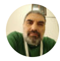
Radon concentration measurements at a University campus In Turkey

Article *in* Turkish Journal of Physics · January 2016
DOI: 10.3906/fiz-1510-1

Celal Aşici
Eskisehir Osmangazi University



Haci Sogukpinar
Adiyaman University

Turkish Journal of Physics

http://journals.tubitak.gov.tr/physics/

Research Article

Turk J Phys
(2016) 40: 69 – 75

doi:10.3906/fiz-1510-1

Radon concentration measurements at a university campus in Turkey

Melekşah ALTINSÖZ[1], **Emel ALĞIN**[2,*], **Celal AŞICI**[1], **Hacı SOĞUKPINAR**[3]
[1]Graduate School of Sciences, Eskişehir Osmangazi University, Eskişehir, Turkey,
[2]Department of Physics, Eskişehir Osmangazi University, Eskişehir, Turkey
[3]Department of Technology, Adıyaman University, Adıyaman, Turkey

Received: 02.10.2015 • **Accepted/Published Online:** 01.01.2016 • **Final Version:** 12.02.2016

Abstract: In this study we measured radon (^{222}Rn) concentrations in offices at the Meşelik campus of Eskişehir Osmangazi University to estimate the effective dose of ^{222}Rn and its progeny for office occupants. The measurements were performed four times in 2011 over a period of 3 months using solid state nuclear track detectors (LR-115). A total of 381 LR-115 detectors were installed in 110 different offices, choosing three offices on each floor in the same building. ^{222}Rn concentrations obtained in the first, second, third, and fourth measurement periods were 163 (73) Bq m^{-3}, 105 (53) Bq m^{-3}, 77 (43) Bq m^{-3}, and 164 (70) Bq m^{-3} respectively. The ^{222}Rn concentrations and seasonal ^{222}Rn variations in the offices were similar to those found in dwellings in Eskişehir. The total annual effective dose was estimated to be 3.398 mSv y^{-1}.

Key words: ^{222}Rn, indoor, track detector, workplace, effective dose

1. Introduction

Radon (^{222}Rn) is a natural radioactive gas resulting from the decay series of uranium and thorium in the soil. ^{222}Rn and its progeny are significant natural sources of radiation exposure to the general population [1]. ^{222}Rn has a half-life of 3.8 days, while the half-life of thoron is only 55 s. The relatively long-lived ^{222}Rn can penetrate considerable distances through soil and rocks. It can transport from the ground into a building if there is a route. Thus, ^{222}Rn concentrations may build up to high levels in poorly ventilated buildings.

We recently reported seasonal variations in ^{222}Rn concentrations in dwellings in Eskişehir, Turkey [2]. The annual effective dose was estimated to be 3.398 mSv y^{-1}. An international publication reported the extent of current knowledge about the health effects of inhaled ^{222}Rn and its progeny and made recommendations for the control of ^{222}Rn exposure in both dwellings and workplaces [3]. Several studies were conducted on ^{222}Rn levels in workplaces [4,5]. In the current study we also aimed to measure ^{222}Rn levels in the workplace. Our survey focused on the Meşelik campus of Eskişehir Osmangazi University in Eskişehir, Turkey. To the best of our knowledge, this is the first extensive study performed on a campus in Turkey. We intended to raise public awareness about ^{222}Rn and ^{222}Rn protection.

*Correspondence: tavukcu@ogu.edu.tr

2. Materials and methods

Eskişehir Osmangazi University is located in Eskişehir, in northwestern Turkey. The university has been in operation since 1993. The area of the Meşelik campus of Eskişehir Osmangazi University is about 1700 acres. A map of Eskişehir and the university, including the sampling points, is shown in Figure 1.

Figure 1. Map of the city and Eskişehir Osmangazi University Meşelik campus, showing all sampling points.

