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DETERMINATION OF RADON GAS LEVELS IN THE AIR IN THE FACULTY BUILDING (BİTLİS)

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ABSTRACT

Living things are exposed to internal and external natural radiation throughout their lives. Natural radiation consists mostly of cosmic rays and terrestrial radiation sources containing many radioisotopes. While uranium, thorium and potassium are the main radionuclides that constitute terrestrial natural radiation sources; radon is a radioactive gas that occurs naturally by the decay of uranium found in soil, rocks and water. People are mostly exposed to natural radiation due to building construction materials and indoor radon concentration.

In this study, measurement of radon gas activity concentration levels in the air in Bitlis Eren University Faculty of Science and Letters building was made using an active radon measurement detector (AlphaGUARD). As a result of these measurements; The average radon activity concentration was determined as 41.13 Bq/m^3. When the measurement results are compared with the limit values; It has been determined that there is no risk to health. Annual effective dose equivalent, AEDE, (average 0.889 mSv/y) and excess lifetime cancer risk, ELCR, (average 3.545) parameters were calculated using radon activity concentration values.

1 INTRODUCTION

Radioactive isotopes that have been present in the structure of the earth's crust since the formation of the earth and high-energy cosmic rays coming from space are the sources of natural radiation. Natural radioactive isotopes found in many environments such as soil, water, air, vegetation, foods and building materials cause external and internal irradiation of our body [1].

The first of the main components of the natural radiation in the environment is the radiation resulting from the decay of uranium, thorium series radionuclides and ^{40}K, which have existed since the formation of the world. The second is cosmic radiation [2].

Living things on earth are exposed to radiation every day from natural radiation sources in the air, water, soil, and even within their own bodies, as well as artificial radiation sources produced by humans. While exposure from natural radiation sources is 80%, exposure from man-made radiation sources is 20% [3].

People spend most of their time in indoor environments. In this regard, the quality of the inhaled air is very important for human health. Along with beneficial gases such as nitrogen, oxygen and hydrogen, harmful gases are also present in the environment. Radon gas, formed as a result of the decay of uranium, is among the gases harmful to human health. Since 1960, as the knowledge that radon gas is concentrated in buildings and causes lung cancer has become widespread, research on determining radon concentration levels in indoor environments has gained importance and maps have been prepared to determine radon activity concentration levels. The Turkish Atomic Energy Agency (TAEK, today known as the Turkish Energy, Nuclear and Mining Research Council (TENMAK)) started working on this subject in 1984, but the radon map of our country has not been completed yet [4]. In order to create a radon map, environmental radon activity concentration measurements are carried out in our country.

Considering that people spend most of their time in closed environments in our country and that a large number of cancer diagnoses are made, the importance of determining indoor ^{222}Rn gas concentrations for human health becomes evident. When the studies carried out in the world and in our country in recent years are examined, it turns out that the biggest cause of lung cancer, especially after smoking, is ^{222}Rn gas. Based on these studies, 3% to 14% of lung cancer cases are thought to be caused by ^{222}Rn [5].

In this study, radon activity concentration levels in the air were determined in some offices located in the Bitlis Eren University Faculty of Science and Letters building. The results of the measurements and calculations were interpreted, taking into account the limits set by the literature and health organizations, and their effects on human health.

2 MATERIAL AND METHODS

2.1 Geological Formation of Bitlis

Bitlis province is located in the Upper Murat-Van Section of the Eastern Anatolia Region. It is surrounded by the provinces of Ağrı and Muş in the north, Van in the east, Batman in the west, and Siirt in the south. Bitlis province consists of 7 districts: the central district, Tatvan, Ahlat, Güroymak, Adilcevaz, Hizan and Mutki [6].

There are various stratigraphic sections throughout the Bitlis Metamorphic belt. No classification study has been carried out according to the acidity and alkalinity values of the rocks of Bitlis province.

