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# Determination of natural radioactivity levels in Kars City center, Turkey

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## ABSTRACT

The objective of this study is to determine the distribution of natural radionuclides in surface soils in the Kars-city center, Turkey. The activity concentrations of $^{238}U$, $^{232}$ Th, $^{40}$ K and $^{137}Cs$ in 38 soil samples collected from the study area were measured through NaI(Tl) gamma spectrometry. The average activities of the samples were determined to be 47.8, 31.2 and 536 Bq·kg$^{-1}$ for the natural radionuclides $^{226}Ra$ ($^{238}U$), $^{232}Th$, $^{40}K$, respectively, and 18 Bq·kg$^{-1}$ for the fission product $^{137}Cs$. When the present results are compared with the data available for other cities in Turkey, the soil radioactivity concentrations obtained in this study indicate that the region has a background radiation level within natural limits but the measured average activity of $^{40}K$ depending on soil texture is slightly higher than the other parts of country.

**Keywords:** Gama dose, radioactivity, soil, Kars, Turkey.

## 1. Introduction

The purpose of the environmental radioactivity monitoring is to determine the level of radiation exposure of human beings. The exposure of human beings to ionizing radiation from terrestrial and cosmic radiation causes irradiating the body with gamma photons. Estimates of total radiation dose according to the UNSCEAR report (2000) have shown that about 86% of the radiation from natural radioactivity while 14% is from man-made sources within a year. Natural radioactivity consists of cosmogenic radionuclides produced from the interactions of cosmic ray from outer space in the atmosphere and the terrestrial radionuclides in the earth's crust.

The natural radionuclides of concern are mainly potassium ($^{40}K$), uranium ($^{238}U$), thorium ($^{232}Th$) and their radioactive decay products. A major contribution to the total dose of background exposure comes from radionuclides in $^{238}U$, $^{232}Th$ series and $^{40}K$. Natural radioactivity and terrestrial radiation depend on geological and geographical conditions of where the samples are collected.

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In addition to long-lived radioactive elements (e.g. $^{238}U$, $^{232}Th$ and $^{40}K$) found in nature, the environmental level of background radiation in a region may be increased by the nuclear weapons testing, nuclear power generation and nuclear reactor accidents like Chernobyl and Fukushima.

Turkish Atomic Energy Authority (TAEA) is trying to obtain a radiation map for Turkey. East Anatolian Region, especially Kars is one of the cities in which TAEA has neither performed soil radiation measurements nor completed the soil radiation map. In this study, we have started evaluating map soil radionuclides concentrations for Kars district by starting with the Kars city center. At an altitude of 1768 meters above sea level, the city of Kars has a surface area of 18,557 $km^2$, consisting of plateaus, mountains and green lands. The study area chosen in this work lies between the longitudes of 40° 34′ - 40° 38′ N and 43° 01′ -43° 08′ E. The population of the city is 73,826 as of 2010. It has 7 districts and 384 villages.

## 2. Materials and Methods

The activity of terrestrial radionuclides $^{238}U$, $^{232}Th$ and $^{40}K$ was determined in soil samples collected from 38 different uncultivated areas around Kars-city centrum (Fig.1). Surface soil samples of approximately 2 kg were collected from 0-10 cm depth, soil samples were obtained from three different points in each station to provide better sampling in the studied area. After the collection process, samples were stored in polyethylene bags for transport and storage. The exact location of each sample site was measured by GPS instrument. All soil samples were eliminated from the ground of stones, pebbles, vegetation and roots and then crushed into fine powder and sieved using the laboratoty sieve of 2 mm-mesh size. Each of the samples was packed and sealed in a cylindrical plastic container and then they were stored in the laboratory for about 40 days period to attain radioactive equilibrium among the decay products of radium and thorium and their short lived decay products.

