Journal of Radioanalytical and Nuclear Chemistry (2021) 330:1017–1025
https://doi.org/10.1007/s10967-021-08046-7

A study on the activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, ^{137}Cs and radiological risk assessments in soil samples from Seydisehir and Beysehir districts of Konya in Turkey

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Received: 14 July 2021 / Accepted: 6 October 2021 / Published online: 18 October 2021

Abstract
The aim of this study is to investigate the activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in soil samples from Seydisehir and Beysehir districts of Konya province in Turkey using gamma-ray spectrometry and to calculate radiological risk parameters. The average radioactivity concentrations of ^{226}Ra and ^{232}Th are higher than world average value whereas the average radioactivity concentration of ^{40}K is lower than world average value. Mean values of absorbed gamma dose rate and annual effective dose equivalent are higher than world mean value while mean value of radium equivalent activity is lower than world average value.

Keywords Natural and artificial radionuclides activity · Radiological risk assessment · Gamma-ray spectrometry · Seydisehir and Beysehir districts · Soil samples

Introduction

People are inevitably subjected to radiation along their lives. The biggest contribution to our radiation environment is caused by long-lived radioactive elements. The radioactivity from these radionuclides, called natural radionuclides, alters pursuant the geologic and geographic structure of the area [1]. Uranium, thorium and their decay products and potassium are main naturally occurring radionuclides in the soil [2]. In addition to natural radionuclides, the presence of artificial radionuclides also causes an increase in radioactivity values in the soil. Artificial radionuclides originate from medical and industrial applications, nuclear weapons, nuclear accidents, etc. [3]. Soils are constant source of radiation for living beings because soils form an environment for environmental migration of parts such as water, air, sediments and biological systems [4].

Ionizing radiation from natural and artificial radionuclides is harmful to human health [5]. Ground-emitted radiation conduces to the aggregate dose absorbed by inhalation, ingestion, and external radiation [6]. Therefore, determination of soil radioactivity is significant component for appraising the radiological effects of living things and determining the radioactivity polluting the environment.

There are various studies in the scientific literature about specification of activity concentration of natural and artificial radionuclides. For example, Stevanović et al. [7] studied activity of natural radionuclides and heavy metals of soil in Toplica area from South Serbia and they reported that there is not important risk for humans in Toplica region besides there was significant correlation among ^{226}Ra and ^{232}Th and heavy metals. Joel et al. [8] investigated natural radionuclides activity levels in soil samples of coastaline area of Ado-Odo/Ota Nigeria using gamma-ray spectrometry and their results indicated that radiological risk values were in the range of acceptable limit values of the scientific literature except for gamma dose rate and annual effective dose equivalent. Dusane et al. [9] examined variations of natural radionuclides activity concentrations in soil samples from Tarapur in India and their results showed that ^{238}U and ^{232}Th activity concentrations were in good agreement with

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the Indian and world mean values of soil samples and mean ^{40}K activity concentrations in their study are smaller than worldwide mean value. Miller and Voutchkov [10] determined activity levels of natural radionuclides in uncontaminated surface soils in Jamaica and they pointed that there were substantial positive correlations for soil properties and gamma activities for ^{232}Th and ^{238}U though negative correlations for ^{40}K. Arafat et al. [11] studied natural and artificial radionuclides activities of water, soil and shore sediments in Marsa Alam-Shalateen area, Red Sea coast in Egypt and they reported that there are not risks in soil samples for humans. Furthermore, Taskin et al. [12] investigated natural and artificial radionuclides levels of soil samples in Kırklareli from Turkey and they obtained that the activity concentrations of radionuclides in soil samples were within the worldwide values though annual effective gamma doses and the excess lifetime cancer risks were bigger than the world mean values. Sahin et al. [13] researched natural radionuclides activity concentrations of soil samples in Kutahya from Turkey and their results indicated that radiological risk values were not higher than world mean and permissible limit values. Kaya et al. [14] surveyed activity levels of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs in soils of Gumushane in Turkey and their results demonstrated that activity concentrations of radionuclides in soils were lower than average values for Turkey. Natural radionuclides activities and risk evaluation in soils from Sakarya in Turkey were carried out by Tabar et al. [15] and they obtained that radiological risk parameters are smaller than national and international limit values. Yildirim et al. [16] analyzed natural and artificial radionuclides levels Saklikent in Antalya from Turkey in terms of effects of quarries and they stated that the variations of ^{238}U and ^{232}Th and ^{40}K were from the quarries in the examined area. Zaim and Atlas [17] explored natural and artificial radionuclides in soils from Edirne in Turkey and they remarked that mean values vaguely overrun the permissible limit values.