Bitlis' rock sequence; Pre-Devonian Lower Unit, Devonian-Upper Triassic Upper Unit, Guleman Group including meta-ophiolites, Kinzu Formation consisting of flysch type sediments and Paleocene-Lower Eocene aged Maden Group sediments are distinguished [7].

In some places within the Upper Unit in the Bitlis rock sequence, there are Mesozoic-Tertiary aged greenstone blocks at faulted contacts with phyllite and pelitic schists. Lateral discontinuity and blocky appearance of durable units such as limestone and quartzite in this unity are observed in many places. The existence of two units, whose relations are regulated by tectonic events, has been shown in the complex structured mass called Bitlis massif [8].

2.2 Geological Formation of Rahova

Rahva plain is located in the Upper Euphrates Section of the Eastern Anatolia Region. This plain, which is within the borders of Bitlis province; It has the feature of a water division line separating the Euphrates, Tigris and Van Lake basins from each other. In other words, Rahva is a threshold area that determines the common boundaries of three hydrographic basins.

In the parts of the Rahva plain close to the Bitlis Mountains, the valleys are buried deeper. The rocks cropping out along the valleys consist of trachyandesitic tuffs and ignimbrites. The volcanics that make up the plain are listed as brownish-red tuff (also called poorly welded ignimbrite) at the top, gray-brown ash below, and light-colored, well-welded trachyandesitic ignimbrite at the bottom, respectively.

Rahva plain is a threshold area between the metamorphic Bitlis old mass and the Nemrut volcano formed as a result of Plio-Quaternary volcanism. While the basic formations of this area consist of schists and recrystallized limestones, the sections close to the surface consist entirely of volcanic formations [9].

2.3 Determination of Radon in Air with AlphaGuard

AlphaGUARD PQ 2000PRO, used in Radon measurements, is a portable radiation detector used to measure the radiation intensities and Gamma (γ) dose rate of Radon (Radon-222), Radon-220 (Thoron) and Radon by-products. AlphaGUARD can make radiation measurements in air, water, soil and building materials. Measurement results; AlphaGUARD detector, which gives Bq (Becquerel) per volume, that is, Bq/m^3, can simultaneously measure three different climatic parameters such as temperature, atmospheric pressure and humidity [10].

The AlphaGUARD Radon detector draws air into the detector ionization chamber with the help of a suction pump integrated into the measurement unit. ^{222}Rn and ^{220}Rn isotopes entering the ionization chamber as a result of absorption decay and create electrical signals by causing ionization in the chamber. During this continuous absorption, Radon byproducts are retained by a plate-shaped filter, and the alpha activity of Radon daughter products accumulated on the filter plate is measured by the alpha-sensitive TN-WL-02 microchip module, which is a sensitive digital processor module placed on the other side of the filter plate. The electrical signals obtained from all measurements are sent as a TTL signal to the Counter-Module counter unit of the AlphaGUARD PQ 2000PRO and are converted into readable data by the software using the calibration information of the detector [10].

The software package (DataEXPERT) developed for AlphaGUARD was used to graphically process, develop, archive and present the received data in a virtual environment.

There is no need for additional equipment with the detector to measure radon concentration in air. On the AlphaGUARD device, '10 min DIFFUSION' was selected as the measurement mode. The detector was positioned approximately 1.5-2 m above the ground in the working environment. The AlphaGUARD radon detector draws air into the detector ionization chamber with the help of a suction pump integrated into the measurement unit. Measurements were made for 24 hours for each study area in order to observe the transitions between day and night and the effect of ventilation on the radon concentration in the environment. In order to make scientific interpretations of the data stored during the measurement, AlphaGUARD was connected to the computer and worked with data analysis software (DataEXPERT) [10].