^{222}Rn measurements were conducted four times in 3-month intervals between January 2011 and January 2012: the first period of measurements covered the months January, February, and March; the second period covered April, May, and June; the third period covered July, August, and September; and the fourth period covered October, November, and December. These periods can also be considered seasonal, i.e. winter, spring, summer, and autumn, respectively. Our survey included 110 offices from 25 departments covering buildings of the Faculty of Engineering and Architecture, the Faculty of Economics and Administrative Sciences, the Faculty of Science, and the Central Library Building. Most buildings have three floors on average. Three offices on each floor were selected randomly. Four track detectors were placed in each office: two for the 3-month period and two for annual measurements.

In order to measure ^{222}Rn concentrations we used an open (bare) mode detector system consisting of a plastic cup (8.2 cm in height, 6.5 cm in diameter at one end, and 4.4 cm in diameter at the other end) in which a Kodak-Pathe LR 115 Type II detector with dimensions of 1.5 cm $\times$ 1.5 cm was fixed. In the first period of the survey, 105 track detectors were distributed to the selected offices; however, the number of measurements in the following periods decreased because the occupants either lost the detectors or were not willing to accept the detectors.

After collecting the detectors at the end of each period, detectors were etched using 10% NaOH solution at 60 °C for 95 min. Then the detectors were washed and dried. The tracks were manually counted under an optical microscope at 100$\times$ magnification. Background track density was determined using 30 unexposed detectors and subtracted from the observed data. In order to determine the calibration factor, a set of LR-115 detectors was installed for 1–5 days inside a ^{222}Rn calibration chamber with an equilibrium ^{222}Rn concentration of 3.2 kBq m^{-3} at the Department of Health Physics of the Çekmece Nuclear Research and Training Center, which participated in the National Radiological Protection Board for intercomparisons (1989, 1991, 1995, and 2000) [6]. The observed track densities were related to ^{222}Rn concentration levels using the calibration factor (0.117 Bq m^{-3} tr^{-1} cm^{2} d).

3. Results and discussions

3.1. Seasonal and annual ^{222}Rn concentrations

A total of 381 detectors were analyzed. The results of the seasonal and annual ^{222}Rn concentrations in the campus offices are summarized in Table. The arithmetic mean of the ^{222}Rn concentrations in the offices for winter, spring, summer, and autumn (with SD in brackets) were 163 (73) Bq m^{-3}, 105 (53) Bq m^{-3}, 77 (43) Bq m^{-3}, and 164 (70) Bq m^{-3} respectively. The seasonal ^{222}Rn average was found to be 127 Bq m^{-3} which was the same value obtained for the dwellings of Eskişehir [2].

Table. Results of the seasonal and annual radon measurements in the campus offices.

	First quarter (January–March)	Second quarter (April–June)	Third quarter (July–September)	Fourth quarter (October–December)	Annual Data	Seasonal
N	105	79	84	63	50	42
AM (Bq m^{-3})	163	105	77	164	102	127
SE (Bq m^{-3})	7.17	6.02	4.68	8.77	10.36	6.43
SD (Bq m^{-3})	73	53	43	70	73	42
Min (Bq m^{-3})	43	25	13	62	19	59
Max (Bq m^{-3})	376	242	219	381	337	252
GM (Bq m^{-3})	147	92	68	151	82	120
GSD (Bq m^{-3})	0.45	0.54	0.53	0.41	0.66	0.32

N = number of measurements; AM = arithmetic mean; SE = standard error of the means; SD = standard deviation; GM = geometric mean; GSD = geometric standard deviation.

Sogukpinar et al. [2] carried out ^{222}Rn measurements during the following periods: December 2010 to February 2011 (winter period), March 2011 to May 2011 (spring period), June 2011 to August 2011 (summer period), and September 2011 to November 2011 (autumn period), as well as for a period of 12 months. Although their measurement periods covered slightly different months than those in our study, we observed a similar trend for the ^{222}Rn concentrations on the university campus: high ^{222}Rn values for autumn and winter and lower values for summer and spring. The arithmetic means of indoor ^{222}Rn concentrations for winter, spring, summer, and autumn measurements (with SD in brackets) were 147 (92) Bq m^{-3}, 120 (77) Bq m^{-3}, 90 (58) Bq m^{-3}, and 151 (81) Bq m^{-3} respectively.