The aim of this study is to investigate radionuclides activity levels of natural radionuclides and ^{137}Cs and is to calculate radiological risk parameters which are absorbed gamma dose rate, annual effective dose equivalent, radium equivalent activity, internal hazard index, external hazard index and gamma representative level in soil samples from Seydisehir and Beysehir districts of Konya in Turkey. Obtained results are compared other studies and permission limit values of the scientific literature.

Experimental process

Study area

Seydisehir and Beysehir districts from Konya province are between 37° 25′, 37° 67′ northern latitudes and 31° 50′ and 31° 72′ eastern longitude. Twenty soil samples were taken from geographical coordinates where are approximately 3 km ranges as shown in Table 1 and Fig. 1 in order to determine natural and artifial radionuclides activity concentration and dose assessments.

The most common soil types of Seydisehir and Beysehir districts are coluvial soils, lime brown soils, chestnut colored soils, red brown mediterranean soils and brown soils. Working area has often alluvial soils showing insufficient drainage, salinity and bauxite deposit [18, 19].

Sampling and counting

The soil samples were collected approximately 1–1.5 kg. Gravels, stones, decayed the biological residues such as root, tree leaves and branches, were seperated and left out of the soil samples therafter each soil samples was put the plastic bags which was pre-labeled and clean. The soil samples were carried to the gamma spectroscopy laboratory. The laboratory has been ventilated for 3–4 days to reach the natural humidity level of each sample.

Afterwards, each sample was dried (24–48 h) at 130 °C in bakery. Then, soil samples were put in the 100 ml plastic containers. Each sample was labeled, weighed with precision scales and was recorded. The samples were waited for approximately 30 days to obtain a secular equilibrium between ^{226}Ra and ^{232}Th with their daughter nuclides [20].

Table 1 Geographical coordinates of examined soils

Sample No.	Latitude (N)	Longitude (E)
1	37°27′32.4″	31°50′17.4″
2	37°28′44.0″	31°49′20.1″
3	37°30′11.6″	31°48′51.7″
4	37°31′16.0″	31°48′43.9″
5	37°32′24.4″	31°48′16.0″
6	37°33′26.8″	31°47′56.4″
7	37°35′11.0″	31°48′18.5″
8	37°36′23.2″	31°47′56.5″
9	37°37′41.0″	31°47′13.3″
10	37°38′50.7″	31°46′35.8″
11	37°40′07.4″	31°45′00.9″
12	37°42′30.1″	31°42′40.7″
13	37°43′43.2″	31°42′16.2″
14	37°44′31.8″	31°41′56.9″
15	37°45′59.0″	31°40′28.7″
16	37°46′29.1″	31°39′46.6″
17	37°47′28.7″	31°39′16.6″
18	37°49′17.4″	31°38′38.1″
19	37°50′55.1″	31°36′41.4″
20	37°51′36.8″	31°35′54.6″