2.4 Annual effective dose equivalent (AEDE)

Quantification of the effects of ionizing radiation to which humans are exposed from air, water and food sources is carried out by calculating the physical quantity called the annual effective dose. The dose exposed over a period of 1 year is defined as the annual effective dose. Annual effective dose equivalent calculation was made using the following Equation 1 [11], [12];

$$AEDE(Sv/y) = A_{Rn} \times DP \times EECC \times T \quad \textbf{(1)}$$

AEDE; annual effective dose equivalent (mSv/y), DP; balance factor between radon and its decay products (0.4), EECC; equilibrium equivalent concentration coefficient (9 x 10^{-9} (Sv/hour)/(Bq/m^3)), T; total working day hours in 2020 (6,000 hours/year).

2.5 Excess lifetime cancer risk (ELCR)

ELCR is a reasonable upper bound estimate of a person's probability of developing cancer sometime in their life after any radiation exposure [13], [14]. Excess lifetime cancer risk calculation was made using the following Equation 2 [11], [12];

$$ELCR = AEDE \times LE \times FRF \quad \textbf{(2)}$$

LE; life expectancy of people (70 years), FRF; fatal risk factor stated in the ICRP report (0.057 Sv^{-1}) [15].

3 RESULTS

In this study; ^{222}Rn concentration in the air, temperature, pressure and relative humidity measurements were made in the Bitlis Eren University Faculty of Science and Letters building. The radon measurement results obtained using the AlphaGUARD active radon measurement device were analysed using the DataEXPERT software for spectrum analysis. Sample graphs of the measurements made are shown in Figure 1.

(a)

(b)

