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Indoor Radon Levels in Dwellings of Kirklareli, Turkey

Selin ÖZDEN*[1], Serpil AKÖZCAN[1]

Abstract

The indoor radon concentrations in Kirklareli, Turkey were measured in living rooms of 19 houses during winter in 2019 using Airthings 222 Corentium Home Radon Gas Detector. The short-term and long-term measurements were performed in 1 and 7 days for each house to investigate radioactive radon gas exposure in Kirklareli buildings. The indoor radon concentrations were varied from 23 to 156 Bq m^{-3} for 1 day period and were varied from 16 to 77 Bq m^{-3} for 7 days period. The average radon gas concentration was found as 43.5 Bq m^{-3} and this result is higher than the average of Turkey and the world average. The annual effective doses due to radon gas exposure were also estimated. The annual effective dose rate ranged from 0.61 to 2.94 mSv y^{-1} with a mean value of 1.09 mSv y^{-1}.

Keywords: Radon, indoor radon concentration, radioactivity, effective dose

1. INTRODUCTION

Radon is a natural radioactive gas and is a member of natural decay of the uranium-238 (^{238}U), thorium-232 (^{232}Th) and uranium-235 (^{235}U). Three essential radioactive isotopes of radon are radon (^{222}Rn) in the ^{238}U chain, thoron (^{220}Rn) in the ^{232}Th chain and actinon (^{219}Rn) in the ^{235}U chain with a half-life of 3.82 days, 55.6 s and 4 s, respectively [1]. Among these isotopes, ^{222}Rn is the main cause of radiation exposure indoors due to high concentrations of ^{238}U in the ground. However, ^{220}Rn and ^{219}Rn have a short half-life and can transfer short distances before decay [2].

Radon is a significant source of ionizing radiation and responsible for more than % 50 of radiation from natural radioactivity sources [3]. Radon is a colorless, tasteless and odorless heavy noble gas which is produced by alpha decay of radium (^{226}Ra) and it exists in different levels in soil, water and air [4-6]. As a result of uranium decay in soil and rock, radon migrates through the ground, diffuses into the air and dissolves into the groundwater. Radon gas penetrates into dwellings through the cracks and pores. Although the outdoor radon gas concentration levels are generally very low, indoor radon gas concentrations depend on the type of building material, soil permeability, water usage, floor level and meteorological conditions such as air temperature and pressure [6-8]. Radon mostly accumulates in closest levels of the dwellings to the soil and rocks such as ground floors and cellars. Studies have shown that indoor radon concentrations tend to increase in winter due to lack of ventilation [9, 10]. In addition, radon concentration levels highly depend on soil

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permeability and high soil permeability increases penetration of radon from soil into dwellings [11].

Indoor radon exposure and inhalation of radon and its progenies are significantly hazardous for human health. Radon progenies stick to dust and particles in the air and human breathes these radioactive dust and particles when radon progenies accumulate in the indoor air. As a result of breathing radon and its progenies, human tissues are affected by alpha particles and tissues are damaged especially in lungs [12]. Inhalation of radon and its progenies is a major reason of lung cancer after smoking and between %3 and %14 of lung cancers is associated to radon [12, 13]. Human exposure to radon and recommended limits of radon gas differ from country to country and change between a few Bq m^{-3} to several thousand Bq m^{-3}. According to The Turkey Atomic Energy Agency, upper limit of inhaled radon in the homes is 400 Bq m^{-3} and in work areas is 1000 Bq m^{-3} [14].

The objective of this research is to carry out radon concentrations in the dwellings of Kirklareli Province. The radon concentration measurements were performed for 19 different dwellings in winter. The effect of floor level on radon concentration was investigated and the average indoor radon concentrations in different floors were calculated. The annual effective dose rates were estimated from measured radon activities. In addition; measured indoor radon concentrations and estimated annual effective dose rates in dwellings were compared with the results of various studies performed around the world and Turkey.

2. MATERIAL AND METHODS

Indoor radon activity levels were measured in 19 dwellings in Kirklareli, Turkey during winter in 2019. The measurements were performed in 1 and 7 days for each house to investigate radioactive radon gas exposure in Kirklareli buildings. In Figure 1, the locations of the dwellings under study are shown.

The ^{222}Rn activity concentrations were measured using the Airthings 222 Corentium Home Radon Gas Detector. The system is a digital radon gas detector and gives results in a maximum accuracy and speed. The detector measures the energy of alpha particles coming out of the decay products of ^{238}U chain. The detector has an accuracy of < 5% ± 5 Bq m^3. The measurement range of the detector is 0 to 9999 Bq m^3.