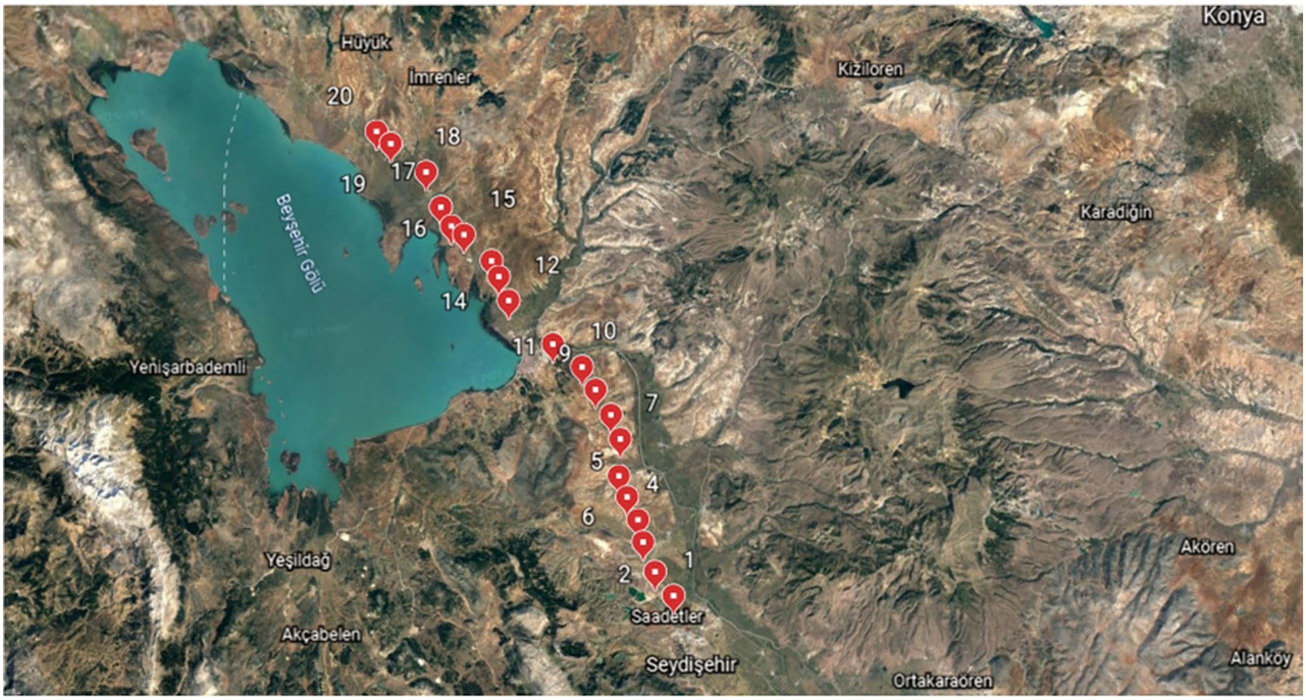

Fig. 1 Geographical coordinates of collected soil samples

Soil samples were counted 86,400 s using high purity germanium (HPGe) dedector which is housed in a lead castle in Department of Physics in Akdeniz University to calculate radioactivity levels of the radionuclides. The full width at half maximum (FWHM) of the HPGe dedector is 1.85 keV for ^{60}Co (1332 keV), 768 eV for ^{57}Co (122 keV) and relative efficiency of the HPGe dedector is 40% [21].

Before counting of soil samples, the background radiation was counted a day. Later, background counts were subtracted from soil samples spectra. Spectra were collected and analyzed using MC^2 Analyzer Program [22].

In gamma spectrum analysis; activity concentration of ^{238}U (^{226}Ra) series was calculated using 351 keV in ^{214}Pb and 609.3 keV in ^{214}Bi, and the ^{232}Th series was calculated using the 911.1 keV in ^{228}Ac. The activity concentration of ^{226}Ra was calculated average value of activity concentration of ^{214}Pb and ^{214}Bi. The radioactivity levels of the ^{40}K and ^{137}Cs was calculated straightly using peak areas of the 1460.8 keV and 661.64 keV energies, respectively.

Determination of activity concentration

Radioactivity levels of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs radionuclides in soil samples were calculated in units of Bq/kg using following fundamental Eq. (1) [23]:

$$A = \frac{N}{\varepsilon \times t \times m \times I_{\gamma}} \tag{1}$$

where N states number of peak counts of soil samples after background substracted,ε stands for the detector efficiency of examined gamma-ray energy, t states counting time (sec), I_{γ} specifies gamma-ray emission probability, m (kg) defines mass of the soil.

Determination of radiological risk parameters

Radium equivalent activity (Ra_{eq}) (Bq/kg) is a suited parameter to compare the particular activity levels of samples including various radioactivity levels of ^{226}Ra, ^{232}Th and ^{40}K. Ra_{eq} depends on the radionuclide activity levels of ^{226}Ra, ^{232}Th and ^{40}K and Ra_{eq} activity is calculated from Eq. 2: [24].

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \tag{2}$$

where A_{Ra}, A_{Th} and A_{K} represent the radioactivity levels of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg), respectively.

Absorbed Dose Rate (D) in outdoor air due to terrestrial gamma radiation 1 m level is calculated based on natural activity levels of ^{226}Ra, ^{232}Th and ^{40}K. 0.462, 0.604 and 0.0417 were dose conversion factors of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The D in air was reckoned as follow (3): [1].

$$D\left(nGyh^{-1}\right) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \tag{3}$$

The radiation doses that people are subjected to during 1 year are determined by calculating the annual effective dose equivalent (AEDE). When calculating AEDE, it is important to know how long are people exposed to gamma-rays. The occupancy factor is a measure of how much of the time is spent indoors and outside. It is thought that 20% of their people's time is spent outdoors. AEDE is calculated using Eq. (4): [1].

$$AEDE = D\left(nGyh^{-1}\right) \times 8760\left(hy^{-1}\right) \times 0.2 \times 0.7\left(Sv(Gy)^{-1}\right) \times 10^{-3} \tag{4}$$

The external hazard index (H_{ex}) is exploited to compute the external radiation damage caused by the disseminated gamma radiation and is determined of Eq. (5): [25].