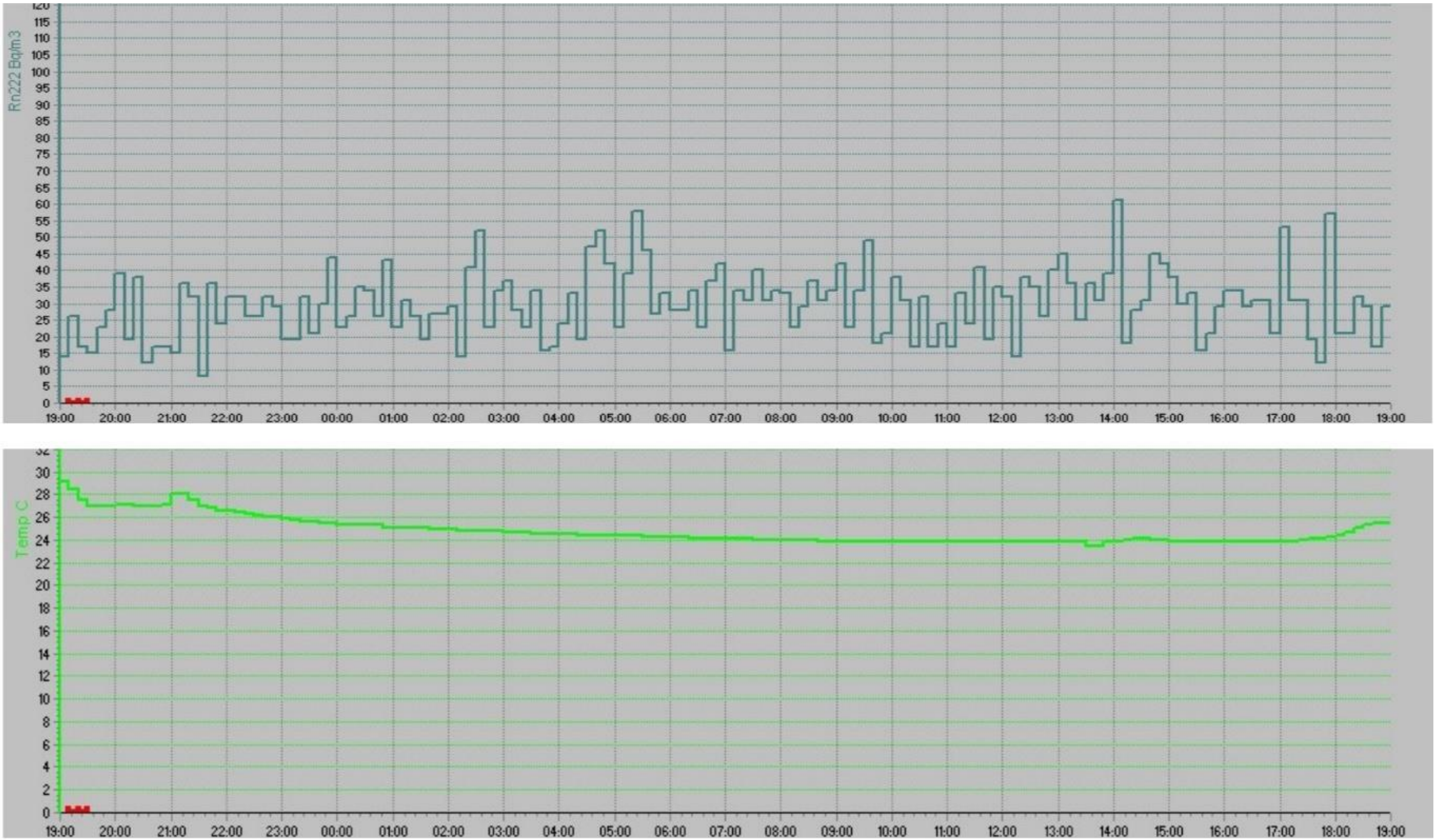
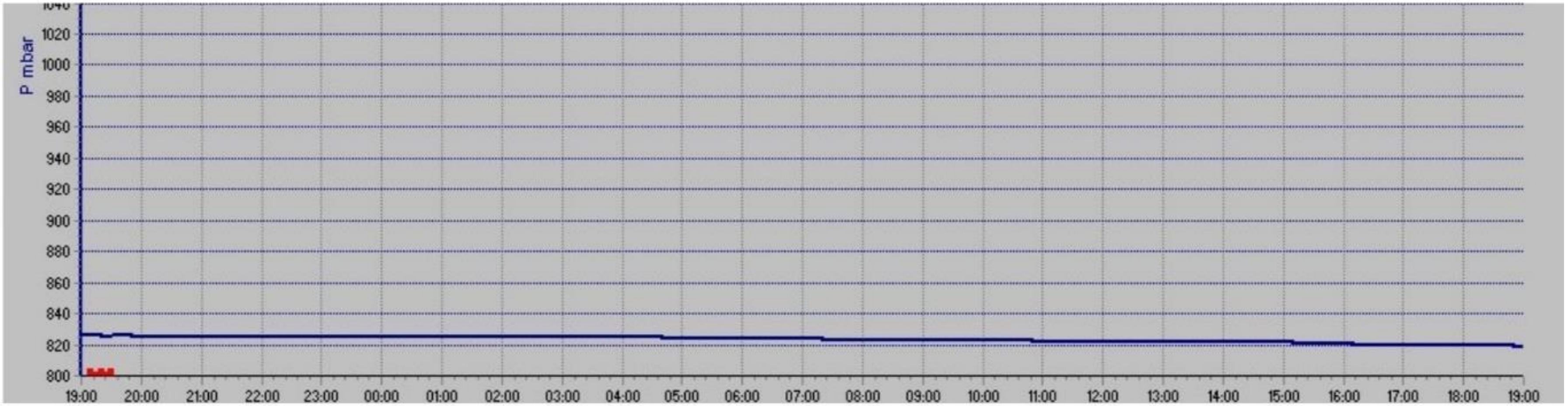


***Figure 1**. Sample graphs of measurements taken from the faculty building (a: ^{222}Rn activity concentration, b: temperature, c: pressure, d: relative humidity).*

(c)



(d)