Figure 2 clearly shows higher ^{222}Rn concentrations for the winter and autumn periods compared with the spring and summer periods. Similar results were observed earlier [2,7–9]. Due to the colder temperatures in the autumn and winter seasons, offices are more heated and less ventilated. This, in turn, results in lower indoor pressure and higher ^{222}Rn accumulation within a building. It should also be noted that autumn ^{222}Rn concentrations were relatively higher than winter ^{222}Rn concentrations. This result may be attributed to the fact that the fourth quarter, the so called autumn season, covers one of the winter months, December. The questionnaires also show that in offices where the rate of ventilation was poor during the day, ^{222}Rn concentrations tended to be higher, as expected.

Figure 3 shows the frequency distributions of ^{222}Rn concentrations for each period. The Kolmogorov–Smirnov normality test (applied to all of these data) confirmed that the ^{222}Rn concentration in each period follows a log-normal distribution ($P > 0.05$).

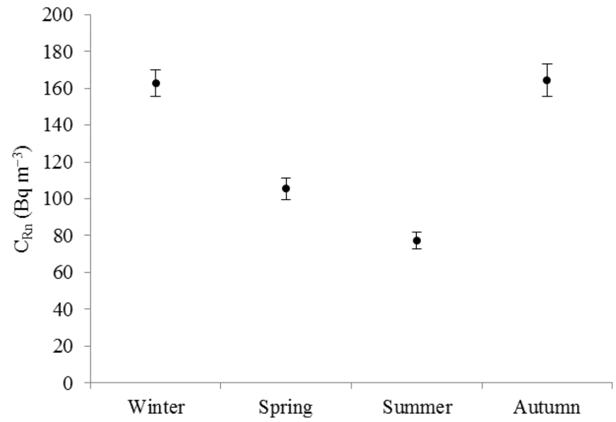


Figure 2. Indoor radon concentration data with SE for each measurement period.

