Journal of Environmental Radioactivity 99 (2008) 1349–1354

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Determination of indoor radon and soil radioactivity levels in Giresun, Turkey

N. Celik [a,*], U. Cevik [a], A. Celik [b], B. Kucukomeroglu [a]

[a] Department of Physics, Karadeniz Technical University, Trabzon 61080, Turkey
[b] Department of Physics, Giresun University, Giresun, Turkey

ARTICLE INFO

Article history:
Received 4 September 2007
Received in revised form 14 April 2008
Accepted 16 April 2008
Available online 23 May 2008

Keywords:
Indoor radon survey
Radioactivity in soil
Radon and lung cancer
Chernobyl

ABSTRACT

Indoor radon survey and gamma activity measurements in soil samples were carried out in the Giresun province (Northeastern Turkey). The result of analysis of variance showed a relationship between indoor radon and radium content in soil ($R^2 = 0.54$). It was found that indoor radon activity concentration ranged from 52 to 360 Bq m^{-3} with an average value of 130 Bq m^{-3}. A model built by BEIR VI was used to predict the number of lung cancer deaths due to indoor radon exposure. It was found that indoor radon is responsible for 8% of all lung cancer deaths occurring in this province. ^{137}Cs activity concentration was measured 21 years after the Chernobyl accident. The results showed that ^{137}Cs activity concentration ranged from 41 to 1304 Bq kg^{-1} with an average value of 307 Bq kg^{-1}. The indoor radon results and the geology of the studied area were discussed. Annual effective doses to the both radionuclides of natural origin and ^{137}Cs were estimated.

1. Introduction

The natural or artificial radioactivity present in the environment is the main source of radiation exposure for human beings. The naturally occurring radionuclides of primary importance are ^{40}K, and the radioactive decay chains of ^{238}U and ^{232}Th. Among radionuclides in the ^{232}Th and ^{238}U series, there are two radioactive gas isotopes of noble gas: ^{220}Rn and ^{222}Rn. These gases enter into the atmosphere from soil and building materials and their decay products attach to the aerosols. Inhaled radon, together with aerosols containing its decay products, irradiates the respiratory track, especially the lungs and causes increasing chance of getting lung cancer. The worldwide annual effective dose from natural sources is estimated to be 2.4 mSv (UNSCEAR, 2000a,b,c).

As a result of nuclear explosions carried out in the earth's atmosphere and the Chernobyl nuclear power station accident, the world has become polluted with radionuclides of artificial origin. Some of these long-lived isotopes (^{134}Cs ($T_{1/2} = 2$ y) and ^{137}Cs ($T_{1/2} = 30$ y)) are still eminent in the environment predominantly in surface soil, as a result of radioactive fall-out from the atmosphere. For environmental protection, measurement of environmental radioactivity is important to determine the amount of fluctuation of natural background in time with respect to any radioactivity release from nuclear weapon tests or nuclear power plant accidents.

The Chernobyl disaster had an impact on many countries. Regions affected by radioactive fall-out included not only Ukraine itself but also Belarus, Georgia, Poland, Sweden, Germany, Austria, Hungary, Finland, Norway, Turkey and others. After this accident, intensive large-scaled radiological investigations of the environmental samples were started worldwide. The main purposes of these studies were to define the contamination level and to protect the environment against harmful effect of artificial radioactivity.

The northeastern part of Turkey was one of the most seriously contaminated regions by this accident (TAEK, 1998). During the emergency, Cekmece Nuclear Research and Training Center performed an analysis of various substances. In their report, it was noted that the surface soil ^{137}Cs activity concentration of the eastern part of the Black Sea mountains was around 4–4.5 kBq kg^{-1} at the 0.5 cm soil in the year 1988 (Unlu et al., 1995). And also the level of ^{137}Cs activity concentration in Turkish tea plant was found to be the maximum value of 44 kBq kg^{-1} for the 1986 products by Gedikoglu and Sipahi (1989).