Figure 1 Study area and dwelling locations

3. RESULTS AND DISCUSSION

The measured radon concentrations in 19 dwellings at the study area are given in Table 1. Indoor radon concentration change graphs with houses for one day and seven days measurement periods are shown in Figure 2. The concentrations of radon in the dwellings ranged from 23 to 156 Bq m^{-3} for short-term 1 day measurements. The arithmetic mean of indoor ^{222}Rn concentration was calculated as 46.2 Bq m^3 and the geometric mean of indoor ^{222}Rn concentration was estimated as 40.4 Bq m^{-3} for 1 day measurement period. In addition, for 7 days period, the level of radon concentration in the dwellings ranged from 16 to 77 Bq m^{-3}. The arithmetic and the geometric mean of indoor ^{222}Rn acticity were found to be 40.8 and 37.5 Bq m^{-3} for 7 days measurement period, respectively.

Indoor radon concentration levels measured in this study are below the concentration levels of 200 Bq m^{-3} recommended by International Commission on Radiological Protection (ICRP) and below the concentration levels of 400 Bq m^{-3} recommended by Turkey Atomic Energy Agency (TAEK) [14, 15]. The average indoor radon concentrations in this study are higher than the Turkey average (35 Bq m^{-3}) and slightly above the world average (40 Bq m^{-3}) [16, 17].

Table 1 Indoor radon concentrations for one day and seven days periods

Houses	^{222}Rn (Bq m^{-3})	
	1 Day	7 Days
1	36	43
2	25	23
3	55	29
4	156	77
5	29	57
6	58	54
7	80	31
8	33	34
9	24	30
10	42	27
11	55	37
12	38	26
13	24	40
14	60	65
15	33	77
16	23	34
17	24	27
18	45	16
19	38	49
Arithmetic Mean	46.2	40.8
Geometric Mean	40.4	37.5

The highest indoor radon levels (77 and 156 Bq m^3) were measured in Kayali region (House 15) and Taşağıl Village (House 4). House 4 was an old building and because of old construction materials had a higher radon concentration level [18]. In addition, Kayali region is covered by various rock types especially metamorphic rocks which are rich in uranium and thorium [19]. The studies have shown that the rock type affecting the concentration of indoor radon activity [20, 21].

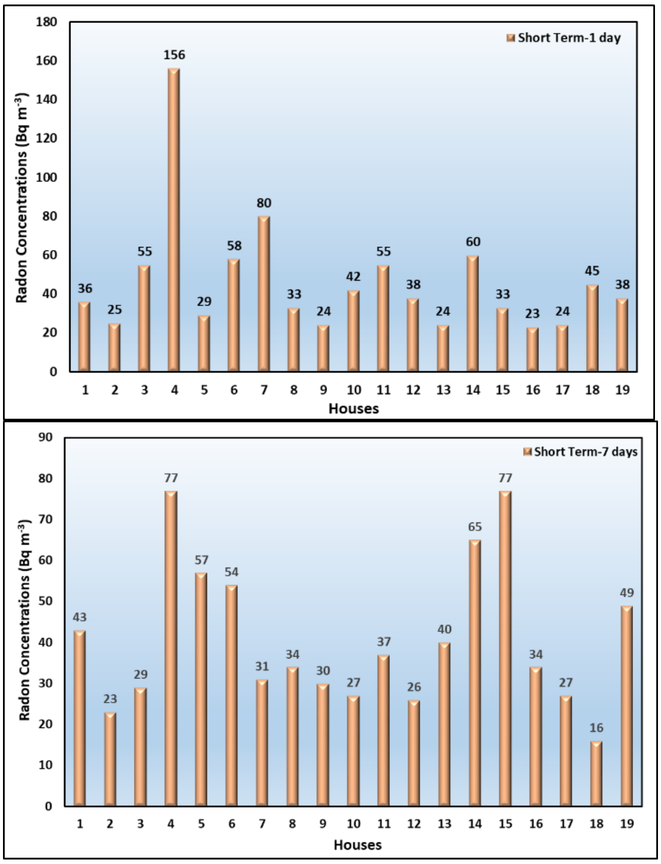

Figure 2 Indoor radon concentration change graphs with houses for one day and seven days measurement periods

Floor level of the house is also important for indoor radon activity concentration results. The effect of floor level on radon activity was investigated and the average indoor radon concentrations in different floors were shown in Figure 3. The average radon concentrations at floor levels were computed as the arithmetic mean of the results. As seen in Figure 3, the average radon concentration value in the first floor was higher compared to those in the 2 nd, 3 rd and 4 th floor. The average radon concentrations were calculated as 62.4, 44.8, 32.6 and 35.0 Bq m^{-3} for 1 st, 2nd, 3rd and 4th floors, respectively. It can be said that the floor level plays a significant role in estimating the indoor radon concentration levels and people in the first floors would have a higher risk of radon gas exposure.