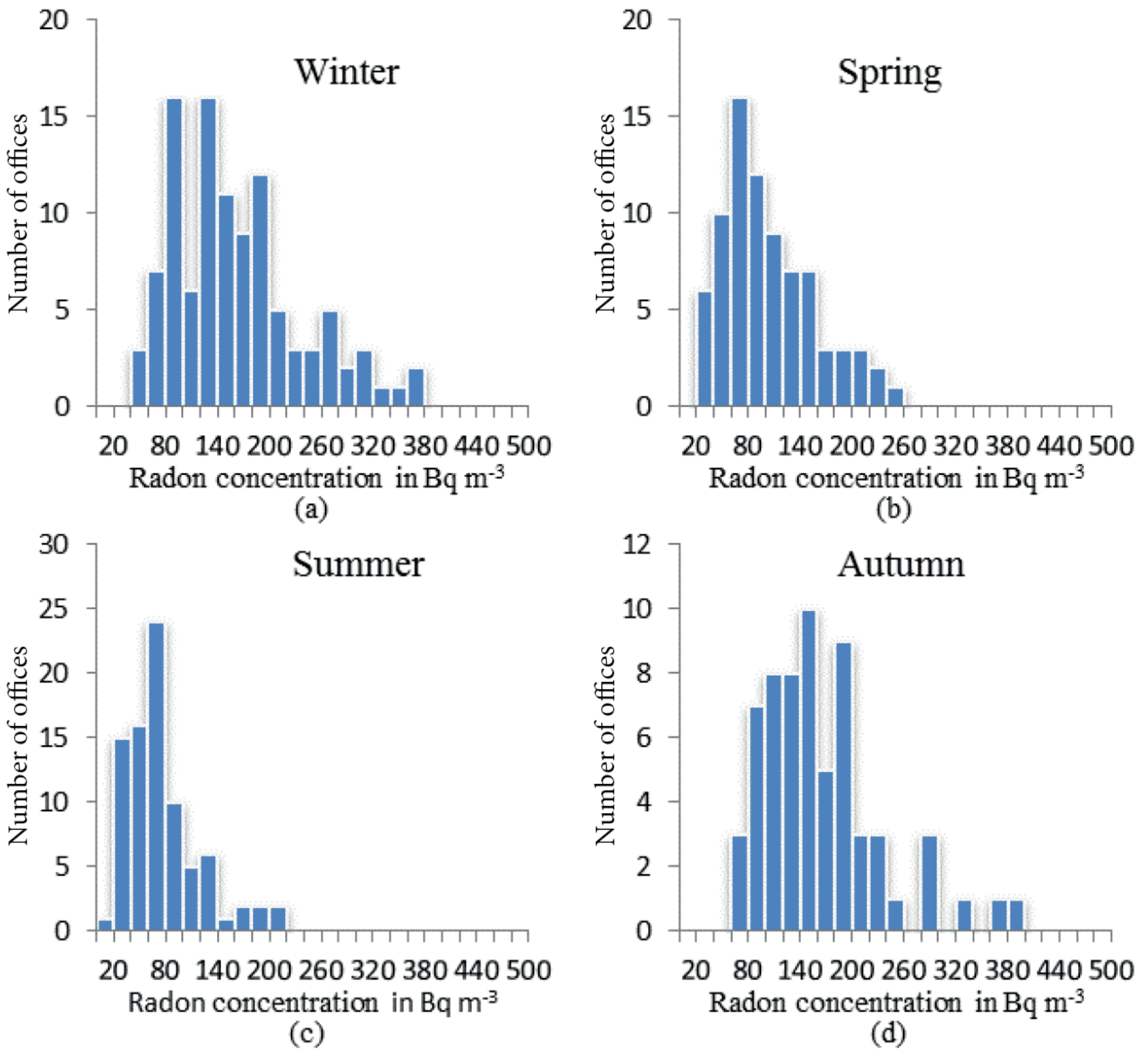


Figure 3. Radon frequency distributions of campus offices for: (a) winter, (b) spring, (c) summer, and (d) autumn periods.

A couple of track detectors were placed in every selected office for a year-long measurement at the beginning of the first quarter. Yearly measurements allow us to compare these data with the seasonal average data. This comparison is shown in Figure 4. The seasonal average ^{222}Rn concentrations were higher than the associated yearly measurements. Ninety three percent of the 12-month-exposed detectors gave significantly lower values due to dust accumulation on the track detectors. The differences between the yearly and seasonally averaged ^{222}Rn concentrations were also examined statistically for all offices for which data were available, and significant differences between the yearly and the seasonally averaged ^{222}Rn concentrations were found (t-test, P = 0.0096). A similar result was obtained earlier elsewhere [10]. Thus, detector sensitivity decreased with measurement time.

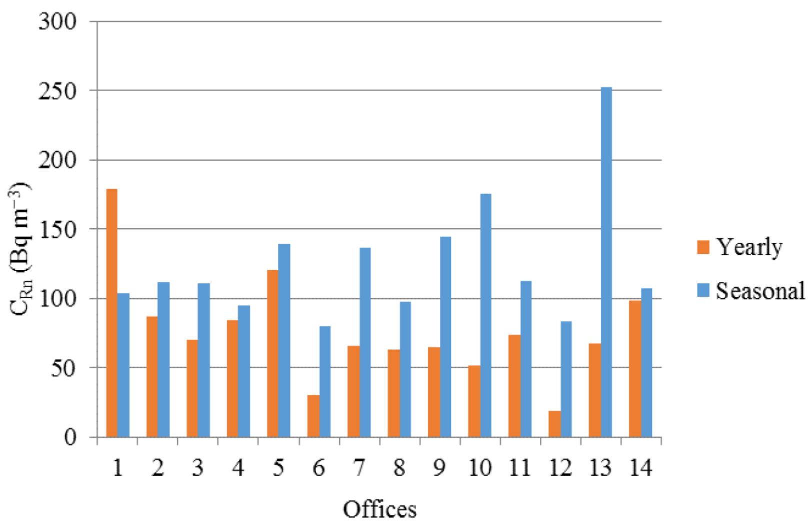


Figure 4. Comparison of yearly and seasonal average radon concentration data.