The Giresun province (Fig. 1) is located in northeastern part of Turkey between the longitudes of 37°50′–39°12′ E and the latitudes of 40°07′–41°08′ N with a total population of 524,000. The province is one of the hazelnut trading centers both in domestic and international markets. Hazelnut, cultivated in this province, has been exported to many countries such as Italy, Germany, Japan, France, Belgium, Netherlands, Russia, Ukraine, Austria, and Brazil. The province has the lung cancer mortality rate above the national

* Corresponding author. Tel.: +90 462 377 38 22; fax: +90 462 325 31 95.
E-mail address: n_celik@ktu.edu.tr (N. Celik).

0265-931X/$ – see front matter
doi:10.1016/j.jenvrad.2008.04.010

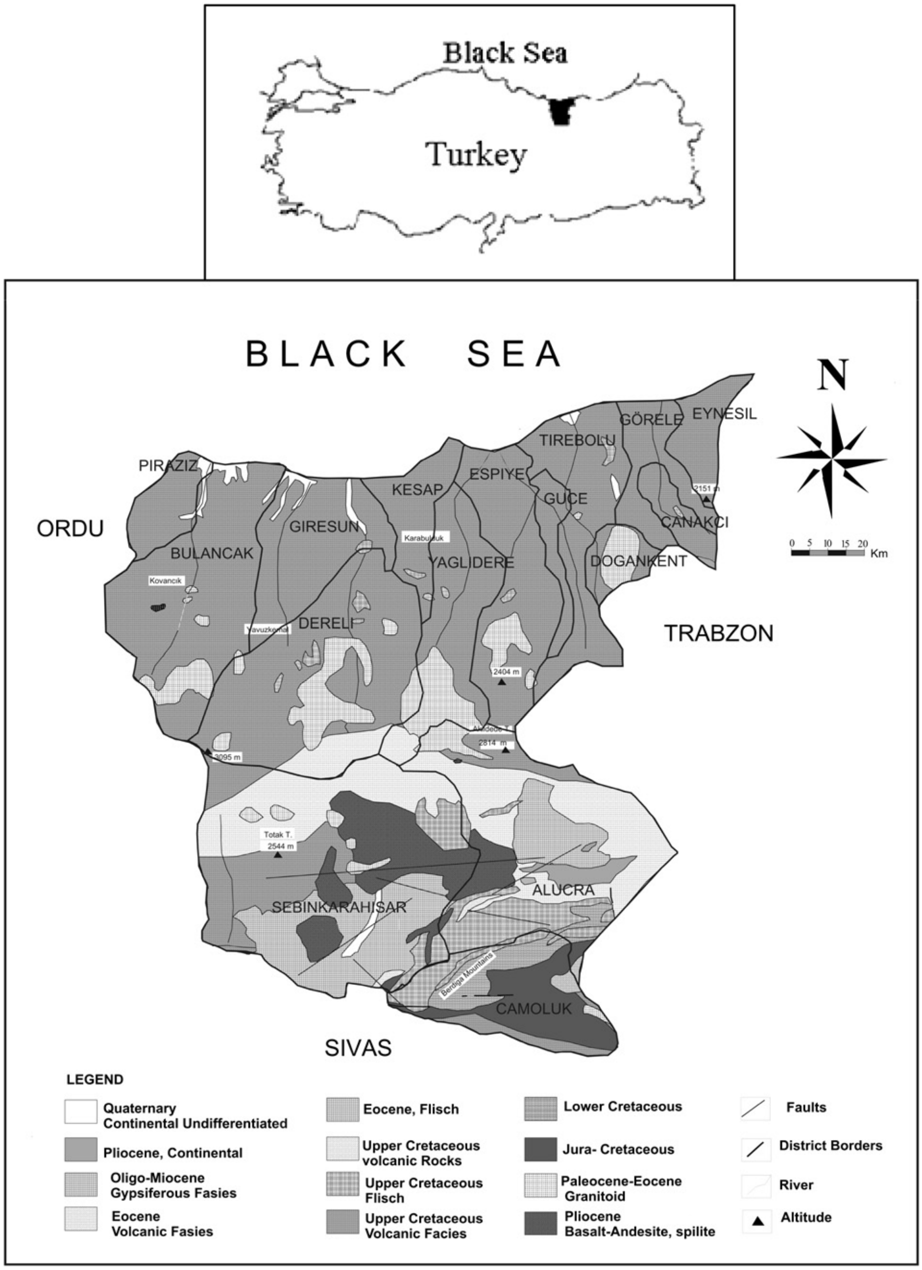

Fig. 1. Geologic map of the Giresun province.

average (MOH, 2002). This fact may be associated with radon inhalation since it is shown that the studied area may have good potential for uranium resources (Yavuz et al., 1999). Unfortunately there are hardly any comprehensive studies or scientific data at any official or academic institutions in Turkey showing the contamination and the natural background activity level of the province. Due to the reasons mentioned above, we believe that the province deserves to be a study area.