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \le 1 \tag{5}$$

Besides the H_{ex}, radon and its short-lived nuclides as well detriment respiratory organs. Therefore, the internal damages occured by radon and its daughter nuclides are determined by internal hazard index (H_{in}) and calculated by Eq. (6): [2].

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \le 1 \tag{6}$$

Gamma representative level ($I_{\gamma r}$) is employed to guess the gamma radiation threat level caused by natural gamma sources in soil samples. It is also important in determining whether these samples are employed as structure matters or not. Gamma representative levels of soil samples were calculated using Eq. (7): [2].

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \tag{7}$$

Minimum detectable activities (MDA) of the radionuclides are computed using following equation which is defined by Currie [26, 27].

$$MDA = \frac{2.71 + 4.65\sigma}{\varepsilon \times t \times m \times I_\gamma} \tag{8}$$

where σ is uncertainty of background count of the related nuclide, t is counting time of the background spectrum,ε is the efficiency of the detection system for energy of radionuclide under consideration, m is mass and I_γ is emission probability of related gamma-ray energy.

Results and discussion

MDAs of radionuclides were calculated using background spectrum as 0.627 Bq/kg for ^{226}Ra, 1.107 Bq/kg for ^{232}Th, 5.462 Bq/kg for ^{40}K and 1.407 Bq/kg for ^{137}Cs. Radioctivity levels of the ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs of investigated soil samples are higher than MDAs.

The radioactivity levels of natural radionuclides (^{226}Ra, ^{232}Th, ^{40}K) and artificial radionuclide (^{137}Cs) of the soil samples are presented in Table 2 and variation of the activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs are displayed in Figs. 2, 3, 4 and 5, respectively. The radioactivity concentrations of soil samples vary in range from 18 ± 1 Bq/kg to 64 ± 1 Bq/kg with a mean value of 42 ± 1 Bq/kg for ^{226}Ra, from 22 ± 1 Bq/kg to 83 ± 2 Bq/ kg with a mean value of 54 ± 2 Bq/kg for ^{232}Th, from 119 ± 4 Bq/kg to 654 ± 10 Bq/kg with a mean value of 338 ± 7 Bq/kg for ^{40}K and from 3.9 ± 0.2 Bq/kg to 13.3 ± 0.4 Bq/kg with a mean value of 8.5 ± 0.3 Bq/kg for ^{137}Cs.

As indicated in Table 2, the smallest activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were recorded in sample 8, while the highest concentrations were found in sample 15

Table 2 The radioactivity concentration of natural radionuclides and artificial radionuclide

Sample No.	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)
1	59 ± 1	60 ± 2	530 ± 9	7.9 ± 0.3
2	54 ± 1	69 ± 2	654 ± 10	12.0 ± 0.4
3	53 ± 1	63 ± 2	598 ± 9	12.3 ± 0.4
4	62 ± 1	68 ± 2	400 ± 7	6.9 ± 0.3
5	26 ± 1	34 ± 1	238 ± 6	12.8 ± 0.4
6	35 ± 1	49 ± 2	258 ± 6	8.1 ± 0.3
7	54 ± 1	83 ± 2	372 ± 7	8.3 ± 0.3
8	18 ± 1	22 ± 1	119 ± 4	13.3 ± 0.4
9	38 ± 1	51 ± 2	232 ± 6	11.4 ± 0.4
10	24 ± 1	29 ± 1	307 ± 6	7.6 ± 0.3
11	35 ± 1	58 ± 2	409 ± 8	10.5 ± 0.4
12	58 ± 1	50 ± 1	417 ± 7	5.0 ± 0.2
13	32 ± 1	44 ± 1	210 ± 5	7.3 ± 0.3
14	34 ± 1	40 ± 1	160 ± 5	9.0 ± 0.3
15	64 ± 1	75 ± 2	341 ± 7	9.1 ± 0.3
16	44 ± 1	58 ± 2	259 ± 6	7.2 ± 0.3
17	33 ± 1	67 ± 2	325 ± 7	3.9 ± 0.2
18	29 ± 1	46 ± 1	258 ± 6	5.8 ± 0.3
19	36 ± 1	54 ± 2	295 ± 6	6.1 ± 0.3
20	56 ± 1	66 ± 2	383 ± 7	5.3 ± 0.3
Average	42 ± 1	54 ± 2	338 ± 7	8.5 ± 0.3
Minimum	18 ± 1	22 ± 1	119 ± 4	3.9 ± 0.2
Maximum	64 ± 1	83 ± 2	654 ± 10	13.3 ± 0.4

