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A study of background radioactivity level for Canakkale, Turkey

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Abstract This study assesses the level of background radiation for Canakkale province of northwestern Turkey. Radon concentrations in indoor air were determined using CR-39 nuclear track detectors and ^{222}Rn activity was found to be 167 Bq m^{-3} (equivalent to an annual effective dose of 4.2 mSv). Measurements of outdoor gamma radiation (of terrestrial and cosmic origin) in air were performed using plastic scintillators, and the average absorbed gamma dose rate was found to be 66.4 nGy h^{-1} (corresponding to an annual effective dose of 81.4 μSv). The radionuclide activity concentrations in soil samples collected from the study area were measured through gamma-ray spectrometry, and the average activities were determined as 94.55, 110.4, and 1,273 Bq kg^{-1} for the natural radionuclides ^{238}U, ^{232}Th, and ^{40}K, respectively, and 19.39 Bq kg^{-1} for the fission product ^{137}Cs. The natural radioactivity sources resulted in an annual effective dose of 184 μSv. The radioactivity levels of drinking water samples were measured as 0.0599 Bq l^{-1} for gross-alpha activity and 0.0841 Bq l^{-1} for gross-beta activity using a low-background counting technique (equivalent to an annual effective dose of 12.25 μSv). The results of this study show that the activity levels of radon in air, radionuclides in soil, and alpha activities in drinking water are higher compared to the data available for other Turkish cities and the world averages. On the other hand, the outdoor gamma dose rates in air and beta activities in drinking water are within natural limits.

Keywords Radon · Gamma dose · Radioactivity · Soil · Water · Canakkale · Turkey

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Introduction

Determining the distribution of naturally or artificially radioactive nuclides that are present in the environment is necessary for assessing the effects of radiation exposure (UNSCEAR 2000). For this reason, measurements of natural radioactivity in air, soil, and drinking water samples are continuously carried out by many researchers throughout the world. In Turkey, some survey studies have been performed, especially in the northern parts of the country, which were affected during the Chernobyl accident (TAEK 1988). However, data for other parts of the country are needed for a complete assessment of the country's background radiation level.

The province of Canakkale is situated in the northwestern part of Turkey between the longitudes of 25°40′–27°30′ E and the latitudes of 39°27′–40°45′ N (peak elevation, 1,767 m above sea level). It has a population of about 460,000, with 53% living in rural areas (Environmental Status Report 2004). The region spans an area of 9,750 km^2 and is divided into 12 administrative units (districts). It has humid and rainy winters (average rainfall, 600 mm) and hot summers. The geology of the area shows characteristics of the Pliocene Epoch of Tertiary Era, and the land is composed of mostly mountainous terrains. The soil in the region has lower ratios of organic matter and higher concentrations of phosphorus and potassium.

In an effort to obtain data on environmental radioactivity for the Canakkale region of Turkey, where abnormally higher levels of background radioactivity have been reported in the past, measurements of indoor radon concentrations, outdoor gamma absorbed doses in air, radionuclide activity concentrations in surface soil, and gross-alpha and gross-beta activities in drinking water have been performed.

Materials and methods

In order to passively determine the ^{222}Rn levels, CR-39 nuclear track detectors, which consist of a 2×2-cm^2 film placed in a plastic cup closed with a semi-permeable membrane, were placed in basements of 40 apartment buildings and houses in Canakkale and were kept in the dwellings for 3 months. The detectors were collected after that period and a chemical process of etching was applied to the films in 30% NaOH solution at 70°C for 17 h. The films were then washed with distilled water and dried in a dust-free chamber. The indoor ^{222}Rn activity concentrations (in units of becquerels per cubic meter) were estimated by counting the tracks left by alpha particles on the films exposed to radon gas, which were visible under a microscope (500× magnification).

In order to measure the outdoor gamma radiation level in the study region, a dose rate meter (Eberline smart portable device, ESP-2, connected with a SPA-6 model plastic scintillation detector) was employed. At 379 locations, readings were taken in air for a preset time of 600 s at 1 m above ground level. The results (in units of microroentgens per hour) included both terrestrial and cosmic ray components of gamma radiation level.