The aim of the present study is not only to define the contamination level of the province by measuring ^{137}Cs activity concentration 21 years after the Chernobyl accident, but also to take into account the assessment of natural background activity level through measuring indoor radon concentrations, naturally derived radionuclides of ^{226}Ra, ^{232}Th, and ^{40}K. Estimation of the doses received due to the both natural and artificial radionuclides, the results of indoor radon concentration and radium content in soil are presented and these data are expected to serve as baseline data of national radioactivity level and will be useful in assessing public doses.

2. Experimental methods

2.1. Indoor radon measurements

A total number of 71 dwellings were surveyed from December to March 2007 for indoor radon. All the dwellings were selected as uniformly distributed on the surface area as possible. Makrofol SSNTDs (Urban and Piesch, 1981; Pinsa et al., 1997) were used for indoor radon measurement. In each selected house one monitor was installed at ground level in the living room. All the detectors were recovered successfully. Questionnaires were provided to collect details about the monitor placement, full address and the characteristics of the houses that may influence ^{222}Rn levels (heating system, whether the house has basement or not). The information collected was summarized in Table 1. All the houses surveyed were cement type.

After three months of exposure, the Makrofol detectors were taken out and sent to the Gent University Laboratory, Belgium for analysis. After pre-etching for half an hour at a temperature of 25 °C in a solution of 95% ethanol and 6 N KOH at a volume of 1–5, electrochemical etching (ECE) was performed in the same solution and at the

Table 1
Characterization of the houses in which the radon measurements were performed

Indoor radon concentration ($Bq\,m^{-3}$)	Number of houses	Heating system		Basement	
		Central	Stove	With	Without
<80	8	5	3	3	5
81–100	13	8	5	6	7
101–120	17	7	10	11	6
121–140	12	5	7	10	2
141–160	6	2	4	2	4
161–180	4	4	–	1	3
181–200	4	1	3	3	1
201–220	2	1	1	2	–
221–240	3	2	1	2	1
>241	2	1	1	2	–
Total	71	36	35	42	29

same temperature applying a high voltage of $800E_{eff}$ at 2 kHz for 3 h. The detectors were then rinsed with water and dried. The alpha tracks were counted under an optical microscope (15×). A calibration factor which depends on the track density and the chamber type for the radon measurement was obtained in the laboratory of Gent University (Belgium) making use of the facilities provided by the National Radiological Protection Board, UK (NRPB). The calibration factor was found to be 12.81 tracks cm^{-2} $(kBq\,m^{-3}\,h)^{-1}$.

Potentially, ^{220}Rn could also be absorbed in Makrofol detectors, as it is chemically identical to ^{222}Rn. However, because of its short half-life (55.6 s), it is not expected to penetrate great depth beneath the surface. It was shown that the alpha tracks formed by thoron and its progeny are discriminated by the etching technique used (Pressyanov et al., 2004). This etching condition allows us to visualize only alpha tracks formed by only ^{222}Rn and its progeny.

2.2. Contents of radionuclides in soil

The soil samples were collected from the undisturbed areas near the houses where indoor radon measurements were performed. The surface soil (at 0–15 cm depth level) samples (three soil samples in each district) collected from the studied area were dried in an oven at a temperature of 70 °C, sieved to remove the stones and pebbles, and crushed in the laboratory to homogenize them. Then they were weighed, sealed and stored at least for three weeks to allow secular equilibrium between radium and thorium and their decay products. Then each sample was measured and the mean values were given (Table 2) in $Bq\,kg^{-1}$ dry weight.

The gamma radiation was measured using HPGe computer controlled detector with 2 keV resolution for 1332 keV energy line of ^{60}Co. Genie 2000 was used as the software. The detector was shielded with 10 cm thick lead layer to reduce the background due to the cosmic rays and the radiation nearby the system.

