

# Radon Level in Dwellings of Trabzon-Turkey

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**Abstract.** In this study, the indoor radon levels have been determined in Trabzon in Eastern Blacksea of Turkey. There is no information about indoor radon concentrations in the dwellings of Trabzon so far. For this reason, passive solid state nuclear track detectors (SSNTD type CR-39) were distributed to 97 randomly chosen houses in Trabzon. The average radon concentration was found to be 34.44 Bq m<sup>-3</sup>. The result have been compared with other indoor radon concentration measurements in different part of the world and also compared to international recommended values. This study is the part of the series of studies investigating the indoor radon concentrations in buildings of Turkey.

**Keywords:** Indoor radon, Passive dosimeter; CR-39, Health Hazards, Trabzon

## INTRODUCTION

Three radioactive series are the primary sources of radon in soil: <sup>222</sup>Rn originates from <sup>238</sup>U series, <sup>220</sup>Rn from <sup>234</sup>Th series and <sup>219</sup>Rn from <sup>235</sup>U series. <sup>219</sup>Rn with his short half-life of 3.96 s usually does not contribute to the signal measured with alpha particle detectors since it decays before reaching the detecting device and the half life of thoron (55 s) is too short to allow for a significant diffusion or advection into the dwelling [1].

<sup>222</sup>Rn is a radioactive gas produced by the decay of the natural radioactive uranium series. The half life of <sup>222</sup>Rn (3.8 days) is long enough so that much of the radon formed either in building materials or in the ground within approximately a meter of building understructures can reach the indoor environment [2].

Radon concentration in soil depends on many physical parameters. The internal soil structure, grain size of soil, type of mineralization and the pore volume determine the value of the emanation coefficient, which is defined as the fraction of the generated radon that enters the soil pores. The regional distribution of radon concentration in buildings is primarily determined by the building materials, the water sources, the domestic gas supplies and in particular by the soil and the geological structures beneath the building. Temperature and pressure differences, wind velocity and humidity also affect the indoor radon concentration. Therefore, the most essential modifying factors are the type of building

constructions, the ventilation conditions, the heating and the cooling systems.

Measurements of indoor radon are of importance because the radiation dose to human population due to inhalation of radon and its daughters contributes more than 60% of the total dose from natural sources [3].

Epidemiological studies showed a positive correlation between the cumulative exposure to radon and its progeny and the incidence of lung cancer, and it was pointed out that >90% of the dose delivered to the lung was owing to radon short lived decay products than radon itself [4].

In the last two decades, there has been a great deal of awareness about the health risks from exposure to radon radioactive gas and its decay products. In fact, the Surgeon General of the United States has warned that radon is the second leading cause of lung cancer in the United States today, next only to smoking, which causes more lung cancer deaths [5].

This paper deals with the measurements of indoor <sup>222</sup>Rn concentration levels of Trabzon in Eastern Black Sea of Turkey, as a part of the nation program to determine public exposure to natural radiation. Up to now, there is no survey has been reported on the radon concentrations in Trabzon. This study is the part of the series of studies investigating the indoor radon concentrations in Turkey buildings.

## EXPERIMENTAL PROCEDURE

In this study, indoor radon concentrations have been measured in Trabzon and 97 randomly chosen dwellings. All measurements were carried out using passive solid state nuclear track detectors (SSNTD type CR-39) in diffusion chamber. The detectors were supplied by Radosys Co. Ltd., Budapest, Hungary. The studied areas are located in Trabzon, Turkey (Fig.1). Detectors were placed in actually used living rooms. Radon monitoring was implemented in 3 month periods during spring. The CR-39 detectors technique is the most popular and reliable technique for integrated and long-term measurement of the radon activity inside dwellings. The CR-39 detectors were designed  $20.0 \times 20.0 \times 1.0 \text{ mm}^3$  in size and placed in a plastic container of 4 mm in height which allows radon to diffuse in. The container was closed with a plastic cap in order to avoid dust deposition on the detector foils. Evaluations of the detectors have been carried out in the laboratory under defined etched in a 30% NaOH at  $70 \text{ }^\circ\text{C}$  for 17 hours. Subsequently the tracks on the etched film were counted manually with an optical microscope (200x).

