7, 15, 16].

Correlation studies were conducted between the natural radionuclide activity concentrations and lifetime cancer risk. As shown in Figure 2 and 3, there is a fairly good correlation between $^{226}Ra$ ($R^2$=0.862), $^{40}K$ ($R^2$=0.856) and $^{232}Th$ ($R^2$=0.800) with lifetime cancer risk. Because the studied soil samples are rich in uranium and potassium, the $^{226}Ra$, $^{40}K$ and $^{232}Th$ series have significant contributions to the annual effective dose rate and the lifetime risk of cancer. The $^{226}Ra$, $^{232}Th$ and $^{40}K$ activity concentrations on the working surface soil are because of both natural and human-induced activities in the study area.

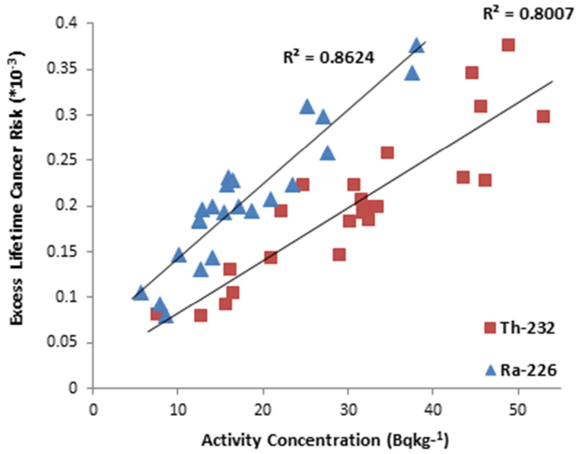


***Figure 2.*** *Scatter plots of the $^{226}$Ra and $^{232}$Th versus lifetime cancer risk.*

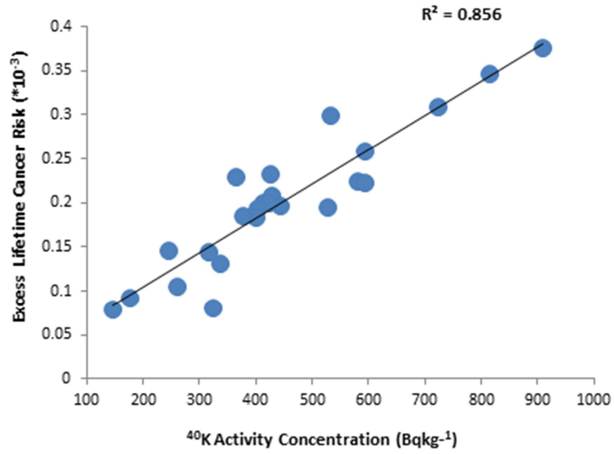


***Figure 3.*** *Scatter plot of the $^{40}$K versus lifetime cancer risk.*

***Table 1.*** *The evaluated activity concentrations of $^{226}$Ra, $^{232}$Th, $^{40}$K and $^{137}$Cs for soil samples in Sarıkamış, Kars, Turkey.*