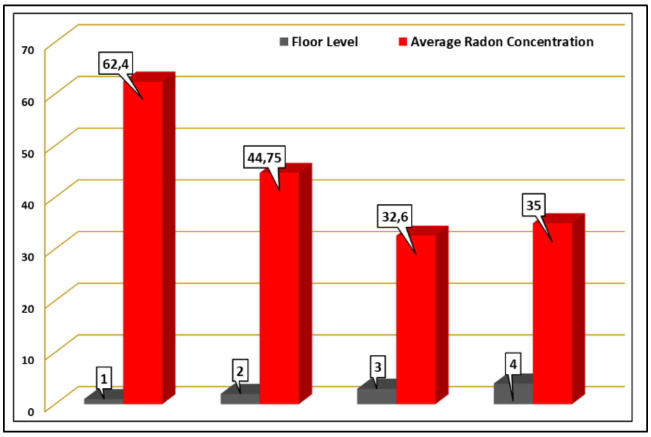

Figure 3 The change of average indoor radon concentrations in Bq m^{-3} with floor level

Epidemiological studies points that indoor radon exposure is responsible for an important number of lung cancers in the general population. For radon gas, the annual effective dose can be predicted from measured radon activity concentrations based on conversion factors given by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report [3].

The annual effective radiation dose (AED) in units of mSv y^{-1} is calculated by the following equation [3]:

$$AED = A_{Rn} \times D_f \times O_f \times E_f \times 24h \times 365 \times 10^{-6} \quad (1)$$

where A_{Rn} is the measured ^{222}Rn activity in indoor (Bq m^{-3}), D_f is the dose conversion factor (9.0 nSv h^{-1} per Bq m^{-3}), O_f is the indoor occupancy (0.8) and E_f is the radon equilibrium factor between radon and its decay products (0.4 for buildings).

The calculated AED values are given in Table 2 and the graph of the change of calculated AED values with dwellings is shown in Figure 4. As seen in Table 1 and Figure 4, the range of annual effective radiation dose ranged from 0.61 (house 2) to 2.94 (house 4) mSv y^{-1}. The average annual radon effective dose rate was found as 1.09 mSv y^{-1}. It has been observed that the all values of the AED are below the recommended action level of 3–10 mSv y^{-1} by ICRP [22, 23].

In Figure 5, the plot of AED values against the average indoor radon gas concentration is shown. It is found that the correlation between average indoor radon concentration and the calculated AED values is high (R^2=1).

Table 2 The calculated AED values in dwellings at the study area

Houses	AED (mSv y^{-1})
1	1.00
2	0.61
3	1.06
4	2.94
5	1.08
6	1.41
7	1.40
8	0.85
9	0.68
10	0.87
11	1.16
12	0.81
13	0.81
14	1.58
15	1.39
16	0.72
17	0.64
18	0.77
19	1.10
Average	1.09

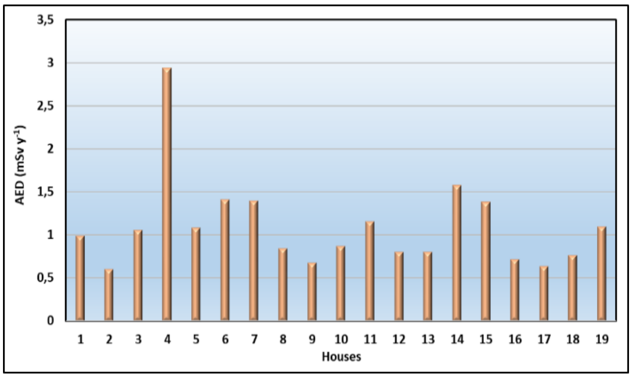

Figure 4 The change of calculated AED (mSv y^{-1}) values with dwellings

Many studies have been reported in the literature to measure radon concentrations in indoor. A comparison of measured indoor radon activity levels in dwellings with the results of various studies performed around the world and Turkey was given in Table 3.