Full energy peak efficiency was determined using Standard Reference Material (IAEA-375) prepared by International Atomic Energy Agency. Decay corrections were performed to the sampling date.

Gamma-ray lines of 238 keV from ^{212}Pb, 352 keV from ^{212}Pb and 609 keV from ^{214}Bi were used to evaluate the ^{226}Ra activity; 583 keV gamma-rays from ^{208}Tl and 911 keV from ^{228}Ac were used to determine the ^{232}Th activity. The activity of ^{40}K and ^{137}Cs was determined using their 1460 keV and 661 keV gamma-ray lines, respectively.

3. Results and discussion

3.1. Indoor radon and radium activity

The frequency distribution of the indoor radon follows a log-normal pattern in Fig. 2 (skewness is 1.73 and the kurtosis is 4.65). The results of indoor radon measurements in the studied area range from 50 to 360 $Bq\,m^{-3}$ with 130 ± 55 $Bq\,m^{-3}$ as average and one standard deviation. Table 2 shows results of indoor radon concentration and the radionuclide concentration in the soil samples collected from the studied area. While Canakci and Sebinkarahisar show the highest mean radon concentration, Keşap shows the lowest mean concentration result. Since ^{222}Rn is the decay product of ^{226}Ra, the houses in the areas which have high ^{226}Ra concentration can be expected to have high levels of indoor radon. The statistical analysis shows that (Pearson correlation, $R^2 = 0.54$) the mean radon concentration presents significant differences in relation to radium activity concentration in soil ($P = 0.001$). The mean radon concentrations are significantly higher in houses built on soils with high radium activity concentration compared to those with lower ones. To visualize that relation, the interpolated maps of the radon concentration and the radium activity in soil were created with ArcView GIS (Fig. 3a and b). The interpolations were made by the ordinary Kriging interpolation method.

From Fig. 3a, it can be seen that radon anomalies are concentrated in the Sebinkarahisar district. The region consists of volcanic rocks and fault systems (Fig. 1). In this region, radon may have the chance to migrate quickly and can reach long distances through fractures due to a carrier such as CO_2 (Annunziatellis et al., 2003) before it decays and causes radon gas anomalies. It has been also shown that the Sebinkarahisar district may have rocks rich in uranium (Yavuz et al., 1999).

The similar distribution of indoor radon and the radium concentration in soil (Fig. 3a and b) shows that houses in areas with high level radium concentration demonstrate high levels of the indoor radon. Most of the anomalous concentrations occur in the Sebinkarahisar district. In this region, indoor radon concentration

Table 2
Indoor ^{222}Rn concentration, radioactivity in soil, and annual effective doses due to natural radionuclides and ^{137}Cs

Districts	Indoor radon concentration ($Bq\,m^{-3}$)		Radioactivity in soil ($Bq\,kg^{-1}$ dry)				Effective dose ($\mu Sv\,y^{-1}$)	
	Monitor distributed	Indoor ^{222}Rn	^{226}Ra	^{232}Th	^{40}K	^{137}Cs	Due to ^{226}Ra, ^{232}Th and ^{40}K	Due to ^{137}Cs
Giresun (Center)	5	103 ± 23	30 ± 13	36 ± 13	483 ± 52	1304 ± 101	70	48
Piraziz	4	122 ± 37	25 ± 11	20 ± 10	800 ± 107	232 ± 41	72	9
Bulancak	7	128 ± 32	53 ± 12	53 ± 15	1036 ± 112	41 ± 13	125	2
Keşap	4	90 ± 25	14 ± 10	6 ± 01	269 ± 38	237 ± 45	26	9
Yaglidere	2	108 ± 21	18 ± 12	40 ± 14	364 ± 42	304 ± 53	61	11
Espiye	2	110 ± 21	64 ± 14	82 ± 22	1301 ± 123	286 ± 47	169	11
Guce	5	100 ± 20	12 ± 05	36 ± 17	1000 ± 113	432 ± 43	88	16
Tirebolu	4	127 ± 27	15 ± 08	80 ± 20	1300 ± 124	303 ± 39	141	11
Gorele	3	124 ± 27	12 ± 07	17 ± 07	823 ± 102	301 ± 39	63	11
Canakci	7	202 ± 41	67 ± 21	74 ± 19	475 ± 48	245 ± 35	120	9
Eynesil	3	126 ± 25	10 ± 04	24 ± 09	220 ± 43	126 ± 32	36	5
Dogankent	5	125 ± 23	21 ± 10	34 ± 15	800 ± 107	324 ± 56	81	12
Dereli	4	103 ± 22	21 ± 12	29 ± 11	558 ± 53	150 ± 21	64	6
Sebinkarahisar	8	201 ± 38	85 ± 23	79 ± 21	1000 ± 113	354 ± 57	161	13
Alucra	5	108 ± 21	45 ± 14	34 ± 15	565 ± 55	129 ± 19	81	5
Camoluk	2	190 ± 37	67 ± 21	56 ± 18	457 ± 41	139 ± 23	105	5
Mean	–	125 ± 28	33 ± 13	43 ± 14	733 ± 86	318 ± 46	92	11

