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Determination of the Health Hazards and Life time Cancer Risk Due to Natural Radioactivity in Soil of Akyaka, Arpaçay and Susuz Areas of Kars, Turkey

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Abstract— In this study, the activity concentrations in 17 soil samples collected from different sample stations in Akyaka, Arpaçay and Susuz regions were measured using NaI(Tl) gamma spectrometry. It was observed that the concentration of the natural radio nuclides ^{40}K, ^{226}Ra and ^{232}Th in the soil samples varied from 294.9±17.4 to 712.5±23.1 $Bqkg^{-1}$, 15.6±7.5 to 48.4±7.4 $Bqkg^{-1}$ and 16.3±4.8 to 45.0±5.1 $Bqkg^{-1}$, respectively. Also relatively low deposits of ^{137}Cs were found in the investigated area, where the activity concentrations ranged from 1±0 to 29.6±3.6 $Bqkg^{-1}$. The averaged outdoor gamma absorbed dose (terrestrial and cosmic), the average annual effective dose and also the average radium equivalent activity in air due to the presence of radionuclides in 17 soil samples were obtained as 52.3 $nGyh^{-1}$, 64.17 μSvy^{-1} and 107,3 $Bqkg^{-1}$, respectively. The life time cancer risk was determined as $0.66x10^{-3}$ for the residents of this studied area. The results presented in this study are compared with the results of similar studies carried out for different parts of Turkey and around the world.

Index Terms— Radioactivity, gamma dose rate, annual effective dose, excess lifetime cancer risk, Kars

1. Introduction

The natural or artificial radioactivity present in the environment is the main source of radiation exposures for all livings. Natural radioactivity is compared of the cosmogenic and primordial radionuclides. Natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K and nuclides from the ^{226}Ra and ^{232}Th series and their decay products [1]. The natural environmental radiation mainly depends on geological and geographical conditions of a region [2]. Besides naturally occurring radionuclides, many radionuclides of radionuclides of artificial origin such as ^{137}Cs have been released into the environment by different processes.

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The knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to these radionuclides. Moreover, measurement of natural radioactivity levels in soil is very important to determine variation in natural background activity with time as a result of any radioactive release. Hence, it will be possible to monitor any radioactive release in environment. For determining the activity concentrations of uranium, thorium and potassium the following gamma rays 186 keV of ^{226}Ra, 352 and 295 keV of ^{214}Pb (from ^{226}Ra) and 609 and 1764 keV of ^{214}Bi (from ^{226}Ra), 338 and 911 keV of ^{228}Ac (from ^{232}Th), 583 keV of ^{208}Tl (from ^{232}Th) and 1460 keV for ^{40}K were used. The 662 keV gamma transition was also used to determine the ^{137}Cs concentrations.

In this study for calculating exposure dose rate in air at 1 m above, the concentration of natural radio

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nuclides measured in soil samples were used in the following Becks formula [3]

$$D\ (nGyh^{-1}) = 0{,}427C_U + 0{,}662C_{Th} + 0{,}043C_K + 0{,}03C_{Cs} \quad (1)$$

where D is the dose rate at above at 1m above ground, C_U, C_{Th}, C_K and C_{Cs} are the activity of concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in soil samples. The conversion factors of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs are 0.427, 0,662, 0.043 and 0.03 $nGyh^{-1}$ per $Bqkg^{-1}$, respectively [3], [1], [4]. The conversion factor (0.7 $SvGy^{-1}$) from absorbed dose in air to effective dose and outdoor occupancy factor (0.2) were used in the following formula for estimating the annual effective dose equivalent [1], [5].

$$\text{Annual effective dose rate } (\mu Svy^{-1}) = D(nGyh^{-1}) \times 8766(hy^{-1}) \times 0.2 \times 0.7(SvGy^{-1}) \times 10^{-6} \quad (2)$$

Distribution of radionuclides in the soil is not uniform, so it is important to know their distribution of radionuclides in the soil in terms of protecting people from radiation hazard. To evaluate the gamma radiation hazards to human associated with the use of the materials from the investigation areas, radium equivalent activity was calculated. This activity index represents the gamma output from different mixture of ^{238}U, ^{232}Th and ^{40}K in the soil samples. The Ra_{eq} was calculated by using the formula [6].