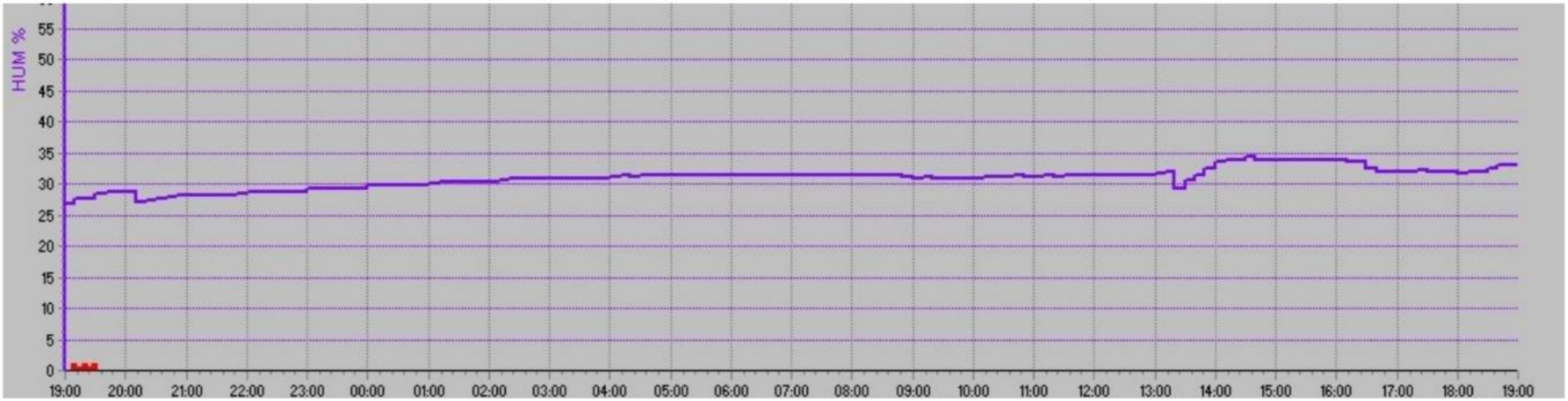


Figure 2. (Continuous) *Sample graphs of measurements taken from the faculty building (a: ^{222}Rn activity concentration, b: temperature, c: pressure, d: relative humidity).*

***Table 1**. Radon activity concentration in the air and some atmospheric data of the measured rooms in the Faculty of Science and Letters building.*

Measure No		Starting date/time	End date/time	^{222}Radon (Bq/m^3)	Temperature (^{0}C)	Pressure (mbar)	Humidity (% rH)	AEDE (mSv/y)	ELCR x 10^{-3}
1	Ground Room 1	18.11.2020/ 16.00	19.11.2020/ 16.00	34 ± 12	24.2	814	29.0	0.734	2.930
2	Ground Room 2	19.11.2020/ 16.05	20.11.2020/ 16.05	30 ± 11	24.6	818	28.3	0.648	2.586
3	Ground Room 3	20.11.2020/ 16.07	21.11.2020/ 16.07	31 ± 11	24.0	810	28.2	0.670	2.672
4	Floor 1 Room 1	16.11.2020/ 15.50	17.11.2020/ 15.50	29 ± 11	25.8	815	31.8	0.626	2.499
5	Floor 1 Room 2	17.11.2020/ 15.55	18.11.2020/ 15.55	8 ± 5	24.8	824	26.4	0.173	0.690
6	Floor 1 Room 3	23.11.2020/ 13.30	24.11.2020/ 13.30	30 ± 11	24.7	823	30.9	0.648	2.586
7	Floor 2 Room 1	24.11.2020/ 13.35	25.11.2020/ 13.35	23 ± 9	24.8	826	20.0	0.497	1.982
8	Floor 2 Room 2	26.11.2020/ 13.50	27.11.2020/ 13.50	47 ± 12	27.2	819	20.9	1.015	4.051
9	Floor 2 Room 3	27.11.2020/ 13.55	28.11.2020/ 13.55	25 ± 10	26.8	825	22.7	0.540	2.155
10	Floor 3 Room 1	30.11.2020/ 13.10	01.12.2020/ 13.10	51 ± 15	25.2	821	25.6	1.102	4.395
11	Floor 3 Room 2	07.12.2020/ 14.20	08.12.2020/ 14.20	25 ± 10	22.7	821	30.3	0.540	2.155
12	Floor 3 Room 3	08.12.2020/ 14.25	09.12.2020/ 14.25	33 ± 13	23.9	821	29.0	0.713	2.844
13	Floor 4 Room 1	09.12.2020/ 14.30	10.12.2020/ 14.30	43 ± 11	23.7	822	28.4	0.929	3.706
14	Floor 4 Room 2	15.12.2020/ 13.30	16.12.2020/ 13.30	106 ± 14	24.5	817	29.9	2.290	9.136
15	Floor 4 Room 3	16.12.2020/ 13.50	17.12.2020/ 13.50	102 ± 16	22.5	819	35.3	2.203	8.791
	Average			41.13 ± 11	24.6	819.7	27.8	0.889	3.545