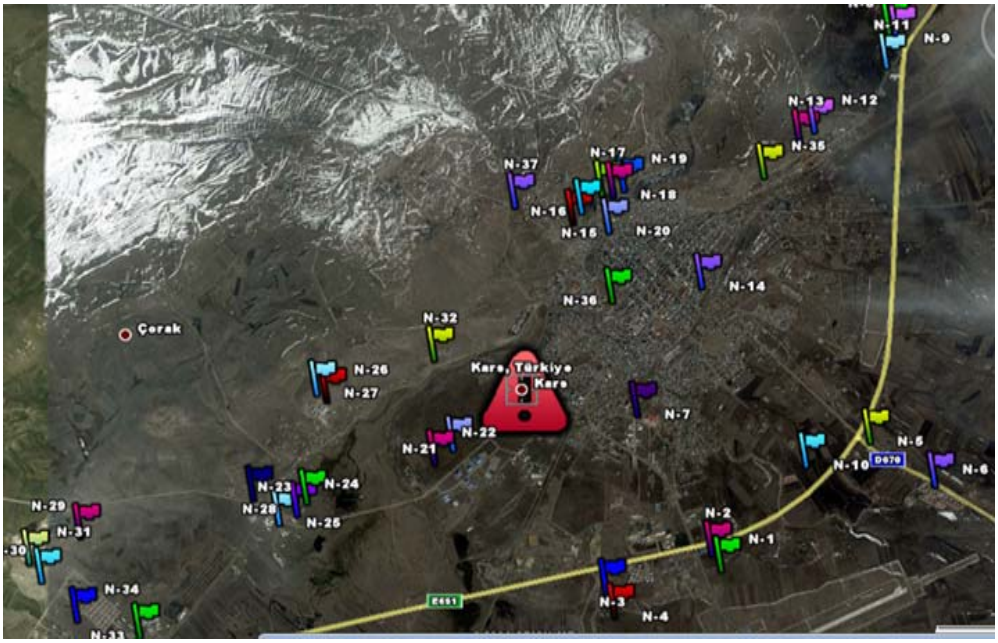


**Figure 1.** The sampling stations around Kars-city center.

The activities of samples were counted using NaI(Tl) detector based on gamma spectrometry system. The output of the detector was analyzed using a MCA system connected to PC. Ortec Maestro software was used for analyzing the gamma-ray spectra. The detector was shielded with a 5 cm thickness lead layer to reduce the background due to cosmic rays and radiation nearby the system. The system was calibrated using a standard reference material (IAEA-375) prepared by IAEA. The activity concentrations were averaged over the relevant photopeaks at several energies in the $^{238}$U and $^{232}$Th decay series and $^{40}$K. The gamma rays of 186 keV of $^{226}$Ra, 352 and 295 keV of $^{214}$Pb(from $^{226}$Ra), 609 and 1764 keV of $^{214}$Bi (from $^{226}$Ra), 338, 911 keV of $^{228}$Ac(from $^{232}$Th), 583 keV of $^{208}$Tl(from $^{232}$Th)and 1460 keV for $^{40}$K were used to determine the activity concentrations of uranium, thorium and potassium, The activity concentration of $^{137}$Cs was also measured directly by the peak at 662 keV. The samples were counted for a period of 24 h.

## 3. Results and discussion

The values of the activity concentrations of $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs measured in the soil samples from all sampling stations are given in Table 1.

**Table 1.** Radioactivity concentrations of $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs measured in the soil samples.