Some of the ^{222}Rn activities for dwellings were found to be lower than İstanbul, Turkey (10-260 Bq m^{-3}); Kastamonu, Turkey (29-177 Bq m^{-3}); Çanakkale, Turkey (9-300 Bq m^{-3}); Ireland (21-

338 Bq m^{-3}); Italy (6.5-388 Bq m^{-3}); Mexico (15-295 Bq m^{-3}); Kosovo (35-814 Bq m^{-3}); Bulgaria (20-1117 Bq m^{-3}) and Portugal (36-1324 Bq m^{-3}). The highest value of the annual effective dose rate of ^{222}Rn in this study were lower than İzmir, Turkey (4.3 mSv y^{-1}); Manisa, Turkey (7.3 mSv y^{-1}); Kastamonu, Turkey (4.46 mSv y^{-1}); Çanakkale, Turkey (5.2 mSv y^{-1}); Ireland (13.3 mSv y^{-1}) and Kosovo (6.47 mSv y^{-1}).

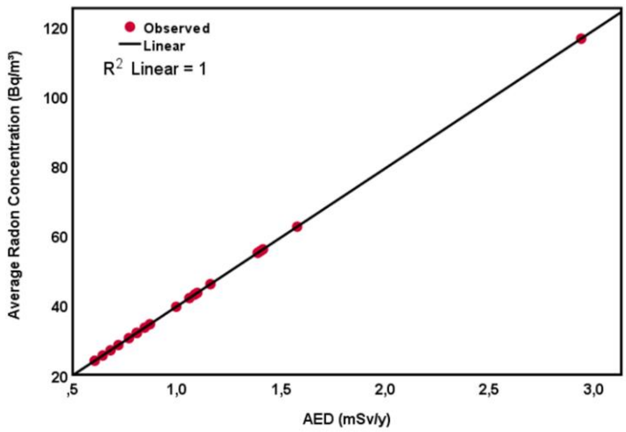

Figure 5 The plot of the calculated AED values against the average indoor radon concentration

Table 3 The comparison of ^{222}Rn activities and annual effective dose rates for indoor air with other studies around the world and Turkey

Location	^{222}Rn (Bq m^{-3})	AED (mSv y^{-1})	Reference
İzmir, Turkey	53-86	2.69-4.3	[24]
İstanbul, Turkey	10-260	-	[25]
Manisa, Turkey	47-146	2.35-7.3	[26]
Kastamonu, Turkey	29-177	0.73-4.46	[27]
Çanakkale, Turkey	9-300	0.4-5.2	[22]
Ireland	21-338	0.8-13.3	[28]
Italy	6.5-388	-	[29]
Mexico	15-295	-	[30]
Kosovo	35-814	0.28-6.47	[31]
Bulgaria	20-1117	-	[32]
Lebanon	3-79.3	-	[33]
Portugal	36-1324	-	[34]
Kirklareli, Turkey	16-156	0.61-2.94	Present Study

The results have shown that measured radon activity levels and the annual effective dose rates for Kirklareli in this study are lower than other studies around the world and Turkey.

Statistical data for average indoor radon concentrations was evaluated using the SPSS software, version 25.0 (SPSS Inc., USA). Mean, median, range, standard deviation, variance, geometric mean, kurtosis and skewness are summarized for average indoor radon concentrations in Table 4. The positive value of the skewness obtained in the statistical data shows that indoor radon concentration distribution is asymmetric with the right tail longer than the left tail. In addition, the positive kurtosis suggests that the indoor radon concentration distribution is higher and narrower than the normal.

Table 4 Statistical data for average indoor radon concentrations in dwellings at the study area

Parameter	Indoor Radon (Bq m^{-3})
Mean	43.53
Median	39.50
Standard Deviation	21.03
Range	24-117
Variance	442.40
Geometric Mean	40.20
Kurtosis	7.93
Skewness	2.48

4. CONCLUSIONS

In present study, indoor radon activity levels were investigated for Kirklareli province, Turkey. Indoor radon concentration measurements were performed in a total of 19 houses during winter in 2019. The arithmetic mean and the geometric mean of indoor ^{222}Rn concentration were calculated as 46.2 Bq m^{-3} and 40.4 Bq m^{-3} for 1 day measurement period, respectively. The arithmetic and the geometric mean of indoor ^{222}Rn activity were found to be 40.8 and 37.5 Bq m^{-3} for 7 days measurement period, respectively.

Indoor radon concentration levels found in this study are below the concentration levels recommended by International Commission on Radiological Protection (ICRP) and Turkey Atomic Energy Agency (TAEK). The mean of indoor ^{222}Rn concentrations is higher than the Turkey average (35 Bq m^{-3}) and slightly above the world average (40 Bq m^{-3}). It is found that the higher indoor radon concentrations are associated with floor level, old construction materials and rock type. In addition; the annual effective radiation dose rates were estimated and it has been found that all AED values are below the recommended action level by ICRP.

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

Authors' Contribution

The first author contributed 60%, the second author 40%.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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