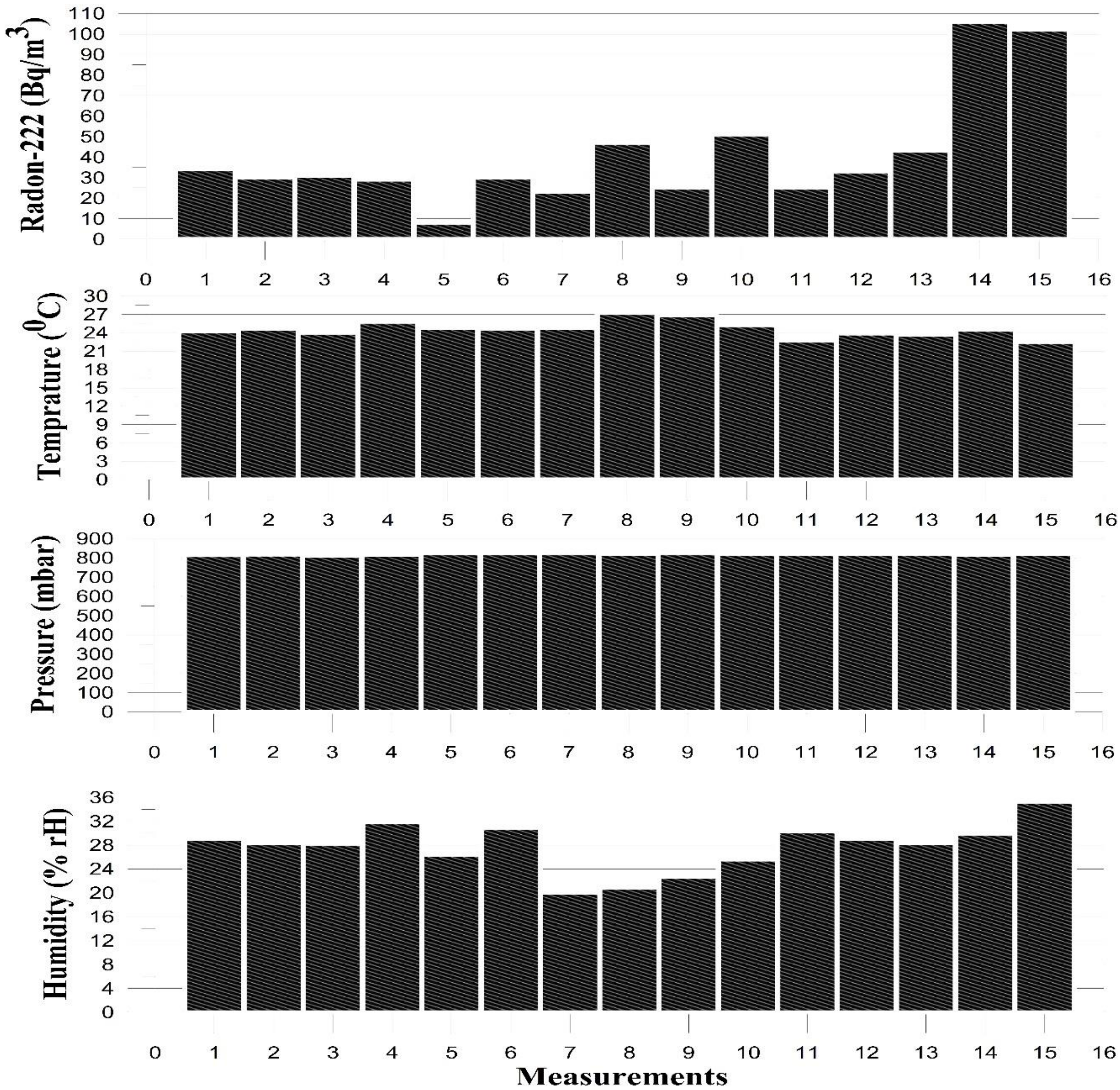


***Figure 2**. Display of radon activity concentration and some atmospheric data.*

When Table 1 and Figure 2 are examined; ^{222}Rn activity concentration between 8 (1st floor) and 106 (4th floor) Bq/m^3, temperature values between 22.5 and 27.2 ^{0}C, pressure values between 810 and 826 mbar, relative humidity values between 20.0 and 35.3 %rH appears to have changed.

The rooms where measurements are made are generally working offices where air circulation is available. Since the offices are closed in the evenings, average values of 24-hours measurements were read from the measuring device.

When examining the variation of radon measurement values according to floors, it was generally observed that the radon activity concentration values measured on the same floors were approximately similar. The 4th (measure in the Floor 1/Room 1) and 5th (measure in the Floor 1/Room 1) radon activity concentration measurements were taken from different study rooms on the same floor. However, it was noted that there was a significant difference between these two measurements. The reason for the 5th measurement being much lower than the 4th could be due to extensive ventilation in the room. Upon detailed examination of the rooms in terms of physical and many other factors, it was found that there were no factors (other than ventilation) that could account for this difference.

The radon activity concentration values of measurements 14 and 15 are observed to be significantly higher than those of the other measurements. These measurements were taken in the offices located on the fourth floor of the building. Similar studies in the literature have shown that indoor radon activity concentration values decrease as you move from the ground floor to the upper floors [16], [17]. This study was conducted during the pandemic period (2020-2021). During this time, schools were closed, and/or remote education