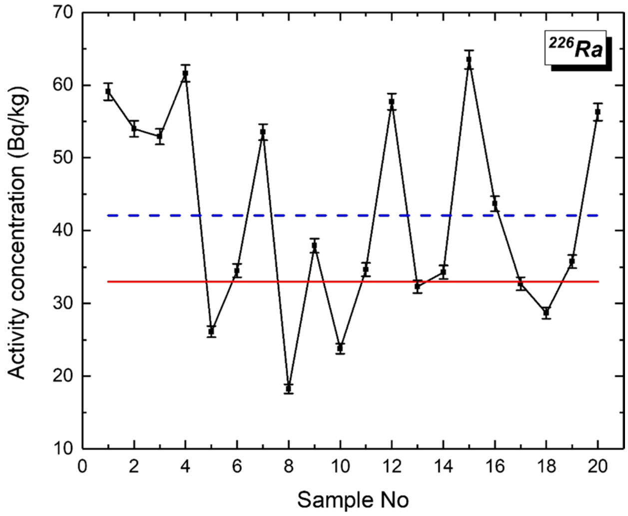

Fig. 2 Variation of ^{226}Ra activity concentration of the soil samples. World mean value from UNSCEAR 2000 [1] and mean value of the present study are shown horizontal solid red line and dashed blue line, respectively

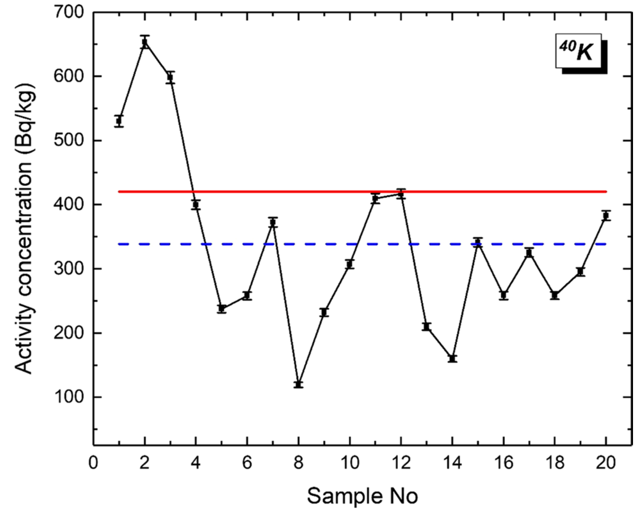

Fig. 4 Variation of ^{40}K activity concentration of the soil samples. World mean value from UNSCEAR 2000 [1] and mean value of the present study are shown horizontal solid red line and dashed blue line, respectively

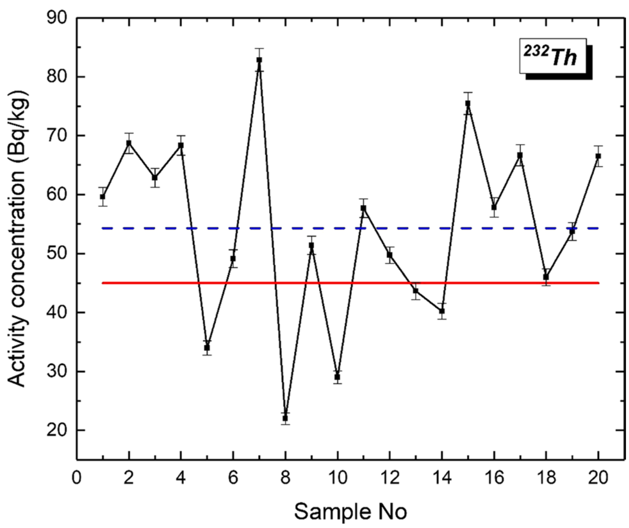

Fig. 3 Variation of ^{232}Th activity concentration of the soil samples. World mean value from UNSCEAR 2000 [1] and mean value of the present study are shown horizontal solid red line and dashed blue line, respectively