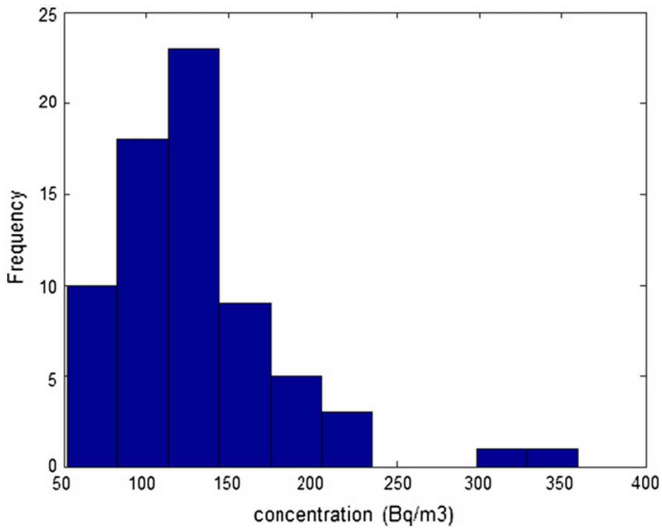

Fig. 2. Frequency distribution of the indoor radon.

and radium concentration in the soil have been found to be more than 300 Bq m^{-3} and 70 Bq kg^{-1}, respectively. However, it can also be seen from Fig. 3a and b that while some houses in areas with high radium concentration in the soil have low levels of indoor radon, other houses on radium-poor soil have high levels of indoor radon. It can be explained by the fact that in addition to the geology, indoor radon level can be influenced by local variability in factors such as soil permeability and climatic conditions, and by factors such as building design, construction, condition and usage. In Table 1, the characterization of the houses in which radon concentration measurements have been performed is summarized. The measured radon concentrations show a statistical difference between different characteristics of the dwellings. The results of analysis of variance show that the radon concentration in the houses with basement is relatively higher than those which have no basement. It may be because of the accumulation of radon in the basement before entering to the building. However, no correlation has been found between the radon concentration results and the heating system.

3.2. *Radon and lung cancer*

Radon has been classified as a known human carcinogen and has been determined to be the second leading of lung cancer after smoking (Little et al., 2001; Vutiovic et al., 2005; Jonathan, 2006). To estimate the number of lung cancer deaths attributable to indoor radon exposure, we used the BEIR VI age concentration model (BEIR VI, 1999). Detailed description of the model can be found elsewhere (Celik et al., 2008).

Twenty-four lung cancer deaths were reported by the Turkish Ministry of Health for the province in the year of 2002 (MOH, 2002). Using this data and 129 Bq m^{-3} as the arithmetic mean value of indoor radon concentration for the whole province, the number of lung cancer deaths attributable to the indoor radon exposure at age 70 y was estimated to be approximately 1. According to the model prediction, the indoor radon exposure was responsible for 8% of the lung cancer deaths occurring in this province.

For estimating the risk imposed by the exposure to indoor radon, the committee (BEIR VI) used the empirical analysis of epidemiologic data as the basis to develop its risk model. Two sources of information were used: data from epidemiologic studies of underground miners and data from case control studies of indoor radon and lung cancer in the general population. However, the model developed is subject to many uncertainties such as sampling variation in the underground miner data (errors in health-effects data including vital status and information on cause of death; errors in data on exposure to radon and radon progeny including estimated cumulative exposures, exposure rates and duration; limitations in data on other exposures including data on smoking and other exposures such as arsenic), uncertainty arising from differences in radon progeny dosimetry in mines and in homes, and uncertainty arising from estimating the exposure distribution for the U.S. population exposure distribution model.