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K \quad (3)$$

where C_{Ra}, C_{Th} and C_K are the activity of concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. While defining Ra_{eq} activity, it has been assumed that 1 $Bqkg^{-1}$ of ^{226}Ra, 0.7 $Bqkg^{-1}$ of ^{232}Th and 13 $Bqkg^{-1}$ of ^{40}K produces the same gamma radiation dose rates. Excess lifetime cancer risk (ELCR) is calculated using below equation [7],

$$(ELCR = AEDE \times DL \times RF \quad (4)$$

where AEDE is the total annual effective dose equivalent (μSvy^{-1}), DL is duration of life (70 year) and RF is risk factor (Sv^{-1}), fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public [7].

2. Materials and Methods

Soil samples were collected from 17 different uncultivated fields where are undamaged by rain water and stream water away from the residential areas. Samples of approximately 2 kg were taken from ten different points and at different depths ranging from 0-15 cm in each station to provide better sampling in the studied area. The locations of sampling areas are $40^0$44'N-$43^0$37'E for Akyaka, $40^0$50'N-$43^0$19'E for Arpaçay and $40^0$46'N-$43^0$8'E for Susuz (Figure 1). The location of each sample site was measured by GPS instrument. The samples were cleaned out from stones and pebbles, and crushed, homogenized, and sieved through a 2 mm mesh in the laboratory. Weighted samples were placed in a completely sealed cylindrical plastic container for about 40 days to attain radioactive equilibrium among the decay products of radium and thorium and their short lived decay products.

The activities from samples which are collected from Akyaka, Arpaçay and Susuz districts were counted using NaI(Tl) scintillation detector based on gamma spectrometry system. The counting time was approximately 24 hours for each sample. The detector was shielded with 5 cm thickness lead layer to reduce the background due to cosmic rays and radiation nearby the system. Standard reference material (IAEA-375) was used to found energy calibration and relative efficiency calibration of the gamma spectrometer. The output of the detector was analyzed using MCA system connected to PC. Ortec Maestro software was used for analyzing the gamma-ray spectra. The activity concentrations of each sample were determined using the total net counts under the relevant photo peaks at several energies in the ^{238} U and ^{232}Th decay series and ^{40}K. In order to be able to calculate the net peak area calculating the contribution coming from outside, the natural background measurements in the same time interval without changing the system was also carried out.