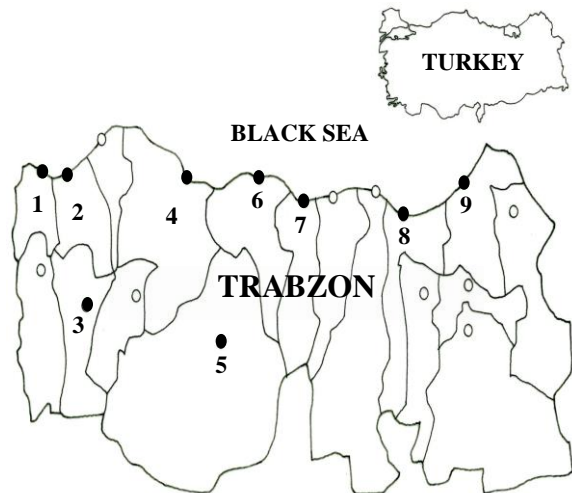


FIGURE 1. The studying areas in Trabzon, Turkey

## RESULTS AND DISCUSSION

Radionuclides in the  $^{238}\text{U}$  decay series, including  $^{226}\text{Ra}$ , the parent of  $^{222}\text{Rn}$ , occur in trace amounts throughout the earth's crust with varying concentrations. In countries with cold climate, where energy saving has led to the tighter sealing of windows and doors, the radon problem may be very significant (Mona Al-Qahtani et al., 2005). The corresponding recommended radon concentrations for annual

exposures are  $200\text{-}600 \text{ Bq.m}^{-3}$  in dwellings. The source of radon is uranium and therefore, there are regional variations in radon concentrations on earth. The action level changes from one country to another. In Turkey, the action level recommended by the Turkish Atomic Energy Authority (TAEK) is  $400 \text{ Bq.m}^{-3}$  [6].

Indoor radon concentration levels were measured in randomly selected dwellings in the city of Trabzon. Distributions of indoor radon concentrations with number of dwellings in Trabzon are given Table 1.

TABLE 1. Distributions of indoor radon concentrations in Trabzon.

Radon concentrations ( $\text{Bq.m}^{-3}$ )	Number of Dwellings
0-19	23
20-39	52
40-59	15
60-79	2
80-99	1
100-119	1
120-139	1
140-159	1
160-179	-
180-200	1

Radon concentrations in dwellings of Trabzon varied from  $8$  to  $187 \text{ Bq.m}^{-3}$  and average value was found as  $34.44 \text{ Bq.m}^{-3}$ . In 22.68% of the dwellings in Trabzon, the radon concentrations varied from  $10$  to  $19 \text{ Bq.m}^{-3}$ , in 26.80% varied from  $20$  to  $29 \text{ Bq.m}^{-3}$ , in 26.80% varied from  $30$  to  $39 \text{ Bq.m}^{-3}$  and in 10.31% varied from  $40$  to  $49 \text{ Bq.m}^{-3}$ . There were four dwellings that had the indoor radon concentration levels higher than  $100 \text{ Bq.m}^{-3}$ . None of the dwellings exceeds the Turkish Atomic Energy Authority's (TAEK) intervention limit of  $400 \text{ Bq.m}^{-3}$ . The radon concentration levels measured are lower than the average of Turkey  $35.12 \text{ Bq.m}^{-3}$  [7] and the international recommended value  $40 \text{ Bq.m}^{-3}$  [8]. Figure 2 shows a clearer picture of the variation of indoor radon concentrations in dwellings of Trabzon.