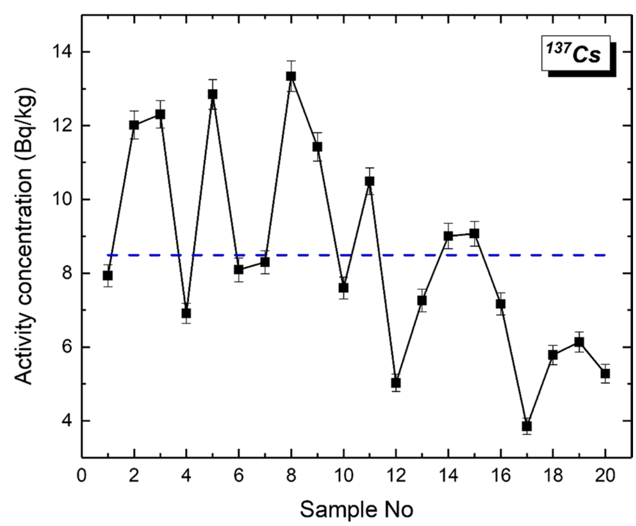

Fig. 5 Variation of ^{137}Cs activity concentration of the soil samples. Mean value of the present study are shown horizontal dashed blue line

for ^{226}Ra, sample 7 for ^{232}Th and sample 2 for ^{40}K. Activity concentrations for ^{137}Cs were found as the lowest in the sample 17 and the highest in the sample 8.

D, Ra_{eq}, AEDE, H_{ex}, H_{in} and $I_{\gamma r}$ of soil samples are presented in Table 3. Variations and comparison of world average values of D, Ra_{eq}, AEDE of soil samples are indicated in Figs. 6, 7 and 8, respectively.

Minimum, maximum, and mean values of D are 27 nGy/h and 94 nGy/h and 66 nGy/h, respectively. Minimum, maximum, and average values of Ra_{eq} are 59 Bq/kg, 203 Bq/kg and 146 Bq/kg, respectively. Minimum and maximum of AEDE are 33 µSv/y and 115 µSv/y, respectively. Mean value of AEDE is 81 µSv/y. Average values of D and AEDE of soil samples in present study are higher than world mean value of 59 nGy/h for D and 70 µSv/y for AEDE while average value of Ra_{eq} of soil samples in present study is lower than world mean value of 370 Bq/kg for Ra_{eq} [1, 28]. Lowest and highest values of H_{ex} are 0.16 and 0.55, respectively. Mean value of H_{ex}

Table 3 Absorbed gamma dose rate (D), radium equivalent activity (Ra_{eq}), annual effective dose equivalent (AEDE), external hazard index (H_{ex}), internal hazard index (H_{in}) and gamma represantative level ($I_{\gamma r}$) of soil samples

Sample No.	D	Ra_{eq}	AEDE	H_{ex}	H_{in}	$I_{\gamma r}$
1	85	185	105	0.50	0.66	1.34
2	94	203	115	0.55	0.69	1.48
3	87	189	107	0.51	0.65	1.38
4	86	190	106	0.51	0.68	1.36
5	43	93	52	0.25	0.32	0.67
6	56	125	69	0.34	0.43	0.89
7	90	201	111	0.54	0.69	1.43
8	27	59	33	0.16	0.21	0.42
9	58	129	71	0.35	0.45	0.92
10	41	89	51	0.24	0.30	0.65
11	68	149	83	0.40	0.50	1.08
12	74	161	91	0.43	0.59	1.16
13	50	111	61	0.30	0.39	0.79
14	47	104	57	0.28	0.37	0.74
15	89	198	109	0.53	0.71	1.41
16	66	146	81	0.39	0.51	1.04
17	69	153	85	0.41	0.50	1.10
18	52	114	64	0.31	0.39	0.82
19	61	135	75	0.37	0.46	0.97
20	82	181	101	0.49	0.64	1.30
Average	66	146	81	0.39	0.51	1.05
Minimum	27	59	33	0.16	0.21	0.42
Maximum	94	203	115	0.55	0.71	1.48

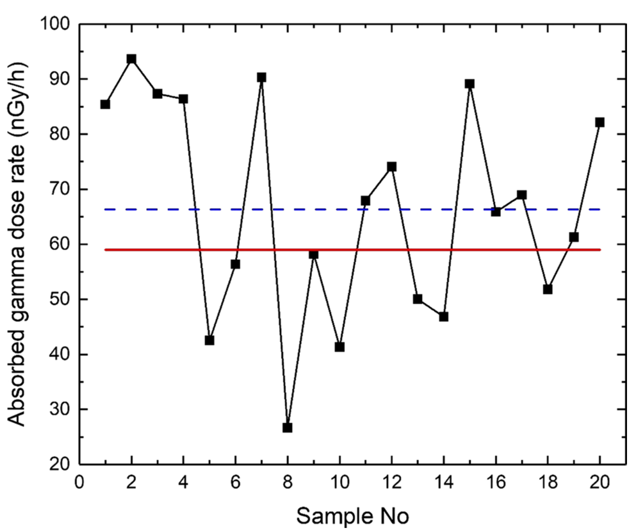

Fig. 6 Absorbed gamma dose rate (D) of the soil samples. World mean value [1, 28] and mean value of the present study are shown horizontal solid red line and dashed blue line, respectively