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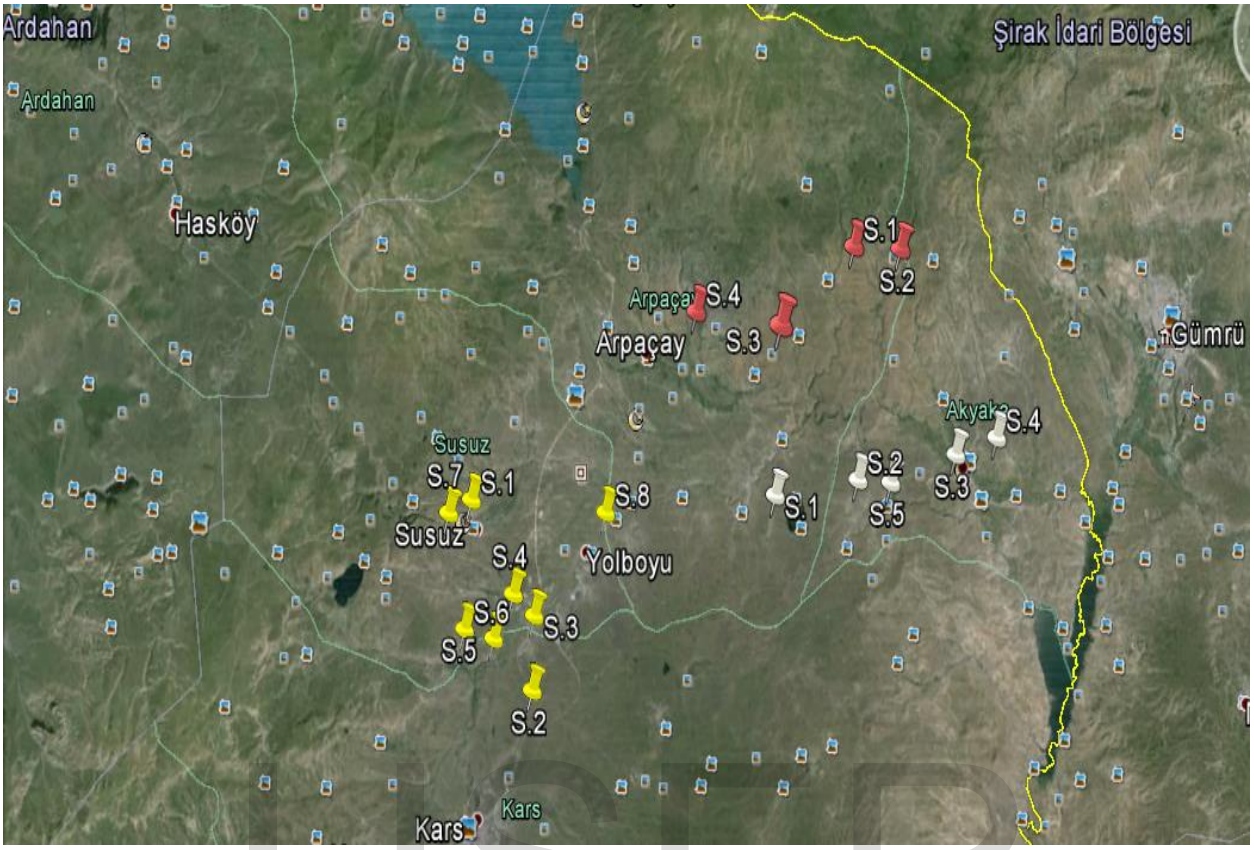

Figure 1: Sampling stations

3. Results and Discussion

The results for the activity concentration of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs measured in soil samples collected from different sampling stations of Akyaka, Arpaçay and Susuz districts, Kars are given in Table 1. The mean concentration of ^{238}U, ^{232}Th and ^{40}K in soil samples ranged from 15.6±6.7 to 48.4±20.7 Bqkg^{-1} with of 31.95±18.5 Bqkg^{-1}, 16.3±10.8 to 45.0±29.8 Bqkg^{-1} with of 27.70±16.5 Bqkg^{-1} and 294.9±12.7 to 712.5±30.6 Bqkg^{-1} with of 458.47±18.6 Bqkg^{-1}, respectively. ^{137}Cs activities varied from below detectable level (BDL) to 29.6±0.9 Bqkg^{-1} with of 14.9±0.4 Bqkg^{-1}. The lowest value of and 294.9±12.7 Bqkg^{-1} of ^{40}K and 16.3±10.8 Bqkg^{-1} of ^{232}Th were found in the soil sample from the Arpaçay district of Kars and high value of 712.5±30.6 Bqkg^{-1} of ^{40}K and also 45.0±29.8 Bqkg^{-1} of ^{232}Th in the soil sample from the Susuz district of Kars. It can be seen from the Table 1 that the lowest value of 15.6±6.7 Bqkg^{-1} of ^{238}U and high value of value of 48.4±20.7 Bqkg^{-1} were found in the soil sample from the Susuz district and Akyaka district of Kars, respectively. In studied area the highest value of ^{137}Cs (29.6±0.9 Bqkg^{-1}) in soil samples was observed in Arpaçay district of Kars.

The measured mean activity concentrations of natural radionuclide in soil samples from sampling stations shown in figure 1 obtained in this study are compared with other reported studies (Table 3). Figure 2 shows that the mean activity concentrations of the ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs obtained in this study are comparable to the results of other studies in different locations in Turkey and worldwide [1].