Measured indoor radon concentrations in dwellings of counties of Trabzon are given in Table 2. The radon level in each location was normal and around  $35 \text{ Bq.m}^{-3}$ . However, the big variation between the minimum and maximum values of radon concentration can be attributed to different ventilation conditions and the type of building constructions. Figure 3 shows a picture of the variation of indoor radon concentrations in dwellings of counties of Trabzon.

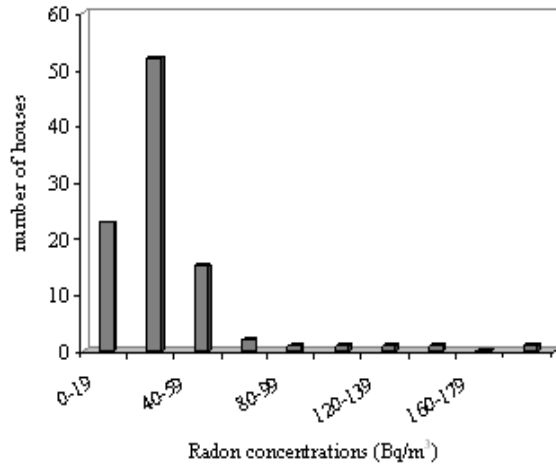


FIGURE 2. Variation of indoor radon concentrations

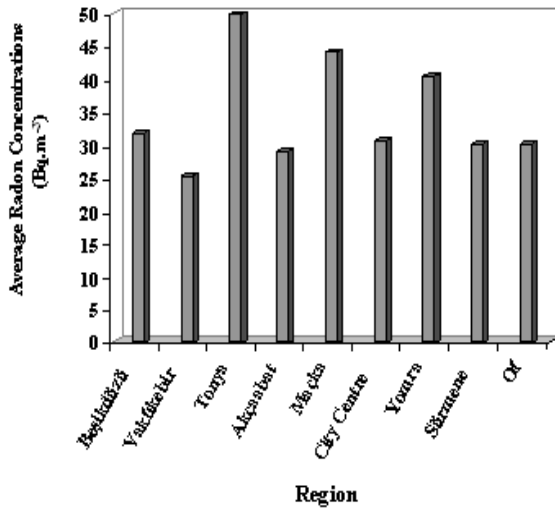


FIGURE 3. Variation of indoor radon concentrations in counties of Trabzon

Table 3 shows the distribution of radon levels in the dwellings with basement and no basement. 58 dwellings (59.79%) which passive dosimeters were distributed with basement and 39 dwellings (40.21%) were distributed with no basement. Radon concentrations in the dwellings with basement varied from 11 to 143 Bq.m<sup>-3</sup> and average radon concentration was observed 32.28 Bq.m<sup>-3</sup>. Radon concentrations in the dwellings with no basement varied from 8 to 187 Bq.m<sup>-3</sup> and average radon concentration was found 37 Bq.m<sup>-3</sup>. Some of these values are higher than the average of Turkey [7]. The average radon concentrations were also found to be building conditions. We determined that the indoor

radon concentrations in the buildings with basement were lower than in the buildings with no basement.

TABLE 3. Distribution of the radon levels depending on whether the buildings had basements or not

Radon concentrations (Bq.m <sup>-3</sup> )	Basement	No Basement
0-19	13	10
20-39	32	20
40-59	9	6
60-79	2	-
80-99	-	1
100-19	1	-
120-139	-	1
140-159	1	-
160-179	-	-
180-200	-	1

For measurement of radon concentrations in Trabzon, 39 dwellings (40.21%) of 97 dwellings which detectors were distributed are heated with central heating and 58 dwellings (59.79%) are heated with stove. Table 4 shows the distribution of radon levels in the dwellings with central heating and stove in Trabzon. Average radon concentration of the dwellings with central heating and stove were found 33.72 Bq.m<sup>-3</sup> and 34.93 Bq.m<sup>-3</sup>, respectively. The average radon concentration in the dwellings using stove is higher than the central heating.