The seasonal variation of ^{222}Rn concentrations by floor level was also examined (Figure 5). The main source of ^{222}Rn in the basement floor was soil. Because ^{222}Rn gas is heavier than air, it tends to accumulate more in basement or ground floor levels. As shown in Figure 5, while a prominent decrease was observed in spring, a moderate decrease in ^{222}Rn concentrations with respect to the floor level was observed in the winter and autumn seasons. There was almost no change in indoor ^{222}Rn concentrations in the summer season between most floors. This is mostly because there is good ventilation in offices during the summer. It was also observed that the buildings without a basement had higher ^{222}Rn concentrations than the buildings with a basement.

3.2. Annual effective dose

The annual effective dose equivalent for ^{222}Rn and decay products can be estimated from the measured ^{222}Rn concentrations based on conversion factors given by UNSCEAR reports. The annual effective dose (D_E) is given by the following:

$$D_E(mSvy^{-1}) = C_{Rn} \times D \times Q \times E \times T, \tag{1}$$

where C_{Rn} (Bq m^{-3}) is the annual mean ^{222}Rn concentration (AM); D (nSv (Bq m^{-3} h)$^{-1}$) is the dose conversion factor; Q is the indoor occupancy factor; E is the indoor ^{222}Rn equilibrium factor; and T (h y^{-1}) is hours per year. In order to calculate the annual effective dose, we used the dose conversion factor D of 0.17 nSv for ^{222}Rn and 9 nSv (Bq m^{-3} h)$^{-1}$ for ^{222}Rn decay products, equilibrium factors E of 0.4 for indoors and 0.6 for outdoors with an occupancy factor Q of 0.8 for indoors and 0.2 for outdoors, as established by UNSCEAR 2000 [11]. Annual effective total dose from ^{222}Rn and its decay products was calculated to be 3.398 mSv y^{-1}. The world average is 1.15 mSv y^{-1}, which varies between 0.5 mSv y^{-1} and 3.5 mSv y^{-1} [11]. The action level for the annual effective dose for dwellings is determined in the range of 3–10 mSv y^{-1} by the International Commission on Radiation Protection [3]. The same values are adopted for the action level for intervention in workplaces. The reason for the high effective dose in our study could be that offices are not occupied during school breaks and weekends, and therefore the offices were not ventilated, resulting in higher ^{222}Rn concentrations.

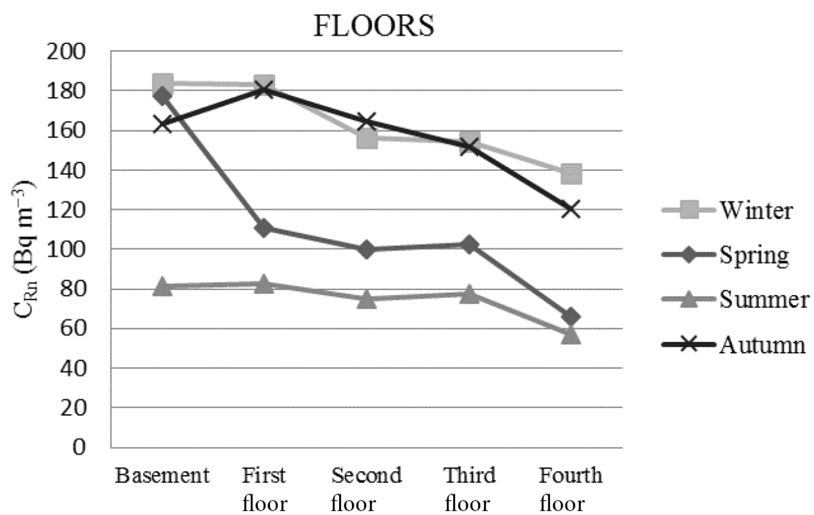


Figure 5. Seasonal radon concentrations as a function of floor level.

Obed et al. [4] measured ^{222}Rn concentrations at a university campus in Nigeria in order to estimate the effective dose: only 24 offices were studied and the ^{222}Rn concentrations ranged from 157 to 495 Bq/m^3. Furthermore, the effective dose to the workers was estimated and varied from 0.99 to 3.12 mSv/y, with a mean of 1.85 mSv/y. This value is less than what was obtained in the present work.