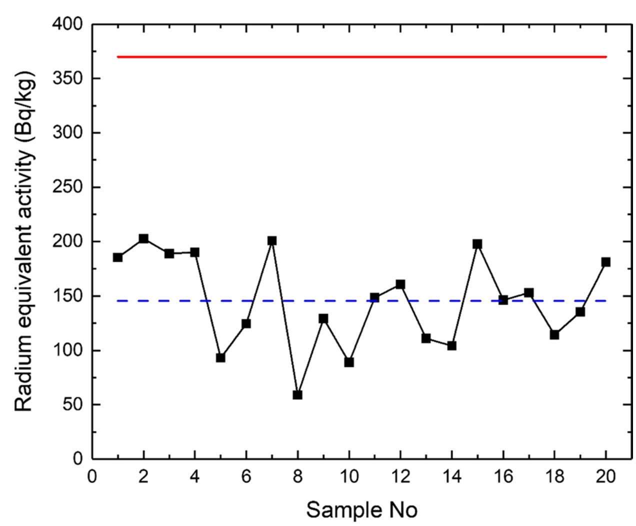

Fig. 7 Radium equivalent activity (Ra_{eq}) of the soil samples. Horizontal solid line is Ra_{eq} level in environmental sample contributing maximum 1 *mSv* of annual effective dose at a height of 1 m above the ground level [1, 28] and dashed blue line is mean value of the present study

is 0.39. Lowest and highest values of H_{in} are 0.21 and 0.71, respectively. Mean value of H_{in} 0.51. Lowest and highest values of $I_{\gamma r}$ are 0.42, and 1.48, respectively. Mean value of $I_{\gamma r}$ is 1.05. Mean values of H_{ex} and H_{in} of soil samples are lower than permissible limit value of 1 while mean value of $I_{\gamma r}$ is higher than permissible limit value of 1 in scientific reports [1, 28].

Many research has been performed to state radioactivity level of radionuclides of soil samples in scientific literature.

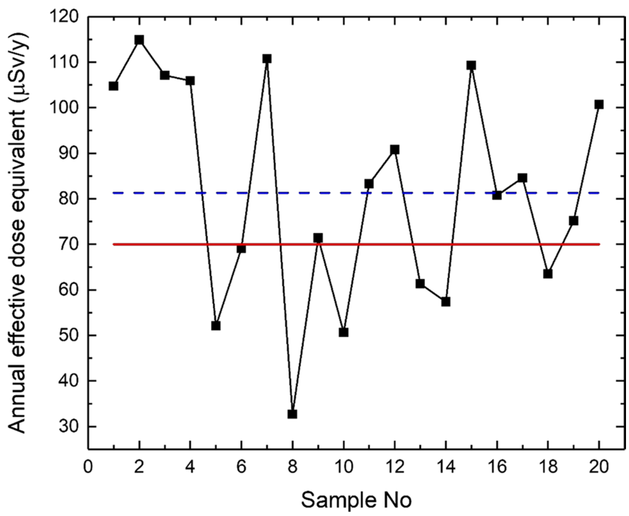

Fig. 8 Annual effective dose equivalent (AEDE) of the soil samples. World mean value [1, 28] and mean value of the present study are shown horizontal solid red line and dashed blue line, respectively

As an example, natural radioanuclide acticity levels of soil samples from various regions of the world are presented in Table 4.

In present study, ^{226}Ra and ^{232}Th activity concentrations are higher than reported worldwide limit values while mean value of ^{40}K activity concentration is lower than worldwide limit value as shown in Table 4.

^{226}Ra radioactivity levels obtained from soil samples in Turkey [30, 35, 39, 40] and abroad [33, 37, 38] are higher than mean activity concentration of ^{226}Ra radioactivity in this study. However, ^{226}Ra activity concentrations in Turkey [31, 34, 44] and abroad [29, 32, 36, 41–43, 45] is lower than mean activity concentration of ^{226}Ra radioactivity in this study.

The average of ^{232}Th activity concentration values in present study is smaller than from India [32], Turkey (Central Black Sea region) [35], Yemen (Delta Abyan) [36], Malaysia (Kedah) [37], Nigeria (Ogun) [38], Turkey (Karaman) [39] although the average of ^{232}Th activity concentration value in present study is higher than Spain (Eastern Canary Islands) [29], Turkey (Rize) [30], Turkey (Mersin) [31], North Cyprus [33], Turkey (Sivas) [34], Turkey (Kütahya) [40], Bosnia and Herzegovina (Tuzla and Lukavac) [41], Iraq (Baghdad) [42], Thailand [43], Turkey (Samsun) [44], Lebanon [45] (see Table 4).