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Table1. Average radioactivity concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in the soil samples.

Sampling stations	Locations	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{40}K (Bqkg^{-1})	^{137}Cs (Bqkg^{-1})
Akyaka,Kuyucuk	40'74295°43'42798°	42,9±7,2	31,2±4,9	609,7±22,0	BDL
Akyaka, Duraklı	40'73985°43'51112°	35,4±6,3	36,7±4,8	450,8±19,4	BDL
Akyaka, Centum	40'73981°43'61073°	48,4±7,4	33,7±5,0	514,4±20,9	BDL
Akyaka,Esenyayla	40'74337°43'65328°	32,4±6,8	25,9±4,9	408,0±20,1	12,1±2,7
Akyaka, Şahnalar	40'73371°43'65328°	29,3±6,4	22,1±4,8	435,9±20,0	27,9±2,9
Akyaka (Mean)		**37,7±6,8**	**29,9±4,8**	**483,8±20,5**	**8±2,8**
Arpaçay,Koçköy	40'86852°43'53903°	27,6±7,1	31,8±5,1	403,0±20,2	18,6±2,4
Arpaçay, Taşdere	40'86058°43'5844°°	27,9±6,7	16,3±4,8	465,6±20,4	21,0±2,7
Arpaçay,Bardaklı	40'83372°43'45560°	35,0±6,8	24,4±4,4	294,9±17,4	17,5±2,5
Arpaçay,Telek	40'85479°43'37569°	25,0±6,5	20,7±4,8	370,6±19,3	29,6±3,6
Arpaçay (Mean)		**28,9±6,8**	**23,3±4,8**	**383,5±19,3**	**21,68±2,8**
Susuz, Centrum	40'78264°43'12973°	15,6±7,5	21,7±4,7	712,5±23,1	BDL
Susuz,Kars-Susuz Road	40'66941°43'16368°	36,1±8,8	33,0±5,4	372,8±20,8	16,7±2,8
Susuz, Mezra	40'71030°43'17569°	34,6±7,0	26,9±5,0	484,6±20,8	7,1±2,3
Susuz, Çamcavus	40'72507°43'15822°	34,9±7,4	19,2±5,1	568,1±22,6	28,6±3,2
Susuz, Boğaz köy1	40'70329°43'13299°	37,1±6,4	21,0±4,5	502,3±19,9	14,1±2,4
Susuz, Boğaz köy2	40'71240°43'10589°	21,2±6,7	28,9±5,0	455,9±20,5	17,9±2,8
Susuz, Çığrılık	40'77849°43'07378°	35,6±7,3	40,2±5,4	468,2±21,6	16,1±2,6
Susuz, Yolboyu	40'75215°43'25935°	35,0±8,3	45,0±5,1	500,5±20,7	BDL
Susuz (Mean)		**31,3±7,4**	**29,5±5,0**	**508,1±21,2**	**14,36±2,6**

Table 2. Absorbed dose rate, annual effective dose, radium equivalent and excess lifetime cancer risk measured in the soil samples.