| Sample stations Id and Locations | Number of Sample | Activity Concentrations (Bqkg$^{-1}$) | | | |
|---|---|---|---|---|---|
| | | $^{226}$Ra | $^{232}$Th | $^{40}$K | $^{137}$Cs |
| S.1. Hamamlı | 5 | 25.2±9.1 | 45.7±8.0 | 723.8±37.2 | 7.8±1.1 |
| S.2. Balabantaşı | 5 | 7.9±4.3 | 15.7±6.1 | 177.7±31.6 | 1.3±0.9 |
| S.3. Bozat | 5 | 15.9±4.8 | 43.5±8.0 | 426.7±36.2 | 2.8±1.0 |
| S.4. Besyo | 4 | 27.2±9.6 | 53.0±7.4 | 531.9±37.6 | 11.5±1.1 |
| S.5. Karakurt | 5 | 38.1±8.9 | 48.8±7.8 | 909.2±38.4 | 8.0±1.1 |
| S.6. Alisofu | 6 | 10.2±2.0 | 29.0±7.2 | 245.6±34.6 | BDL |
| S.7. Karakurt 2 | 4 | 15.8±8.5 | 30.7±6.7 | 582.0±35.2 | 21.0±1.1 |
| S.8. Köroğlu | 5 | 8.5±8.1 | 12.7±5.8 | 148.0±31.2 | 3.3±0.9 |
| S.9. Yenigazi | 5 | 17.2±9.7 | 32.1±7.8 | 414.1±37.7 | 4.9±1.1 |
| S.10. Yağbasan | 6 | 12.9±9.6 | 31.9±7.4 | 444.1±37.8 | 6.6±1.1 |
| S.11. Boyalı | 5 | 16.5±9.1 | 46.1±7.5 | 364.8±35.2 | 8.7±1.1 |
| S.12. Kalebaşı | 4 | 12.7±8.5 | 16.2±6.5 | 336.5±33.2 | 9.0±1.0 |
| S.13. Mescitli | 5 | 37.6±8.5 | 44.6±7.5 | 814.2±35.7 | 5.9±1.0 |
| S.14. Divik | 5 | 20.9±8.8 | 31.5±6.8 | 429.2±34.2 | 6.0±1.0 |
| S.15. Süngütaşı | 6 | 18,7±8.4 | 22.2±6.8 | 527.8±33.6 | 3.3±1,0 |
| S.16. Handere | 6 | 14.1±9.0 | 33.5±6.9 | 423.5±35.3 | BDL |
| S.17. Sırataşlar | 4 | 15.4±8.8 | 31.8±7.1 | 402.6±34.4 | 2.7±1.0 |
| S.18. Boyalı | 5 | 27.7±9.8 | 34.6±7.5 | 594.7±38.9 | 6.7±1.1 |
| S.19. Armutlu | 5 | 14.0±9.0 | 20.9±6.9 | 316.1±34.7 | 1.0±1.0 |
| S.20. Taşlıgüney | 5 | 23.6±8.1 | 24.8±6.5 | 594.1±32.9 | 2.3±0.9 |
| S.21. Beşyol | 4 | 12.5±8.9 | 30.2±6.7 | 400.7±34.9 | 4.8±1.0 |
| S.22. Parmakdere | 6 | BDL | 7.6±0.7 | 323.7±25.8 | 3.9±0.8 |
| S.23. Balıklı | 6 | 12.6±8.4 | 32.4±5.9 | 376.8±32.5 | 4.3±1.0 |
| S.24. Kayalıboğaz | 5 | 5.7±4.2 | 16.5±6.7 | 259.9±31.1 | 1.0±0.9 |
| Mean | 121 | 17.9±7.7 | 30.7±6.8 | 448.7±34.6 | 5.8±1.0 |

BDL; Below dedection limit.

***Table 2.*** *Radium equivalent activity ($Ra_{eq}$), absorbed dose rate (ADR), annual effective dose (AED), lifetime cancer risk (LCR) of soils of Sarıkamış, Kars, Turkey.*

| Sample stations Id and Locations | $Ra_{eq}$ (Bqkg$^{-1}$) | ADR nGyh$^{-1}$) | AED µSvy$^{-1}$) | LCRx10$^{-3}$ |
|---|---|---|---|---|
| S.1. Hamamlı | 146.3 | 72.1 | 88.5 | 0,31 |
| S.2. Balabantaşı | 44.0 | 21.4 | 26.2 | 0,09 |
| S.3. Bozat | 110.9 | 53.9 | 66.1 | 0,23 |
| S.4. Besyo | 144.0 | 69.6 | 85.3 | 0,30 |
| S.5. Karakurt | 177.9 | 87.7 | 107.5 | 0,38 |
| S.6. Alisofu | 70.5 | 34.1 | 41.8 | 0,15 |
| S.7. Karakurt 2 | 104.5 | 52.1 | 63.9 | 0,22 |
| S.8. Köroğlu | 38.1 | 18.4 | 22.6 | 0,08 |
| S.9. Yenigazi | 95.1 | 46.4 | 56.9 | 0,20 |
| S.10. Yağbasan | 92.7 | 45.7 | 56.1 | 0,20 |
| S.11. Boyalı | 110.5 | 53.2 | 65.3 | 0,23 |
| S.12. Kalebaşı | 61.7 | 30.6 | 37.5 | 0,13 |

