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Measurement of Seasonal Indoor Radon Concentration in Sakarya University, Turkey

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Indoor radon measurements were performed using LR-115 type-II solid state nuclear track detectors in Sakarya University in classrooms, laboratories and offices during the period from July 2013 to June 2014. The results show that the radon concentration in studied buildings ranges from 0.20 ± 0.04 to 94.1 ± 10 Bq/m^3 with an average value of 40 ± 5 Bq/m^3. The annual effective doses from radon were estimated to range from 0.18 to 2.00 mSv/y with a mean value of 1.00 mSv/y. These results indicate no radiological health hazard, as the measured activities are well below International Commission on Radiological Protection recommended level of 200 Bq/m^3 for indoor radon.

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1. Introduction

^{222}Rn (radon) is an alpha-emitting radioactive noble gas and continuously produced in soil by the decay of radium (^{226}Ra) in the natural decay series of ^{238}U [1]. Produced atoms of ^{222}Rn escape from the soil and enter the air or water filled pores and move through the atmosphere [2]. When a building is present on its way, radon can enter it through openings around drains, construction joints, cracks in walls, crawl spaces, and in some cases from well water [3]. The primary hazards of radon are due to the inhalation of its short-lived decay products namely ^{218}Po and ^{214}Po [2]. They tend to attach to the aerosols in the atmosphere. When these aerosols are inhaled, they decay inside the lung and emit high energy alpha particles and may lead to serious diseases like lung cancer. Exposure in educational buildings is one of the main radon exposures for the general population after that in dwellings, since these buildings are workplaces of high occupancy times for students and staff [4]. The aim of the study was to determine the radon concentration levels in Sakarya University and to evaluate the health hazards related to radon activity if any.

2. Material and methods

Indoor radon activities were measured in offices, classes and laboratories using LR-115 type-II (Dosirad, France) solid state nuclear track detectors. Figure 1 shows the location of the campus and the study areas and of the buildings.

LR-115 detectors with dimensions 1.5 cm × 1.5 cm were mounted in a plastic cup of 7 cm height, 7.2 cm diameter at one end and 5 cm at the other end. After exposure, the detectors were chemically etched in 2.5 M NaOH solution at 60 °C for 120 min. After etching, track density of alpha particles was counted under an optical microscope at magnification 100× [5]. Calibration coefficient of these detectors was determined as 0.051 track cm^{-2} d^{-1} Bq^{-1} m^3. The annual mean effective doses for indoor air were calculated using the formula recommended by UNSCEAR [6] where C_{Rn} is the indoor radon concentration (in Bq/m^3), F is the equilibrium factor between radon and its decay products (0.4), T is the average indoor occupancy time per person (7000 h/y) and DCF is a dose conversion factor [6].

3. Results and discussion

A total of 68 locations including classes, offices and laboratories were investigated for three measuring periods. Table I shows minimum and maximum ^{222}Rn activities along with arithmetic means. As can be seen from Table I, radon activities ranged from 0.2 ± 0.04 to 70.8 ± 8 Bq/m^3 during autumn period, from 13.4 ± 4 to 94.1 ± 10 Bq/m^3 during winter period and from 3.3 ± 0.2 to 86.7 ± 9 Bq/m^3 during spring period. Another study [7] performed in Sakarya city centre to determine radon activities in dwellings showed that radon levels ranged from 27.1 to 60.8 Bq/m^3 and from 24.9 to 118.6 Bq/m^3 in winter and in summer, respectively. It may be explained to the fact that in university campus the geographical, climatic features and the soil structure are same as in the city centre. Indoor radon concentration levels measured in this study are well below the action levels of 200 Bq/m^3 recommended by International Commission on Radiological Protection (ICRP) [8].