| Sample Number | Location | Activity concentrations (Bq·kg$^{-1}$) | | | |
|---|---|---|---|---|---|
| | | $C_U$ | $C_{Th}$ | $C_K$ | $C_{Cs}$ |
| **N-1** | 40°34'22,73" 43°6'24,69" | 13.5±12 | 8.8 ± 2.4 | 593±56 | <MDA |
| **N-2** | 40°34'16,34" 43°6'29,54" | <MDA | 79.2±15.3 | 442±51 | <MDA |
| **N-3** | 40°34'7,06" 43°5'28,43" | 71.35 ± 6.95 | <MDA | 392±57 | 38.5 ± 3.6 |
| **N-4** | 40°35'56,57" 43°5'32,99" | <MDA | 69±16 | 373±51 | <MDA |
| **N-5** | 40°35'9,82" 43°7'49,03" | 22±6 | <MDA | 496±41 | 5.15 ± 1.8 |
| **N-6** | 40°34'51,73" 43°8'23,45" | 32±3.2 | <MDA | 476±46 | 28.5 ± 2.2 |
| **N-7** | 40°35'21,08" 43°5'45,01" | <MDA | 7.7±2.35 | 460±52 | <MDA |
| **N-8** | 40°38'0,91" 43°01'704" | 74.5±7 | 7.4±2.5 | 616±59 | <MDA |
| **N-9** | 40°37'58,74" 43°8'3,71" | <MDA | 90.3±15 | 427±48 | 14.2±2.4 |
| **N-10** | 40°34'59,83" 43°7'15,18" | 66±7 | <MDA | 343±51 | 15.3±2.7 |
| **N-11** | 40°37'47,14" 43°7'58,23" | 6.85±1 | <MDA | 458±42 | <MDA |
| **N-12** | 40°37'19,91" 43°7'19,36" | <MDA | <MDA | 315±5 | 15.8±2.6 |
| **N-13** | 40°37'15,01" 43°7'11,65" | 52±5 | <MDA | 419±50 | <MDA |
| **N-14** | 40°36'14,78" 43°6'19,56" | 76±1.3 | <MDA | 465±56 | <MDA |
| **N-15** | 40°36'41,56" 43°5'10,80" | <MDA | <MDA | 859±79 | <MDA |
| **N-16** | 40°36'46,12" 43°5'15,32" | 39±4 | <MDA | 1068±82 | <MDA |
| **N-17** | 40°36'53,73" 43°5'26,16" | 56.7±7.03 | <MDA | 3028±124 | 18±2 |
| **N-18** | 40°36'53,08" 43°5'32,25" | 55±7 | <MDA | 543±56 | 11±3 |
| **N-19** | 40°36'55,58" 43°5'38,05" | 59.5±7 | <MDA | 532±60 | 14±3 |
| **N-20** | 40°36'38,02" 43°5'29,99" | 66.4±7 | <MDA | 497±51 | <MDA |
| **N-21** | 40°35'6,70" 43°4'6,82" | 67.5±7 | <MDA | 428±60 | <MDA |
| **N-22** | 40°35'0,89" 43°3'56,93" | 35.3±3.5 | <MDA | 477±54 | 12.4±2.6 |
| **N-23** | 40°34'44,3" 43°2'48,55" | 43.8±4.4 | <MDA | 475±57 | <MDA |
| **N-24** | 40°34'39,20" 43°2'43,46" | <MDA | 7±2.4 | 405±52 | 15±3 |
| **N-25** | 40°34'35,53" 43°2'33,86" | 32±3.2 | <MDA | 574±55 | <MDA |
| **N-26** | 40°35'27,08" 43°2'59,49" | 34.4±3.5 | <MDA | 323±52 | 43.3±3.6 |
| **N-27** | 40°35'30,06" 43°2'54,34" | 74.5±7 | <MDA | 224±51 | <MDA |
| **N-28** | 40°34'45,82" 43°2'20,20" | 62±7 | <MDA | 346±56 | <MDA |
| **N-29** | 40°34'30,15" 43°0'48,63" | 64±7 | <MDA | 317±52 | <MDA |
| **N-30** | 40°34'11,44" 43°0'27,64" | 33±3.3 | <MDA | 270±48 | 9.87±2.5 |
| **N-31** | 40°34'19,28" 43°0'21,40" | 51.75±7 | <MDA | 338±51 | <MDA |
| **N-32** | 40°35'44,39" 43°3'56,66" | 36.5±3.6 | 7±3 | 633±65 | 9.4±3 |
| **N-33** | 40°33'48,16" 43°1'19,62" | 64.8±6.5 | <MDA | 387±51 | <MDA |
| **N-34** | 40°33'55,00" 43°0'46,36" | 18±7 | <MDA | 435±50 | <MDA |
| **N-35** | 40°37'0,80" 43°6'52,66" | <MDA | <MDA | 442±53 | 24.3±3 |
| **N-36** | 40°36'8,79" 43°5'31,77" | 74±7 | <MDA | 614±63 | <MDA |
| **N-37** | 40°36'48,03" 43°4'39,77" | 71.55±7.15 | <MDA | 443±52 | <MDA |
| **N-38** | 40°37'49,49" 43°7'82,17" | 38.13±4 | 7.1±2.3 | 446±51 | <MDA |
| **Mean** | | **49.5±5.5** | **31.5±5.2** | **536±55** | **18.3±2.7** |

**Minimum detectable activity (MDA) is 5 Bq·kg$^{-1}$ for $^{137}$Cs, 15 Bq·kg$^{-1}$ for $^{226}$Ra and 5 Bq·kg$^{-1}$ for $^{232}$Th**

The mean activity concentrations of $^{238}$ U, $^{232}$ Th and $^{40}$ K in soil samples ranged from 6.85±1 to 74.5±7 Bq·kg$^{-1}$with of 49.73±5,52 Bq·kg$^{-1}$, 7±3to 90.3±15 Bq·kg$^{-1}$with of 31.5±5.13 Bq·kg$^{-1}$, 224±51 to 1068±82 Bq·kg$^{-1}$with of 536±55 Bq·kg$^{-1}$, respectively. For man-made radionuclide $^{137}$Cs, this study finds the activity concentration in the 5.15±3.6 Bq·kg$^{-1}$to 43.3±3.6 Bq·kg$^{-1}$range with of 18.3±2.7 Bq·kg$^{-1}$. Fig. 2 shows the frequency distributions of $^{238}$U, $^{232}$Th, $^{40}$K and $^{137}$Cs concentrations in the soil samples.