3.3. *Activity concentrations of natural radionuclides*

From Table 2, it can be seen that the Sebinkarahisar district shows the highest ^{226}Ra activity concentration (85 Bq kg^{-1}) and Eynesil shows the lowest ^{226}Ra activity concentration (10 Bq kg^{-1}). Table 2 shows that while the average ^{226}Ra activity concentration is lower than the world average value, ^{232}Th and ^{40}K activity concentrations are higher than the world figure reported in UNSCEAR (2000a,b,c). Average world concentrations are 37, 36 and 442 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively (UNSCEAR, 2000a,b,c).

3.3.1. *^{137}Cs activity results*

In the present study, the ^{137}Cs activity concentrations in surface soil samples have been reported 21 years after the Chernobyl accident. Although the studied area seems a very small part of the

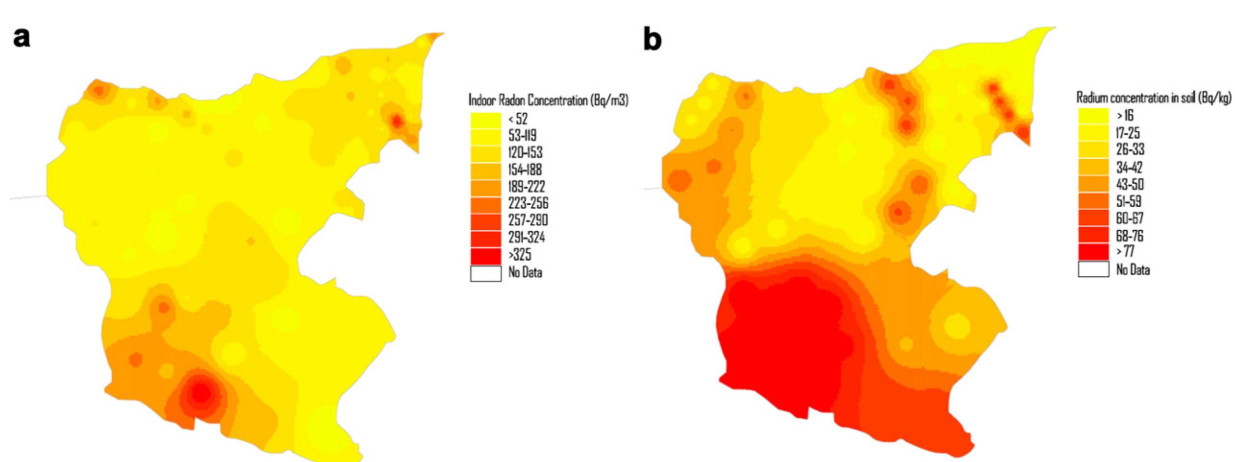

Fig. 3. Interpolated maps of the studied area for (a) indoor radon and (b) radium.

Eastern Black Sea region of Turkey, the results enable us to predict the ^{137}Cs contamination figure of the region. ^{137}Cs activity concentration results in soil samples are given in Table 2. ^{137}Cs activity concentration ranges from 41 to 1305 Bq kg^{-1} with the average value of 249 Bq kg^{-1} for the soil samples.

The interpolated map of ^{137}Cs activity concentration in the soil of the studied area is shown in Fig. 4. While some regions show high activity concentration results, the others show low results. It could be explained by the complex dispersion pattern of the release of radionuclides after the accident and the migration of cesium from one place to another by rain.

The present study shows that ^{137}Cs is still eminent in the region of interest. This artificial radioactivity may have different origins: nuclear weapon and bomb tests and the well known Chernobyl accident. Although the lack of data related to ^{137}Cs activity concentration level in the region of interest before the Chernobyl event makes the evaluation of the above mentioned origin's respective contributions quite difficult, it seems to be quite obvious that the Chernobyl event is the best candidate. We readily deduce that ^{137}Cs activity concentration due to the Chernobyl accident has added up to that global fall-out.

