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Measurement of Radon Level in Dwellings of the Yıldırım County in Bursa

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It was well known that inhalation of high levels of radon can lead to lung cancer. Indoor radon concentration measurements were carried out in randomly selected 18 dwellings of Yıldırım county in Bursa, Turkey using Makrofol-DE Solid State Nuclear Track Detectors. The results of the radon measurements ranged from 13 to 98 Bq m^{-3}, with as 42 Bq m^{-3} average value. The range of annual effective dose was between 0.33 and 2.47 mSv y^{-1}.

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1. Introduction

Radon is a naturally occurring radioactive gas without odour, colour, and taste. It is produced from the decay of ^{238}U, ^{235}U, and ^{232}Th which are found in varying amounts in Earth's crust.

Some part of the radon produced in rocks or soils escapes to the atmosphere; therefore people are exposed to radon and its short-lived decay products by breathing elsewhere. The ^{222}Rn, which is produced as a result of natural decay of ^{238}U, has a half-life of 3.82 days. ^{210}Pb and ^{210}Po, produced from the decay of ^{222}Rn, have long half-life; therefore they are important in dose evaluations. ^{220}Rn, which is a member of ^{232}Th series, has a very short half-life and the half-lives of its decay products are not long [1].

Intake of radon and its decay products by inhalation or ingestion leads to some health problems. When the air is inhaled, ionizing alpha particles emitted by the decay of radon and decay products interact with tissue in lung and these interactions lead to DNA damage. It is well known that radon is the second most important cause of lung cancer after smoking in many countries; therefore the measurement and reduction of radon concentration in buildings are important [2].

The reason of observation of high indoor radon concentration can be based on multiple factors such as ventilation rate, wind direction, atmospheric pressure, soil characteristic, amount of ^{226}Ra in the ground close to buildings [3, 4]. The content of ^{226}Ra varies depending on specific site and geologic material [5]. Igneous rocks such as granite contain higher radon concentration with respect to sedimentary rocks [1].

WHO [2] proposes a reference level of 100 Bq/m^3 to reduce the radon concentration in indoor air. The recommended level for Turkish Atomic Energy Authority (TAEK) [6] in dwellings is 400 Bq/m^3. International Commission on Radiological Protection (ICRP) [7] determines the upper limit as 600 Bq/m^3 in dwellings.

The aim of the present study is to measure the radon concentrations in dwellings of Yıldırım County, which is one of the oldest settlements of Bursa province, to evaluate the radon exposure to the human.

2. Materials and method

2.1. Study area

The sampling stations are shown from Fig. 1 which roughly was prepared by using Google Earth (ver. 7.0.2).

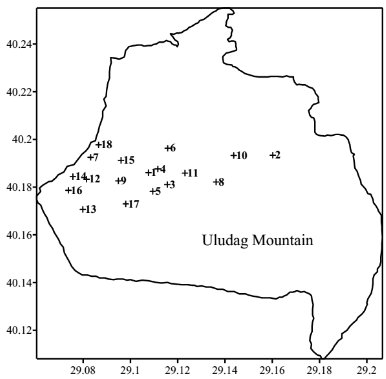

Fig. 1. The map of Yıldırım county and sampling locations.

The Yıldırım county is situated in foothill of Uludag Mountain, which is the highest mountain (2 543 m) in the Marmara region of Turkey. The north of county is located on Bursa plain and the settlement in this part is rare. The area of county is 399 km^2 and the population is around 600 000. The mean annual temperature and humidity is 14.4 °C, 58%, respectively. The Yıldırım county shows similar climatic characteristics with Bursa

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province. While the coldest month is January (with a mean temperature of 5.4 °C), the hottest month is July (with a temperature of 24.5 °C) [8].

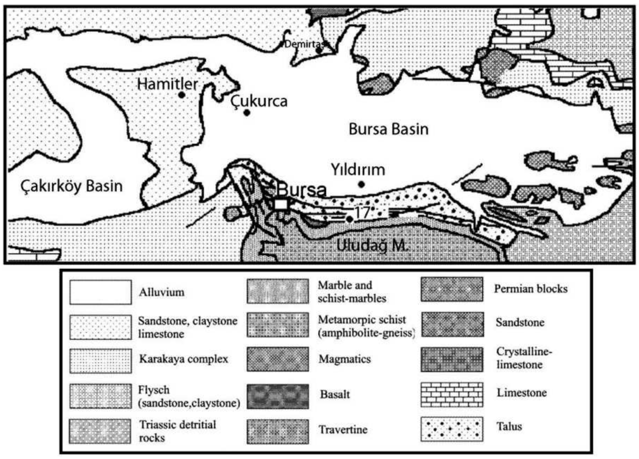

Fig. 2. Geology map of the Bursa region [9].