In order to quantify the radioactivity levels in soil, surface samples were collected from uncultivated locations of the study area. At each location, the ground was cleared of stones, pebbles, vegetation, and roots, and 1–2 kg of material from the first 10 cm of topsoil was placed in a labeled polythene bag. Twelve soil samples were transferred to the laboratory, where they were first dried in air and then ground into fine powder to pass through a 100-mesh screen. In order to maintain radioactive equilibrium between ^{226}Ra and its daughters, the homogenized samples were sealed in 1,000-ml Marinelli beakers, dry-weighed, and stored for a period of 1 month. Each sample was then counted using a gamma spectroscopy device (Canberra, model 85) connected to a coaxial high-purity germanium detector. The system was calibrated using standard mixtures of gamma-emitting isotopes in 1,000-ml Marinelli beakers. Each sample was counted for 50,000 s to reduce statistical uncertainty. The activity of each sample was determined using the total net counts under the selected photopeaks (^{238}U series: 186 keV for ^{226}Ra, 352 keV for ^{214}Pb, and 609 keV for ^{214}Bi; ^{232}Th series: 583 keV for ^{208}Tl and 911 keV for ^{228}Ac; 1,461 keV for ^{40}K; 662 keV for ^{137}Cs), the measured photo-peak efficiency, the gamma intensity, and the sample weight. After correcting for background and Compton contribution, the activity concentrations (in units of becquerels per kilogram) of the above-mentioned radionuclides were obtained for each soil sample.

In order to evaluate the radioactivity levels in water, a total of eight drinking water samples

Table 1 Indoor ^{222}Rn activity concentrations (40 measurements) and comparison with literature

	^{222}Rn activity concentration (Bq m^{-3})	Effective dose (mSv year^{-1})
Mean	167	4.2
Standard deviation	56	1.4
Minimum	82	2.1
Maximum	318	8.0
Median	157	3.9
Edirne (Bozkurt and Kam 2007)	49.2 (13–221)	1.24 (0.33–5.57)
Istanbul (Koksal et al. 2004)	10–260	0.5–13
Izmir (Erees and Yener 1999)	53–86	2.65–4.3
Kastamonu (Kam and Bozkurt 2007)	98.4 (29–177)	2.48 (0.73–4.46)
Manisa (Erees et al. 2006)	97 (47–146)	4.86 (2.35–7.3)
Tekirdag (Yarar and Kam 2005)	87	2.01
World (Thorne 2003)	39	1.01

The data in parentheses are the corresponding ranges

were collected from selected locations of the study area and were transported to the laboratory in 500-cm^3 plastic bottles. They were then prepared for radionuclide analyses according to a routine procedure outlined by Karahan et al. (2000). Each sample was counted for gross alpha and beta radioactivities (in units of becquerels per liter) in a low-background counter (Berthold, LB770-PC 10-Channel Low-Level Planchet Counter).

Results and discussion

The summary statistics for the measurement results of indoor ^{222}Rn activity concentrations are presented in Table 1. The average concentration obtained in this study is 167 Bq m^{-3}, which is comparatively higher than those from some cities in Turkey and is a factor of four greater than the world average of 39 Bq m^{-3} (UNSCEAR 2000).

Table 2 Gamma absorbed doses in air (379 readings) and the corresponding annual effective doses for the districts of Canakkale and comparison with literature

District	Nu. of readings	Abs. dose (μR h^{-1})				Abs. dose (nGy h^{-1})	Eff. dose (μSv y^{-1})
		Mean	Std. dev.	Min.	Max.		
Ayvacik	128	11	4.15	1.8	21.9	95.6	117
Bayramic	19	5.97	1.86	3.66	11.5	51.9	63.7
Biga	16	4.5	1.18	2.84	6.59	39.1	48
Bozcaada	7	9.54	5.37	4.14	20.4	83	102
Can	28	5.47	1.48	2.08	8.5	47.6	58.4
Canakkale	50	5.15	1.54	1.86	8.71	44.8	54.9
Eceabat	16	4.68	4.81	2.14	22.1	40.7	49.9
Ezine	30	9.42	5.11	2.25	20.5	81.9	101
Gelibolu	27	3.66	0.81	1.82	5.45	31.9	39.1
Gokceada	6	3.75	1.18	2.18	5.21	32.6	40
Lapseki	29	6.33	3.76	3.01	20.0	55	67.5
Yenice	23	7	1.53	3.99	9.78	60.9	74.7
Canakkale (This study)	379	7.63	4.34	1.8	22.09	66.4	81.4
Gaziantep (Osmanlioglu et al. 2007)	94	5.76	2.38	2.6	17.7	50.11	61.5
Istanbul (Karahan and Bayulken 2000)						65 (32–94)	
Kastamonu (Kam and Bozkurt 2007)	60					48.03 (36.1–84.6)	58.9
Manisa (Erees et al. 2006)						(78.3–135.72)	
Sanliurfa (Bozkurt et al. 2007)	112	7	1.52	4.03	11.2	60.94 (35.06 – 97.44)	74.7
Tekirdag (Yarar and Kam 2005)						43 (30.3–54.3)	
World (UNSCEAR 2000)						59	70