4. Dose estimation

4.1. Effective dose due to indoor radon

Annual effective dose due to indoor radon exposure can be estimated from the following formula (UNSCEAR, 2000a,b,c):

$$D = C_{Rn}F(O)(DCF) \quad (1)$$

where C_{Rn} is radon activity concentration (Bq m^{-3}), F is equilibrium factor (which is taken to be 0.4), O the occupancy (7000 h), DCF is the dose conversion factor which converts radon concentration into effective dose 9 nSv (Bq h m^{-3})$^{-1}$. Using 129 Bq m^{-3} as the mean indoor radon concentrations, the annual effective dose was estimated to be approximately 3 mSv for indoor radon exposure. Considering the worldwide annual effective dose value of 1.2 mSv due to radon (UNSCEAR, 2000a,b,c), it can be noted that the present result is quite higher than this figure.

4.2. Effective dose due to both natural and artificial radionuclides

The total absorbed dose rate D (nGy h^{-1}) in air at 1 m above ground level due to the presence of natural and artificial radionuclides in the samples is estimated using the following formula (UNSCEAR, 2000a,b,c):

$$D = aC_{Ra} + bC_{Th} + cC_K + dN_{Cs} \quad (2)$$

where a, b, c, and d are the dose rates per unit activity concentrations of Ra, Th, K, and Cs Gy h^{-1} (Bq kg^{-1})$^{-1}$; C_{Ra}, C_{Th}, C_K, and C_{Cs} are the activity concentrations of Ra, Th, K, and Cs (Bq kg^{-1}), respectively. The values of a, b, c, and d are taken to be 4.27×10^{-10}, 6.62×10^{-10}, 0.43×10^{-10}, and 0.30×10^{-10} Gy h^{-1} (Bq kg^{-1})$^{-1}$, respectively (UNSCEAR, 2000a,b,c; Jibiri et al., 2007).

To determine the biological hazard to which an individual is exposed, Gy is converted to Sv taking into account the conversion factor for the biological effectiveness of the dose in causing damage in human tissue recommended by The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the occupancy factor of 0.2 (UNSCEAR, 2000a,b,c; TAEK, 2007) that specifies the proportion of the total time spent outdoors. In the present work, while the annual effective dose due to the natural radionuclides ranges between 26 and 161 with the mean value of 92 μSv; the annual effective dose due to the ^{137}Cs ranges between 2 and 48 with the mean value of 11 μSv (Table 2). As can be seen from the table, the annual effective dose received due to the exposure to natural radionuclides is relatively higher than the annual effective dose due to ^{137}Cs. The mean value of 92 μSv (due to natural radionuclides) is higher than the worldwide annual effective dose value of 70 μSv reported by UNSCEAR (2000a,b,c).

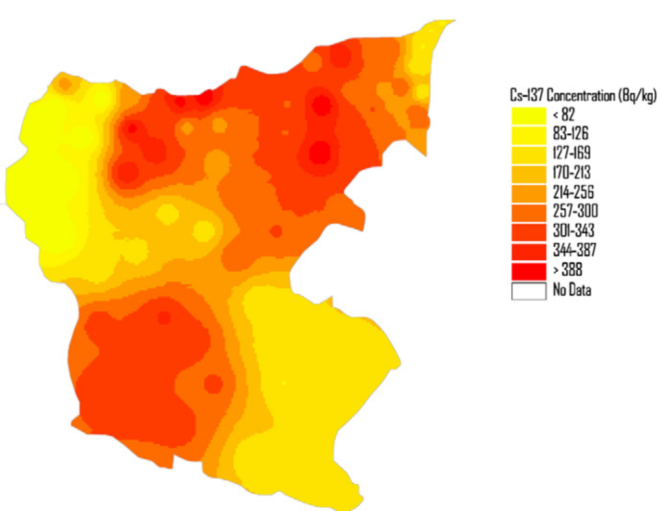

Fig. 4. Interpolated the surface soil ^{137}Cs activity concentration map of the studied area.