The frequency distribution of ^{222}Rn concentrations is illustrated in Fig. 2a. Statistical analysis showed that the frequency distributions in the current study can be better fitted to a normal distribution. As expected, the activities measured in winter (47.02%) are higher than other periods. This may be due to the less ventilation in winter

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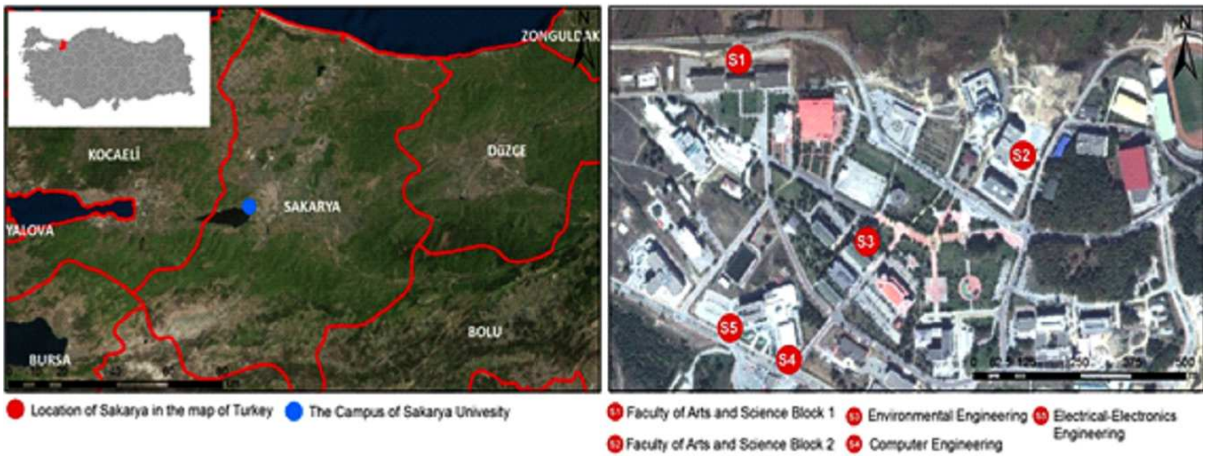

Fig. 1. The location of study area and buildings.

TABLE I

Summary of indoor radon levels [Bq/m^3] in different seasons in Sakarya University.

Site	Radon activity [Bq/m^3]								
	autumn			winter			spring		
	min.	max.	a.m.	min.	max.	a.m.	min.	max.	a.m.
S1	23.6 ± 5	70.4 ± 8	17.7 ± 3	13.4 ± 4	70.4 ± 8	40.2 ± 9	8.4 ± 3	32.8 ± 6	24.6 ± 4
S2	0.2 ± 0.04	20.6 ± 5	7.0 ± 4	17.8 ± 4	59.7 ± 8	31.2 ± 8	$3.3 \pm .2$	30.5 ± 6	12.2 ± 5
S3	10.0 ± 3	13.9 ± 4	11.4 ± 3	14.2 ± 4	62.2 ± 8	40.4 ± 6	10.0 ± 3	43.1 ± 7	23.4 ± 5
S4	30.7 ± 6	70.8 ± 8	54.8 ± 7	42.9 ± 7	87.6 ± 9	74.2 ± 7	37 ± 6	77.2 ± 9	62 ± 7
S5	25.6 ± 5	56.7 ± 8	39.7 ± 6	81.3 ± 9	94.1 ± 10	87.5 ± 2	72.9 ± 9	86.7 ± 9	78.9 ± 3

TABLE II

The comparison of ^{222}Rn levels in indoor air and related annual effective doses (AED) determined in this study with those reported worldwide.

Object	^{222}Rn activity [Bq/m^3]	AED [mSv/y]	Study	Country
school	15–1390	–	[9]	Italy
school	301–1582	–	[10]	Spain
school	31–157	0.06–1.40	[11]	Trabzon, Turkey
school	10–96.5	0.36–0.38	[12]	Sakarya, Turkey
campus	27–213	0.16–2.32	[3]	Pakistan
campus	157–495	0.99–3.12	[13]	Nigeria
campus	40–335	0.79–4.27	[4]	Izmir, Turkey
campus	0.2–94.1	0.18–2.00	this study	Sakarya, Turkey

than in the other seasons [4]. In winter period the radon entering the rooms easily accumulates since most of the doors and windows remain closed. On the other hand, no significant difference was observed between autumn and spring seasons. This may be related to occur of same climatic conditions in spring and autumn in Sakarya.