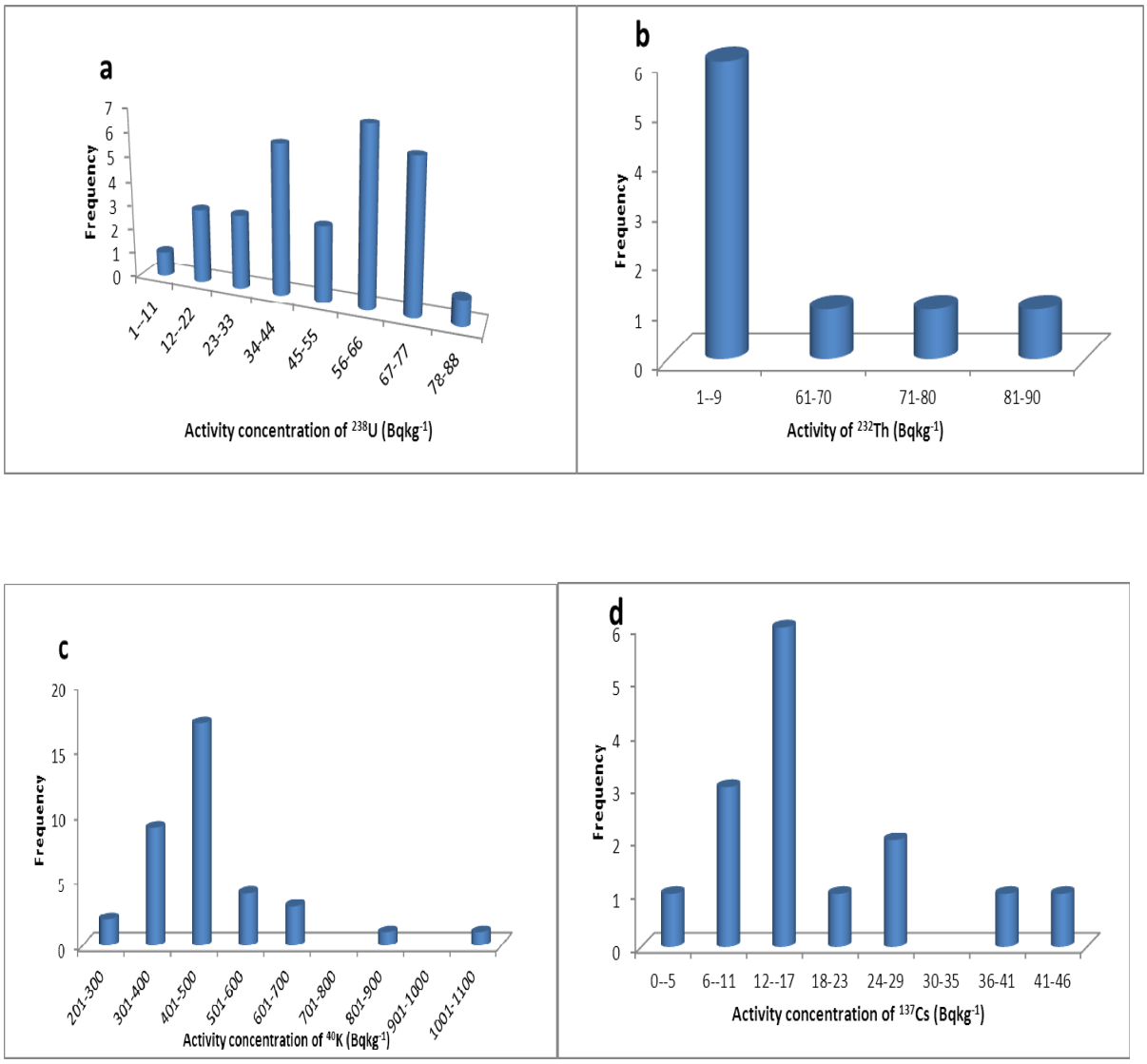


**Fig. 2.** Frequency distribution of the activity concentrations of (a) $^{238}$U, (b) $^{232}$Th, (c)$^{40}$K and (d) $^{137}$Cs in soil samples.

The measured mean activity concentrations of natural radionuclides in soil samples around Kars city center obtained in this study are compared with other reported studies (Table 2). The mean activity concentrations of the $^{238}U$ and $^{232}Th$ obtained in this study are comparable to the results of other studies conducted in different locations in Turkey and worldwide, however, the measured average activity of $^{40}K$ is slightly higher than the reported international average (UNSCEAR, 2000) (Fig.3). This relatively higher concentration may be due to partly the use of potassium rich-fertilizer or soil texture composition.