5. Conclusion

Indoor radon survey and determining the contents of radionuclides in soil have been performed in the Giresun province, Turkey. Since ^{222}Rn is a decay product of ^{226}Ra, one can expect a relationship between indoor radon and the radium content in soil. Some researchers even believe that soil radon measurements can be used to predict indoor radon level. The result of the statistical analysis and the similar distribution pattern of indoor radon and the radium content in Fig. 3a and b seems to prove this suggestion. However, in addition to the geology, indoor radon level can be influenced by local variability in factors such as soil permeability and climatic conditions, and by factors such as building design, construction, condition and usage.

The measurement of ^{137}Cs activity concentration shows that this radionuclide is still eminent in the Giresun province. However, a comprehensive study is needed to determine the contamination level of the whole Eastern Black Sea region of Turkey.

References

Annunziatellis, A., Ciotoli, G., Lombardi, S., Nolasco, F., 2003. Short- and long-term gas hazard: the release of toxic volcanic area (central Italy). Journal of Geochemical Exploration 77, 93–108.

Biological Effects of Ionizing Radiation (BEIR) VI Report: Health Effects of Exposure to Radon, 1999. National Academy Press, Washington D.C. doi:10.1029/2003GL018019.

Celik, N., Poffijn, A., Cevik, U., Schepens, L., 2008. Indoor radon survey in dwelling of the Kars province, Turkey. Radiation Protection Dosimetry 128, 432–436.

Gedikoglu, A., Sipahi, B.L., 1989. Chernobyl radioactivity in Turkish tea. Health Physics 56, 97–101.

Inside ArcView GIS (Paperback), second ed., 1997 High Mountain Press.

International Atomic Energy Agency (IAEA-375), 2000. Radionuclides and Trace Elements in Soil. Analytical Quality Control Services, Wagramer Strasse 5, Vienna, Austria.

Jibiri, N.N., Farai, I.P., Alausa, S.K., 2007. Estimation of annual effective dose due to natural radioactive elements in ingestion of foodstuffs in tin mining area of Jos-Plateau, Nigeria. Journal of Environmental Radioactivity 94, 31–40.

Jonathan, M.S., 2006. Residential radon and lung cancer: end of story? Journal of Toxicology and Environmental Health Part A 69, 527–531.

Little, M.P., Haylock, R.G.E., Muirhead, C.R., 2001. Modelling lung tumour risk in radon-exposed uranium miners using generalizations of the two-mutation

model of Moolgavkar, Venton and Knudson. International Journal of Radiation Biology 78 (1), 49–68.
MOH (Ministry of health), 2002. Cancer National Records. MOH, Ankara, Turkey.
Pinsa, C., Armas, J.H., Poffijn, A., 1997. Radon concentration in dwellings of Lanzarote (Canary islands). Radiation Protection Dosimetry 69 (3), 217–220.
Pressyanov, D., Buysse, J., Poffijn, A., Deynse, A.V., Meesen, G., 2004. Integrated measurements of ^{222}Rn by absorption in Makrofol. Nuclear Instruments and Methods in Physics Research A 516, 203–208.
Turkish Atomic Energy Authority (TAEK), 1998. Türkiye'de Çernobil Sonrasi Radyasyon ve Radyasyon Calismalari. TAEK. TAEK report, April 1988.
Turkish Atomic Energy Authority (TAEK), 2007. Türkiye için doz değerlendirmeleri. TAEK. TAEK report, June 2007.
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000a. Effects and Risks of Ionizing Radiations. UN, New York.
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000b. Exposure and Effects of the Chernobyl Accident. UN, New York.
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000c. Exposures from Natural Radiation Sources. UN, New York.
Unlu, M.Y., Topcuoğlu, S., Kucukcezzar, R., Varinlioglu, A., Gungor, N., Bulut, A.M., Gungor, E., 1995. Natural effective half-life of ^{137}Cs in tea plants. Health Physics 65, 94–99.
Urban, M., Piesch, E., 1981. Low level environmental radon dosimetry with a passive track etch detector device. Radiation Protection Dosimetry 1 (2), 97–109.
Vutiovic, B., Radolid, D.F., Planinic, J., 2005. Indoor radon and lung cancer: a case–control study. Isotopes in Environment and Health Studies 41 (2), 169–176.
Yavuz, F., Celik, M., Karakaya, N., 1999. Fibrous foitite from Sebinkarahisar, Giresun Pb–Zn–Cu(U) mineralized area, northern Turkey. Canadian Mineralogist 37 (1), 155–161.