In Table II, the ^{222}Rn activity level and associated annual effective doses observed in this study is compared with other similar studies in literature. As can be seen in Table II, there is large discrepancy in the reported values of indoor radon from different locations. The discrepancies in these studies are probably caused by the different geological structure of the study areas. Generally, content of radon in granite areas is higher than in sandstone and rhyolite areas [6]. The comparison of our results with the result of an early study [12] conducted in Sakarya for schools show that the average ^{222}Rn concentrations in Sakarya University campus is very similar that measured in schools of Sakarya. As mentioned above, it possibly due to same geographical, climatic features and the soil structure.

The variation of ^{222}Rn concentration with floor levels is shown in Fig. 3a. The average ^{222}Rn activity were found to be 52.6 ± 7, 44.0 ± 6, 33.3 ± 5, and 25.0 ± 5 Bq/m^3 for ground, first, second, and third floors, respectively. There is a decrease in radon activity from ground floor

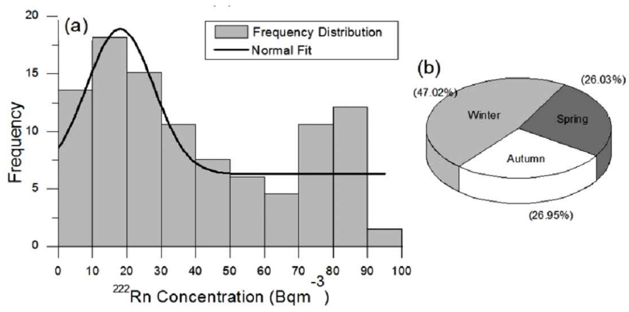

Fig. 2. (a) Frequency distributions of ^{222}Rn activity, (b) seasonal variation of ^{222}Rn activity.

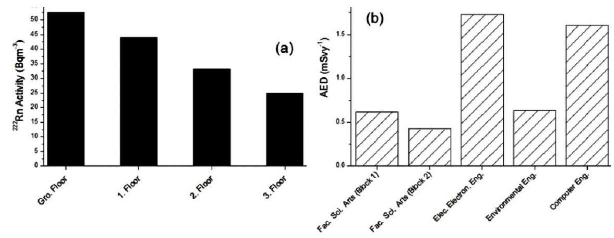

Fig. 3. (a) The dependence of mean ^{222}Rn concentrations on floor number, (b) estimated annual effective doses for the buildings studied.

to upper floors. The same trend was observed in other studies [4]. Differences in ^{222}Rn activity level between the ground and other floors could be due to the different air exchange rate in the different floors [4]. On the other hand, no significant differences were observed between the rooms in same floor.

Age of the dwellings is also another important factor affecting the radon concentrations in indoor air. It is well known that the radon concentrations in old buildings are relatively higher than in new buildings since cracked walls in the old buildings allow radon escape [3]. In the present study, the same age buildings (about 10–15 years) were chosen due to the comparability of concentrations. Another factor is building materials, but they usually contribute very little compared to other factors [6]. As can be seen from Fig. 3b, the calculated mean annual effective doses range from 0.18 to 2.00 mSv/y with a mean value of 1.00 mSv/y. These values are well below the lower limit of recommended action level of ICRP (3–10 mSv/y) [8].

4. Conclusion

An indoor radon survey has been carried out using passive radon detectors in 68 locations including classes, offices and laboratories in Sakarya University campus. Differences have been observed between the ground floors and upper floors in accordance with other studies. As expected the highest radon concentration was measured in winter. The activities reported in the present study are less than the reference level (200 Bq/m^3) suggested by ICRP. Moreover, the calculated effective mean doses are also well below the lower limit level (3–10 mSv/y) recommended by ICRP [8].

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