The data in parentheses are the corresponding ranges

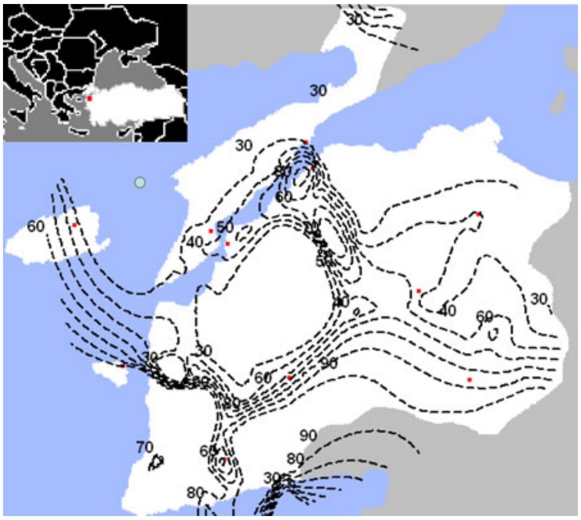

Fig. 1 Iso-dose contour map of gamma absorbed dose rate (nGy h^{-1}) for Canakkale

The annual average effective dose corresponding to this ^{222}Rn activity can be calculated using the conversion factor of 9 nSv Bq^{-1} h^{-1} m^3, as suggested by UNSCEAR (2000), together with the equilibrium factor of 0.4 and the occupancy factor of 0.8 for indoor exposure. The mean value is 4.2 mSv $year^{-1}$, which is larger than the world average of 1.01 mSv $year^{-1}$ (Thorne 2003).

The average gamma doses absorbed in air are given in Table 2. The measured values, converted to nanograys per hour using the conversion factor of 8.7 nGy μR^{-1} (from the definition of Roentgen), are depicted in Fig. 1 in the form of an iso-dose contour map of the region. The average of 379 gamma absorbed dose readings in air are calculated as 66.4 nGy h^{-1}, which is comparable with other Turkish cities as shown in Table 2. This average can further be converted to annual effective dose in millisieverts per year using the conversion factor of 0.7 Sv Gy^{-1} and the outdoor occupancy factor of 0.2 (UNSCEAR 2000). The calculated values of annual effective dose due to gamma radiation range from 19.2 to 236 μSv with a mean value of 81.4 μSv, which is above the world average of 70 μSv (UNSCEAR 2000).

The activity concentrations of the soil samples collected from the study region are given in Table 3 for the radionuclides ^{226}Ra, ^{214}Pb, ^{214}Bi, ^{208}Tl, ^{228}Ac, ^{40}K, and ^{137}Cs. The average concentrations of 12 samples measured in this study are 94.55 Bq kg^{-1} for ^{238}U series, 110.4 Bq kg^{-1} for ^{232}Th series, and 1,273 Bq kg^{-1} for ^{40}K, and are higher than the data for other Turkish cities and the world averages as shown in Table 3. For the man-made radionuclide ^{137}Cs, this study has found an activity concentration of 19.39 Bq kg^{-1}.