Sampling stations	Absorbed dose rate (nGyh^{-1}) Terrestrial+cosmic	Annual effective dose rate (μSvy^{-1}) Terrestrial+cosmic	Ra_{eq} (Bqkg^{-1})	ELCR(x10^{-3})
Akyaka,Kuyucuk	65,2	80,0	134,5	0,840
Akyaka, Duraklı	58,8	72,1	122,6	0,757
Akyaka, Centum	65,1	79,9	136,3	0,839
Akyaka,Esenyayla	48,9	60,0	100,9	0,625
Akyaka, Şahnalar	46,7	57,3	94,4	0,590
Akyaka (Mean)	**56,9**	**69,8**	**117,7**	**0,730**
Arpaçay,Koçköy	50,8	62,2	104,2	0,646
Arpaçay, Taşdere	43,3	53,2	87,0	0,550
Arpaçay,Bardaklı	44,3	54,3	92,5	0,563
Arpaçay,Telek	41,2	50,5	83,1	0,519
Arpaçay(Mean)	**44,9**	**55,1**	**91,7**	**0,570**
Susuz, Centrum	51,7	63,4	101,5	0,665
Susuz,Kars-Susuz Road	53,8	66,0	112,0	0,686
Susuz, Mezra	53,6	65,8	110,4	0,688
Susuz, Çamcavus	52,8	64,8	106,0	0,669
Susuz, Boğaz köy1	51,7	63,5	105,8	0,661
Susuz, Boğaz köy2	48,4	59,3	97,7	0,616
Susuz, Çığrılık	62,4	76,6	129,2	0,798
Susuz, Yolboyu	66,2	81,2	137,8	0,853
Susuz (Mean)	**55,1**	**67,6**	**112,5**	**0,705**

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From the average radionuclide concentrations data in table1, the absorbed gamma dose rate in air and annual effective dose values ranged from 41.2 to 66.2 $nGyh^{-1}$ and 50.5 to 81.2 μSvy^{-1}, respectively. From the averaged absorbed dose 52.3 $nGyh^{-1}$, the average effective dose due to terrestrial and cosmic radiation in studied area was calculated (and shown in table 2) to be 64.17 μSvy^{-1}, which are comparable with the world population-weight mean of 60 $nGyh^{-1}$ and 70 μSvy^{-1}, respectively. The average values of radium equivalent radioactivity varied from 83,1 to 137,8 $Bqkg^{-1}$ with an average value of 107,3 $Bqkg^{-1}$ as seen table 2. The estimated average value of radium equivalent radioactivity in this study is lower than the 370 $Bqkg^{-1}$ [1]. The range of Excess life time cancer risk is $0{,}519x10^{-3}$ to $0{,}853x10^{-3}$ with an average of $0{,}717x10^{-3}$. According to these results, the risk of cancer is slightly more than the world average value of $0{,}29x10^{-3}$ [7].

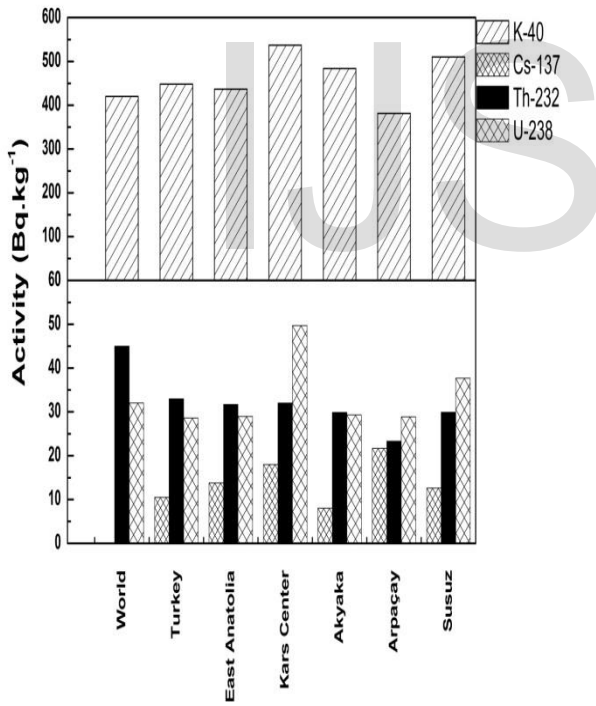

Figure 2: The comparison of the activity concentration of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs for studied area with literature.

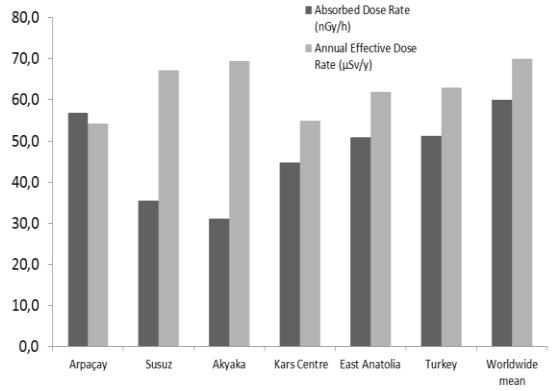

Figure 3: The comparison of the obtained mean outdoor gamma absorbed dose in air and the obtained mean annual effective dose rate for studied area with literature.