Mean activity concentration of ^{40}K of soil samples in this study are greater than some values informed in similar studies in Turkey [31, 34] and abroad [37, 38, 41, 45]. Furthermore, mean activity concentration of ^{40}K of soil samples in this study lower than ^{40}K radioactivity levels in Turkey [30, 35, 39, 40, 44] and abroad [29, 32, 33, 36, 42, 43, 45].

Average activity concentrations of ^{137}Cs from the scientific literature are given in Table 4. Mean activity concentrations of ^{137}Cs in Refs. [33, 35] are smaller values than present study however mean activity concentrations of ^{137}Cs

Table 4 Comparison of the average activity concentrations of radionuclides in this study and reported values from other studies

Country	Activity concentration (Bq/kg)				References
	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)	
Spain (Eastern Canary Islands)	25.2	28.9	384.4	–	[29]
Turkey (Rize)	85.75 ± 11.77	51.08 ± 9.4	771.57 ± 37.65	236.38 ± 13.49	[30]
Turkey (Mersin)	27.1	34.3	37.5	18.6	[31]
India (Ramanagara,Tumkur, Karnataka)	33.78 ± 1.99	77.44 ± 2.37	791.58 ± 5.78	–	[32]
North Cyprus	83.7 ± 9.0	53.6 ± 5.9	593.9 ± 54.0	7.1 ± 0.8	[33]
Turkey (Sivas)	37	17	222	–	[34]
Turkey (Central Black Sea region)	68	62	479	8	[35]
Yemen (Delta Abyan)	33.15	77.25	1220,59	–	[36]
Malaysia (Kedah)	102.08 ± 3.96	133.96 ± 2.92	325.87 ± 9.83	–	[37]
Nigeria (Ogun)	45 ± 10	135 ± 8	195 ± 20	–	[38]
Turkey (Karaman)	135.1–32.7	140.6–49.5	651.2–250.1	–	[39]
Turkey (Kütahya)	56.4	25.9	538.4	–	[40]
Bosnia and Herzegovina (Tuzla and Lukavac)	41	32	331	37	[41]
Iraq (Baghdad)	16.94	9.4	374.60	–	[42]
Thailand	29	49	344	–	[43]
Turkey (Samsun)	38.1 ± 1.4	39.3 ± 0.8	375.3 ± 10.2	12.1 ± 0.7	[44]
Lebanon	37	24	206	23	[45]
World average value	33	45	420	–	[1]
Turkey (Seydisehir and Beysehir districts of Konya)	42 ± 1	54 ± 2	338 ± 7	8.5 ± 0.3	Present work

calculated in Refs. [30, 31, 41, 44, 45] are greater than present study.

The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in present study are higher than some regions as indicated in Table 4. This situation is due to the greater uranium and thorium substance of the rock and soil formation that form the geological structure of the region.

Conclusions

Natural and artificial radionuclides activity levels of twenty soil samples from Seydisehir and Beysehir districts of Konya in Turkey were calculated using HPGe dedector. The average radioactivity levels are 42 ± 1, 54 ± 2 and 338 ± 7 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. In addition, the average activity of ^{137}Cs which is artificial radionuclide is 8.5 ± 0.3 Bq/kg. Also, D, AEDE, Ra_{eq}, H_{in}, H_{ex} and $I_{\gamma r}$ of soil samples were determined. Obtained results were compared to world average values and permissible limit values of the scientific reports. Mean values of D, Ra_{eq} and AEDE are 66 nGy/h, 146 Bq/kg and 81 µSv/y, respectively. Mean values of H_{ex}, H_{in} and $I_{\gamma r}$ are 0.39, 0.51 and 1.05, respectively.

As result, mean activity levels of ^{226}Ra and ^{232}Th of this study are not in the range of world average values specified in scientific literature. Mean activity level of ^{40}K of this study is in the range of world average value however activity levels of ^{40}K of some investigated areas are higher than world average value. ^{137}Cs which is artificial radionuclide is detected all investigated regions. In addition, mean values of D and AEDE are higher than world mean values in present study but mean value of Ra_{eq} is lower than world mean value in this study. Mean value of $I_{\gamma r}$ is higher than unity value whereas mean values of H_{ex} and H_{in} are smaller than unity in this study. The knowledge presented in this research can be utilized as a basis for the future detailed studies for the studied area.

Acknowledgements We respectfully commemorate Hüseyin Özkara for his support in collecting soil samples.

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