Oikawa et al. [4] performed ^{222}Rn measurements from 2000 to 2003 at 705 sites in four categories: office, factory, school, and hospital. Measurements took place quarterly for 3 years. ^{222}Rn levels were found to decrease in the following order: school > office > hospital > factory. ^{222}Rn concentrations measured from July to September were lower than those in the other periods. ^{222}Rn concentrations in the winter months were relatively higher than in the other periods, as found in the present study. Furthermore, the effective dose was estimated to be in the range from approximately 0.42 to 0.52 mSv y^{-1} for each job category. These values were also less than what was obtained in the present study.

4. Conclusions

The indoor ^{222}Rn levels on a university campus in Turkey were measured. Measurements were conducted in offices four times with 3-month periods in 2011. Annual measurements were also performed in order to compare the annual average with the seasonal average data. Based on 381 measurements, the arithmetic means of ^{222}Rn concentrations with standard deviations in parenthesis were 163 (73) Bq m^{-3}, 105 (53) Bq m^{-3}, 77 (43) Bq m^{-3}, and 164 (70) Bq m^{-3} for winter, spring, summer, and autumn respectively. The annual mean of

^{222}Rn concentrations for all offices was in the range of 59–252 Bq m^{-3}, with an arithmetic mean and standard deviation of 127 (42). The measured ^{222}Rn concentrations were below the recommended ICRP action level range of 200–300 Bq m^{-3} [12].

Seasonal variations in ^{222}Rn concentrations in offices were similar to those found in dwellings in Eskişehir, i.e. higher in autumn and winter and lower in spring and summer. The effective dose of ^{222}Rn to the public was calculated to be 3.398 mSv y^{-1}. This value is slightly higher than the recommended action level of 3–10 mSv y^{-1} by the International Commission on Radiation Protection [3]. The annual effective dose in this study was found to be relatively higher than that of workplaces in other countries. This may be due to the fact that the offices studied in the current study were not generally occupied (and thus not ventilated) during weekends and school breaks, leading to higher ^{222}Rn concentration levels.

Acknowledgment

This work was supported by the Eskişehir Osmangazi University Scientific Research Project (Project no: 2010/19014).

References

[1] UNSCEAR *Ionizing Radiation: Sources and Biological Effects*, New York, NY, USA, 1982.

[2] Sogukpinar, H.; Algin, E.; Asici, C.; Altinsoz, M.; Cetinkaya, H. *Radiat. Prot. Dosim.* **2014**, *162*, 410-415.

[3] ICRP *Protection Against Radon-222 at Home and at Work. A Report of a Task Group of the International Commission on Radiological Protection*, ICRP Publication 65. Ann. ICRP *23* (2), 1993.

[4] Obed, R. I.; Lateef, H. T.; Ademola, A. K. *J. Med. Phys.* **2010**, *35*, 242-246.

[5] Oikawa, S.; Kanno, N.; Sanada, T.; Abukawa, J.; Higuchi, H. *J. Environ. Radioactiv.* **2006**, *87*, 239-245.

[6] Köksal, E. M.; Çelebi, N.; Ataksor, B.; Ulug, A.; Taşdelen, M.; Kopuz, G.; Akar, B; Karabulut, M. T. *J. Radioanal. Nucl. Chem.* **2004**, *259*, 213-216.

[7] Cortina, D.; Duran, I.; Llerena, J. J. *J. Environ. Radioactiv.* **2008**, *99*, 1583-1588.

[8] Rahman, S.; Mati, N.; Matiullah, Ghauri; B. M. *Radiat. Meas.* **2007**, *42*, 1715-1722.

[9] Stojanovska, Z.; Januseski, J.; Bossew, P.; Zunic, Z. S.; Tollefsen, T.; Ristova, M. *Radiat. Meas.* **2011**, *46*, 602-610.

[10] Rahman, S.; Matiullah, Ghauri, B. M. *Radiat. Meas.* **2010**, *45*, 247-252.

[11] UNSCEAR *Sources and Effects of Ionizing Radiation*, New York, NY, USA, 2000.

[12] ICRP *International Commission on Radiological Protection Statement on Radon*, ICRP Ref. 00/902/09, 2009.