To estimate the terrestrial component of the gamma level from the measured ^{238}U, ^{232}Th, and ^{40}K concentrations, the procedure outlined by UNSCEAR (2000) has been followed. This method utilizes the conversion factors of 0.462,

Table 3 Soil radioactivity concentrations (in becquerel per kilogram; 12 samples) and in comparison with literature

	^{238}U series			^{232}Th series		^{40}K	^{137}Cs
	^{226}Ra	^{214}Pb	^{214}Bi	^{208}Tl	^{228}Ac		
Mean	114.9	89.23	79.55	117.5	103.4	1,273	19.39
Standart deviation	54.9	41.47	38.11	42.64	42.26	730.7	19.25
Minimum	29.39	21.39	21.89	42.52	38.84	583.1	2.04
Maximum	253.1	181.6	164.9	177.2	160.9	3,307	72.26
Median	109.9	83.28	72.3	113	103.5	1,208	13.68
Canakkale (This study)	94.55			110.4		1273	19.39
Gaziantep (Osmanlioglu et al. 2007)	25.2			23.7		289.2	8.02
Istanbul (Karahan and Bayulken 2000)	21			37		342	
Kastamonu (Kam and Bozkurt 2007)	32.93			27.17		431.43	8.02
Kestanbol (Merdanoglu and Altinsoy 2006)	115			193		1,207	
Manisa (Erees et al. 2006)	28.5			27		340	
Sanliurfa (Bozkurt et al. 2007)	20.8			24.95		298.61	9.08
World (UNSCEAR 2000)	33			45		420	

Table 4 Gross alpha and gross beta radioactivity levels in drinking water (in becquerels per liter; eight samples) and comparison with literature

	Gross alpha (Bq l^{-1})	Gross beta (Bq l^{-1})
Mean	0.0599	0.0841
Standart deviation	0.0957	0.0506
Minimum	0.0179	0.0405
Maximum	0.296	0.199
Median	0.0249	0.0758
Gaziantep (Osmanlioglu et al. 2007)	0.0493 (0.0065–0.3026)	0.1284 (0.0198–0.4183)
Giresun (Damla et al. 2006)	0.0071	0.0971
Istanbul (Karahan and Bayulken 2000)	0.0228 (0.007–0.045)	0.0664 (0.02–0.13)
Kastamonu (Kam and Bozkurt 2007)	0.0089 (0.0014–0.026)	0.271 (0.0162–2.241)
Rize (Damla et al. 2006)	0.0083	0.0828
Sanliurfa (Bozkurt et al. 2007)	0.038 (0.0018–0.4323)	0.1324 (0.006–0.9247)
Trabzon (Damla et al. 2006)	0.0065	0.1008

The data in parentheses are the corresponding ranges

0.604, and 0.0417 (nGy h^{-1})/(Bq kg^{-1}) for ^{238}U, ^{232}Th, and ^{40}K, respectively, to estimate the absorbed doses in air due to natural radionuclides in soil samples. Based on the average radionuclide concentrations measured in this study, the mean absorbed gamma dose in air has been calculated as 150 nGy h^{-1} (min, 59.15 nGy h^{-1}; max, 305.2 nGy h^{-1}) and is higher than the world average of 60 nGy h^{-1} (UNSCEAR 2000). The average contributions of terrestrial radionuclides ^{238}U, ^{232}Th, and ^{40}K to absorbed dose in air are 30.45, 66.7, and 53.1 nGy h^{-1}, respectively, with ^{232}Th series being the dominant contributor. From the calculated average absorbed dose of 150 nGy h^{-1}, the average annual effective dose due to terrestrial gamma radiation in Canakkale is found to be 194 μSv, which falls well above the world average of 70 μSv (UNSCEAR 2000).

The gross alpha and gross beta activity measurements for the drinking water samples collected in this study are presented in Table 4. The average gross alpha activities of eight samples obtained in this study are generally higher compared to other parts of Turkey, as seen in Table 4, and are lower than the no-action screening level recommended by World Health Organization for drinking water, which are 0.5 Bq l^{-1} for gross alpha activity and 1 Bq l^{-1} for gross beta activity (WHO 2004). In order to estimate the total annual effective dose from the average gross alpha activity, a dose conversion coefficient of 2.8×10^{-4} mSv Bq^{-1} for ^{226}Ra (an alpha emitter) can be used, assuming that an adult, on the average, consumes 2 l of water per day (WHO 2004). This results in an annual effective dose of 12.25 μSv for this study.

Conclusion

This study intends to layout the background radiation level for the coastal province of Canakkale (Turkey) through measurements of indoor radon concentration, outdoor gamma doses in air, radionuclide concentrations in surface soil, and gross-alpha and beta activities in drinking water. In comparison with the data available for other Turkish cities and the world averages, the results of this study suggest higher levels of radon activity in air, radionuclides concentration in soil, and alpha activities in drinking water. On the other hand, outdoor gamma dose rates in air and beta activities in drinking water are within natural limits.

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