Table 3 lists the comparison of natural radioactivity levels in soil samples, absorbed dose rate and annual effective dose rate at present studied stations with values reported in literature. In figure 3, the obtained mean outdoor gamma absorbed dose in air and the obtained mean annual effective dose rate for studied area were compared with the reported mean values of Kars Centre, East Anatolia, Turkey and worldwide. According to this study, the mean contribution of uranium decay series, thorium series, non-series nuclide potassium and artificial nuclide ^{137}Cs to the absorbed dose in air were found to be 26.65%, 34.85%, 37.64% and 0.85%, respectively (Figure 4).

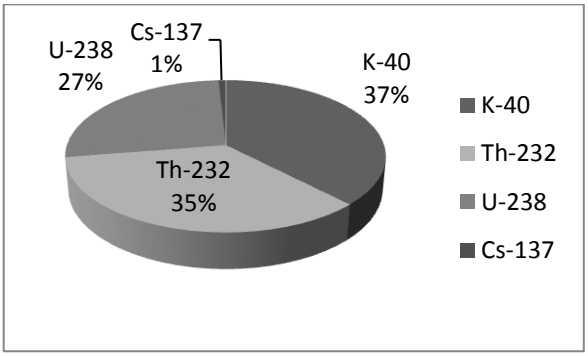

Figure 4: Relative contributions of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in soil samples to the absorbed dose in air.

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

References	Region	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{40}K (Bqkg^{-1})	^{137}Cs (Bqkg^{-1})	ADR (nGyh^{-1}) Terrestrial	AED(μSvy^{-1}) Terrestrial
Present Study	Akyaka, Arpacay, Susuz	31.95±18.5	27.70±16.5	458.47±18.6	14.9±0.4	52.3	64.17
8	Kars Centre	47.8	31.2	536	18	44.76	54.89
9	Artvin,	22±2	19±2	358±4	54±2	38	47
	Ardahan	36±1	31±0.6	341±3	14±0.4	50	62
10	Rize	11-188	10-105	105-1235	19-232	77.4	
11	Kastamonu	32.93	27.17	431.43	8.02	48.03	60
12	Adana	17.6	21.1	297.5	6.8	67	82
13	Sanliurfa	20.8	24.95	298.6		38.24	46.9
14	Manisa	29	27	340		54	66
15	Istanbul	21	37	342	1.8-81	49	65
4	Giresun	33±13	43±14	733±86	318±46		92
16	Trabzon	41	35	437	21	59	72
7	Kırklareli	28±13	40±18	667±282	8±5	71	87
17	East Anatolia	28.5-46.4	32.1-49.7	440.1-637	9.78	51.3	63
18	Turkey	34.7±1.7	35.4±0.8	450±17.9	11.6±0.5	54.6	70
1	Worldwide	35	30	400		60	70

4. Conclusion

This study aimed to obtain the concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in 17 different soil samples for Akyaka, Arpaçay and Susuz districts in Kars located in eastern of Turkey. The absorbed gamma dose and the annual effective dose with the obtained the mean concentrations of terrestrial and cosmic radionuclides in soil samples and UNSCEAR 2000 formula. According to the results of the present study the average soil activity concentrations, radium equivalent radioactivity, absorbed gamma dose rate and annual effective gamma doses are comparable with other reported studies in different locations of Turkey and worldwide mean value. This study also showed that the risk of cancer is negligible in the region under investigation. The data presented here will serve as a base line for terrestrial and anthropogenic radionuclides concentration in the study area and also gives a base line for further research for generating a radiation map of the Kars region.

Acknowledgments

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