| Sample stations Id and Locations | $Ra_{eq}$ (Bqkg$^{-1}$) | ADR nGyh$^{-1}$) | AED µSvy$^{-1}$) | LCRx10$^{-3}$ |
|---|---|---|---|---|
| S.13. Mescitli | 164.0 | 80.6 | 98.8 | 0,35 |
| S.14. Divik | 98.9 | 48.2 | 59.1 | 0,21 |
| S.15. Süngütaşı | 91.1 | 45,4 | 55.6 | 0,19 |
| S.16. Handere | 94.6 | 46.4 | 56.9 | 0,20 |
| S.17. Sırataşlar | 91.8 | 44.9 | 55.1 | 0,19 |
| S.18. Boyalı | 123.0 | 60.3 | 74.0 | 0,26 |
| S.19. Armutlu | 68.2 | 33.4 | 41.0 | 0,14 |
| S.20. Taşlıgüney | 104.7 | 52.0 | 63.8 | 0,22 |
| S.21. Beşyol | 86.5 | 42.6 | 52.2 | 0,18 |
| S.22. Parmakdere | 36.7 | 19.3 | 23.7 | 0,08 |
| S.23. Balıklı | 87.9 | 43.0 | 52.7 | 0,18 |
| S.24. Kayalıboğaz | 49.3 | 24.5 | 30.1 | 0,11 |
| Mean | 95.5 | 46.9 | 57.5 | 0.20 |

***Table 3.*** *Comparison of natural radioactivity levels in soil samples, absorbed dose rate, annual effective dose rate and lifetime cancer risks at present study stations with values reported in literature.*

| References | Region | Activity Concentrations (Bqkg$^{-1}$) | | | | | Terrestrial | | LCR X10$^{-3}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | $^{226}$Ra | $^{232}$Th | $^{40}$K | $^{137}$Cs | $Ra_{eq}$ (Bqkg$^{-1}$) | ADR (nGyh$^{-1}$) | AED (µSvy$^{-1}$) | |
| This Study | Sarıkamış | 17.9±7.7 | 30.7±6.8 | 448.7±34.6 | 5.8±1.0 | 95.5 | 46.9 | 57.5 | 0.20 |
| Cengiz et al | Kars Center | 47.8 | 51.08 | 771.57 | 18.0 | | 44.76 | 54.9 | |
| Dizman et al | Rize | 85.75 | 27.17 | 431.43 | 236.38 | 218.2 | 110.69 | 136.0 | 0.48 |
| Değerlier et al. | Adana | 17.6 | 21.1 | 297.5 | 6.8 | | 67.0 | 82.0 | |
| Taşkin et al. | Kırklareli | 28±13 | 40±18 | 667±282 | 8.0±5.0 | | 71.0 | 87.0 | 0.51 |
| Karataslı et al | Mersin | 27.1 | 34.3 | 370.5 | 18.6 | | 51.0 | 62.0 | 0.22 |
| Kapdan et al. | Yalova | 22.36 | 26.87 | 419.32 | 2.53 | | 48.89 | 59.96 | 0.42 |
| Abu Samreh et al | Palestine | 41.4 | 19.5 | 113.3 | 2.8 | 77.6 | 35.3 | 40.0 | 1.02 |
| Rafique et al | Pakistan | 31.25 ±0.5 | 44.1±1.07 | 575±8.9 | 15.04±0.3 | | 89 | 164.0 | 0.543 |
| Chandrasekaran et al | India | 19.16 | 48.56 | 1146.88 | | | | | 0.70 |
| Oyeyemi et al | Nigeria | 25.498 | 77.772 | 710.704 | | | 148.22 | | 0.635 |
| Alzubaidi et al | Malaysia | 102.08±3.9, | 133.96±2.92, | 325.8 ±9.8 | | 458.8 | 141.62 | 169.0 | |
| TAEA, 2010 | Turkey | 34.7±1.7 | 35.4±0.8 | 450.0±18 | 11.6±0.5 | | 54.6 | 70.0 | |
| UNSCEAR 2000 | Worldwide | 35.0 | 30.0 | 400.0 | 14.8 | | 60.0 | 70.0 | 0.29 |

# 5. Conclusions

The $^{232}$Th and $^{40}$K radioactivity concentration values in the soil samples of Sarıkamış District were higher than the world average (30 Bqkg$^{-1}$ and 400 Bqkg$^{-1}$), respectively, while the $^{226}$Ra radioactivity concentration value was lower than the world average (35 Bqkg$^{-1}$). Radium equivalent activity ($Ra_{eq}$), absorbed dose rate (ADR ), annual effective dose rate (AED) and lifetime cancer risk (LCR) were calculated to determine the health effects of background radiation levels on the population living in the studied region. Annual effective gamma doses and the lifetime risks of cancer were lower than the world's average.