TABLE 4. Distribution of the radon levels depending on heating system

Radon concentrations (Bq.m <sup>-3</sup> )	Central Heating	Stove
0-19	10	13
20-39	19	33
40-59	9	6
60-79	1	1
80-99	-	1
100-19	-	1
120-139	1	-
140-159	-	1
160-179	-	-
180-200	-	1

Indoor radon concentrations in other parts of the world, given in Table 5, are also comparable with those of the present study. It is obviously clear that these average values are higher than our result.

**TABLE 2.** Distributions of indoor radon concentrations in counties of Trabzon

REGION	Number of Houses	Indoor Radon Concentration Levels (Bq.m <sup>-3</sup> )				
		Minimum Value	Maximum Value	Arithmetic Mean	Geometric Mean	Standard Deviation
1 Beşikdüzü	8	5	54	31.75	29.08	12.51
2 Vakfikebir	6	13	37	25.33	23.76	8.84
3 Tonya	8	16	187	49.75	36.87	51.93
4 Akçaabat	9	8	61	29	23.86	17.61
5 Maçka	9	26	80	44.11	40.89	17.98
6 City Center	27	11	139	30.74	26.29	23.45
7 Yomra	13	13	143	40.46	30.05	37.95
8 Sürmene	8	14	54	30.13	26.90	13.83
9 Of	9	17	45	30.11	29.79	9.19

**TABLE 5.** Concentrations of indoor radon from different parts of the world, compared with those of the present study

REGION	Indoor <sup>222</sup> Rn concentrations (Bq.m <sup>-3</sup> )		
	min	max	average
Canary Islands [9]	21	104	50
Jordan [10]	46	1553	206
Turkey [7]	10	380	35
Saudi Arabia [11]	4	32	-
Mexico [12]	15	260	122
Iraq [2]	10	90	44
India [13]	96	202	153
Morocco [14]	40	532	-
Norway [15]	10	1250	204
Trabzon/Turkey (present study)	8	187	34

## REFERENCES

- D. Mazur, M. Janik, J. Loskiewicz, P. Olko and J. Swakon, *Radiation Measurements* **31**, 295-300 (1999).
- H.H. Mansour, S. Khdar, H.Y. Abdulla, N.Q. Muhamad, M.M. Othman and S. Qader, *Radiation Measurements* **40**, 544-547 (2005).
- UNSCEAR, United Nations Scientific Committee on the Effect of Atomic Radiation, United Nations, New York, 1993.
- A. Fişne, G. Ökten and N. Çelebi, *Radiation Protection Dosimetry* **113** (2), 173-177 (2005).
- BEIR (Biological Effects of Ionizing Radiation) VI, Committee on Health Risks of Exposure to Radon, Health Effects of Exposure to Radon, National Academy Press, Washington, DC, 1999.
- TAEK, Regulations for the Radiation Safety, No. 23999, 2000.
- E.M. Köksal, N. Çelebi and B. Özçınar, *Health Physics* **65** (1), 87-88 (1993).
- UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation Sources, Effects and Risks of Ionizing Radiation, United Nations sales publication, No.E.00.IX.3, New York, 2000.
- C. Pinza, H. Armas and A. Poffijn, *Radiation Protection Dosimetry* **69**(3), 217-220 (1997).
- M. Kullab, *Applied Radiation and Isotopes* **62**, 765-773 (2005).
- Mona Al-Qahtani, M. I. Al-Jarallah, Fazal-ur Rehman, *Radiation Measurements* **40** (2-6), 704-706 (2005).
- G. Espinosa, J.I. Golzarri, J. Rickards and R.B. Gammage, *Radiation Measurements* **31**, 355-358 (1999).
- S. Singh, M. Kumar and R.K Mahajan, *Radiation Measurements* **39**, 535-542 (2005).
- L. Oufni, M.A. Misdag and M. Amrane, *Radiation Measurements* **40**, 118-123 (2005).
- A.V. Sundal and T. Strand, *Journal of Environmental Radioactivity* **77**, 175-189 (2004).