**Table 2.** Comparison of the measured activities of $^{238}U$ ($^{226}Ra$), $^{232}Th$, $^{40}K$ and $^{137}Cs$ in soil samples within various studies.

| Area | Activity concentration (Bqkg-1) | | | | References |
|---|---|---|---|---|---|
| | $C_U$ | $C_{Th}$ | $C_K$ | $C_{Cs}$ | |
| Kars Center | 47.8±5.36 | 31.2±3 | 536±52 | 18±2 | Present study |
| Kırklareli | 28±3 | 40±18 | 667±282 | 8±5 | Taskın et al. 2009 |
| Trabzon | 41 | 35 | 437 | 21 | Kurnaz et al. 2011 |
| Giresun | 33±13 | 43±14 | 733±86 | 318±46 | Celik et al. 2008 |
| İstanbul | 21 | 37 | 342 | 1.8-81 | Karahan and Bayulken |
| Çanakkale | 174.78 | 204.69 | 1171 | 0.6-57 | Orgun et al. 2007 |
| Şanlıurfa | 20.8 | 24.95 | 298 | 9.08 | Bozkurt et al. 2007 |
| Rize | 11-188 | 10-105 | 105-1235 | 19-232 | Kurnaz et al. 2011 |
| Kütahya | 33 | 32 | 255 | Not reported | Sahin and Cavas et al. 2008 |
| Manisa | 28.5 | 27 | 340 | Not reported | Erees et al. 2006 |
| Adana | 17.6 | 21.1 | 297.5 | 0.1-28 | Degerlier et al 2008 |
| Bayburt | 34.9 | 37.2 | 481.5 | Not reported | Kucukomeroglu et al. 2009 |
| Ordu | 13.4-151.7 | 14.3-98.5 | 303-1107 | 67.4-275.2 | Çelik et al. 2010 |
| Kocaeli | 11-49 | 11-65 | 161-954 | Not reported | Karakelle et al. 2002 |
| East Anatolia | 28.5-46.4 | 32.1-49.7 | 440.1-637 | 9.78 | TAEA, 2010 |
| Turkey | 28.6 | 33 | 448.5 | 13.4±0.8 | TAEA, 2010 |
| Worldwide | 35 | 30 | 400 | | UNSCEAR 2000 |

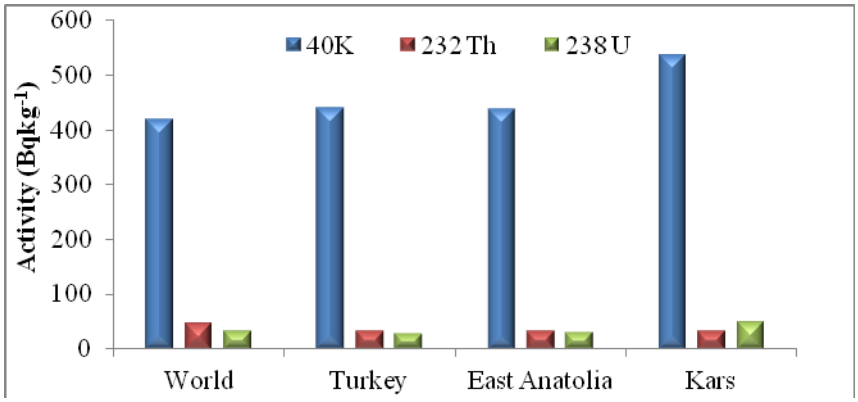


**Fig 3.** The comparison of the mean values of activity concentrations of $^{238}$ U, $^{232}Th$ and $^{40}K$ for Worldwide values with Turkey, East Anatolia Region and Kars city region.

## 3. Conclusions

The average activity concentrations of $^{238}U$, $^{232}Th$, $^{40}K$ and $^{137}$ Cs in soil were determined in the Kars city center using NaI(Tl) detector. The mean values of $^{238}U(^{226}Ra)$, $^{232}Th$ and $^{137}$ Cs were found to be 47.8±5.36 $Bq{\cdot}kg^{-1}$, 31.2±6 $Bq{\cdot}kg^{-1}$ and 18±2 $Bq{\cdot}kg^{-1}$, respectively. The mean activity concentrations of $^{238}U$ ($^{226}Ra$), $^{232}Th$ and $^{137}Cs$ were comparable to the reported values. However, the mean $^{40}K$ activity values were found to be slightly higher than the reported values due to soil texture content in Kars district. The results of this study can be used as data baseline for future research and also generating a radiation map of the study area.

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