The province of Bursa is located on the south-western segments of the North Anatolian Fault (NAF) zone. The geology map of Bursa plain is shown in Fig. 2. The map was prepared by Akyol et al. [9] by using the study of Ersan et al. [10]. It is seen from Fig. 2 that Bursa plain is a basin filled with Quaternary deposits. It is situated on a metamorphosed and highly deformed unit. Permian limestone is observed in the northern slopes of Uludag Mountain. Besides, same limestone can be observed at the hills bordering the Bursa plain to the north and on the east [9, 11].

2.2. Radon measurements and statistical analyses

Indoor radon measurements were carried out in 18 dwellings of Yıldırım county. We used 0.3 mm thick foils (Makrofol® DE 1-4, commercial product of Bayer AG, Leverkusen, Germany) for the present experiments. Each detector was made of one Makrofol-DE foil with the size of 5 cm × 5 cm which was cut from 50 cm × 100 cm sheets. The foils were placed into metal diffusion chambers with making sure that the sensitive sides of them were upside position. Detectors were installed in the living rooms of ground floors. All of the houses except sample 4 have a cellar. Measurements were performed from February 2010 to May 2010 during two and a half months. After the exposure, the detectors were taken from houses and brought to the Gent laboratory, Belgium for analysis. The foils were pre-etched during 30 min at 25 °C in a solution of 95% ethanol and 6 N KOH at a volume ratio of 1 to 5. After removal of the surface layer (pre-etching), electrochemical etching was then performed in the same conditions as pre-etching applying a high voltage $800E_{\text{eff}}$ at 2 kHz for 3 h. The detectors were then rinsed with water and dried. The alpha tracks were counted via an optical microscope (15×). Statistical analyses were performed using SPSS (ver. 20.0) software.

3. Results and discussion

Figure 3a shows the indoor radon concentrations of dwellings. Radon concentrations ranged from 13 ± 10 to 98 ± 8 Bq/m^3 with a mean value of 44 ± 7 Bq/m^3. The highest values are generally observed in houses which are situated in the slope of Uludag Mountain. Sample 4 has a high level as the some houses, which are situated close to Uludag Mountain, due to the lack of cellar as expected. TAEK [6] reported the indoor radon concentrations for Bursa province in the range of 65.5–106.6 Bq/m^3. The mean value of indoor radon concentrations of Turkish houses were reported to be 82.66 Bq/m^3 in the same report. None of them showed a high value from the 400 Bq/m^3, while the 18% of our measurements was above this mean value. Descriptive statistics obtained from the data are given in Table. The distribution has positive skew. The positive value of the skewness coefficient indicates that the distribution is asymmetric with the right tail longer than the left tail. A low coefficient of kurtosis means that the distribution of data is close to the normal and the variance of data is low. The Kolmogorov–Smirnov or Shapiro–Wilk normality tests are used for the determining whether the data follows the normality plot or not. The Shapiro–Wilk test is more appropriate when the number of sample is lower than 50. The data shows a log–normal pattern since the significance level (p) is lower than 0.05 in the results of performing the Shapiro–Wilk test.

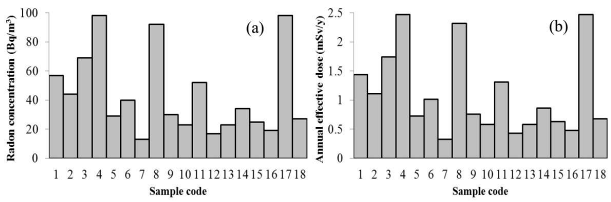

Fig. 3. (a) Indoor radon concentrations of Yıldırım dwellings, (b) annual effective dose rates.

TABLE

Statistical results for indoor radon concentrations.

Statistics	Indoor radon	Statistics	Indoor radon
median	32	range	13–98
arithmetic mean ± SE	44 ± 7	skewness	1.036
standard deviation	28	kurtosis	−0.169
geometric mean	37	frequency distribution	log–normal ($p = 0.008$)

We calculated the annual effective dose rates using the conversion factors which were proposed from UNSCEAR [1]. The committee determined 9.0 nSv/h per Bq/m^3 to be used as a conversion factor, 0.4 the equilibrium factor of ^{222}Rn indoors and 0.8 for the indoor occupancy factor. The annual effective doses are derived

$$H(\mathrm{mSv/y}) = C_{\mathrm{Rn}} DTF,$$

where C_{Rn} is the measured radon concentration (in Bq/m^3), D is the dose conversion factor (9 nSv/h per Bq/m^3), T is the indoor occupancy time (0.8×24 h $\times$ $365.25 = 7012.8$ h y^{-1}), and F is the radon equilibrium factor (0.4). Calculated annual effective doses are presented in Fig. 3b.

4. Conclusion

Indoor radon concentrations in dwellings of the Bursa province in Turkey were investigated by using Makrofol Solid State Nuclear Track Detectors. None of the measured houses exceeds the action limits determined by WHO, ICRP and TAEK.

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