The results of the study may constitute a reference for similar assessments to be made in this region in the future.

# References

[1] United Nation Scientific Committee on the Effect of Atomic Radiation. (2000), "Sources and Effect of Ionizing Radiation", UNSCEAR 2000 Report Vol. 1 to the General Assembly, with scientific annexes, United Nations Sales Publication, United Nation, New York.

[2] TAEA (2010). 'Türkiye'deki Çevresel Radyoaktivitenin İzlenmesi 2009'. Technique Report, Ankara 9-14.

[3] Tzortzis, M., H. Tsertos, S. Christofides, G. Christodoulides (2003). 'Gamma-ray measurements of naturally occurring radioactive samples from Cyprus characteristic geological rocks'. Radiation Measurements 37, 221-229.

[4] IAEA (2005). 'Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, Safety Standards Series No. 44 IAEA, Vienna.

[5] Abu Samreh, M. M., K. M. Thabayneh, F. W. Khrais (2014). 'Measurement of activity concentration levels of radionuclides in soil samples collected from Bethlehem Province, West Bank, Palestine'. Turkish J Eng Env Sci, 38: 113-125.

[6] Alzubaidi, G., Fauziah B. S. Hamid and I. Abdul Rahman (2016). 'Assessment of Natural Radioactivity Levels and Radiation Hazards in Agricultural and Virgin Soil in the State of Kedah, North of Malaysia'. The Scientific World Journal, 1-9.

[7] Chandrasekaran A., R. Ravisankar, G. Senthilkumar, K. Thillaivelavan, B. Dhinakaran, P. Vijayagopal, S. N. Bramha, B. Venkatraman (2014). 'Spatial distribution and lifetime cancer risk due to gamma radioactivity in Yelagiri Hills, Tamilnadu, India'. Egyptian journal of basic and applied sciences 1 38-48.

[8] Dizman S., F. K. Görür, R. Keser (2016). 'Determination of radioactivity levels of soil samples and the excess of lifetime cancer risk in Rize province, Turkey'. International Journal of Radiation Research, 14 (3): 237-244.

[9] Beretka, J. and P. J Mathew (1985). 'Natural radioactivity of Australian building materials, industrial wastes and by-products'. Health Phys., 48, 87–95.

[10] ICRP (1990) Recommendations of the International Commission on Radiological Protection, vol 212 No. 1–3, publication 60.

[11] Taskin H., M. Karavus, P. Ay, A. Topuzoglu, S. Hidiroglu, G. Karahan (2009). 'Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey'. Journal of Environmental Radioactivity, 100, 49-53.

[12] Değerlier, M, Karahan, G., Ozger, G. (2008). 'Radioactivity concentrations and dose assessment for soil samples around Adana, Turkey'. Journal of Environmental Radioactivity, 99 (7), 1018–1025.

[13] Karataslı M., S. Turhan, A. Varinlioglu, Z. Yegingil (2016). 'Natural and fallout radioactivity levels and radiation hazard evaluation in soil samples'. Environ Earth Sci, 75: 424.

[14] Kapdan, E., Varinlioglu, A. and Karahan, G (2011). 'Radioactivity Levels and Health Risks due to Radionuclides in the Soil of Yalova, Northwestern Turkey'. Int. J. Environ. Res., 5 (4): 837-846.

[15] Rafique M, S Ur Rahman, M Basharat, W Aziz, I Ahmad, K A Lone, K Ahmad, Matiullah (2014). 'Evaluation of excess life time cancer risk from gamma dose rates in Jhelum valley'. Journal of Radiation Research and Applied Sciences, 7 29-35.

[16] Oyeyemi K D, M R Usikalu, A P Aizebeokhai, J A Achuka and O Jonathan (2017). 'Measurements of radioactivity levels in part of Ota Southwestern Nigeria: Implications for radiological hazards indices and excess lifetime cancer-risks'. IOP Conf. Series: Journal of Physics: Conf. Series 852, 1-8.

[17] Cengiz, G. B., S. Reşitoğlu (2014). 'Determination of natural radioactivity levels in Kars City center'. Turkey. Journal of Nuclear Sciences, 1, 32-37.