was being conducted. As a result, many offices remained closed for weeks and were not ventilated. The offices where measurements 14 and 15 were taken were among these and were not ventilated for a long period. During the winter months, the indoor air being warmer than the outdoor air can create low pressure inside the building, increasing the radon activity concentration [16], [17]. The lack of ventilation for an extended period during that time may have caused these measurements to be significantly higher than the others.

Radon activity concentration varies regionally because the main source of radon is uranium. Because; Limit values of radon activity concentration also vary between countries. The limit value is accepted as 200 Bq/m^3 in the UK, 400 Bq/m^3 in European countries, and 800 Bq/m^3 in Canada. Within the framework of the International Atomic Energy Agency Essential Safety Standards (IAEA-BSS), recommended levels for radon in homes are determined as 200-600 Bq/m^3. According to the Atomic Energy Authority Radiation Safety Regulation in Turkey, the allowed limit value for homes is 400 Bq/m^3 and for workplaces it is 1000 Bq/m^3 [18].

Table 2. *Radon activity concentration values of some similar studies.*

Location	Average Radon-222 (Bq/m^3)	References
Isparta (faculty buildings)	220	[19]
İstanbul (school buildings)	125.06	[20]
Nevşehir (school buildings)	67	[21]
İstanbul (faculty buildings)	24.6	[22]
İstanbul (faculty buildings)	14.47	[23]
Kastamonu (school buildings)	28.43	[10]
Kırklareli (faculty buildings)	16.78	[17]
This study	41.13	

According to the standards set by Turkish Energy, Nuclear and Mineral Research Agency (TENMAK) and various organizations in other countries and the results of similar studies conducted in our country (Table 2), it is seen that the results obtained in this study (average radon activity concentration 41.13 Bq/m^3) are below the permissible limits and the results of similar studies.

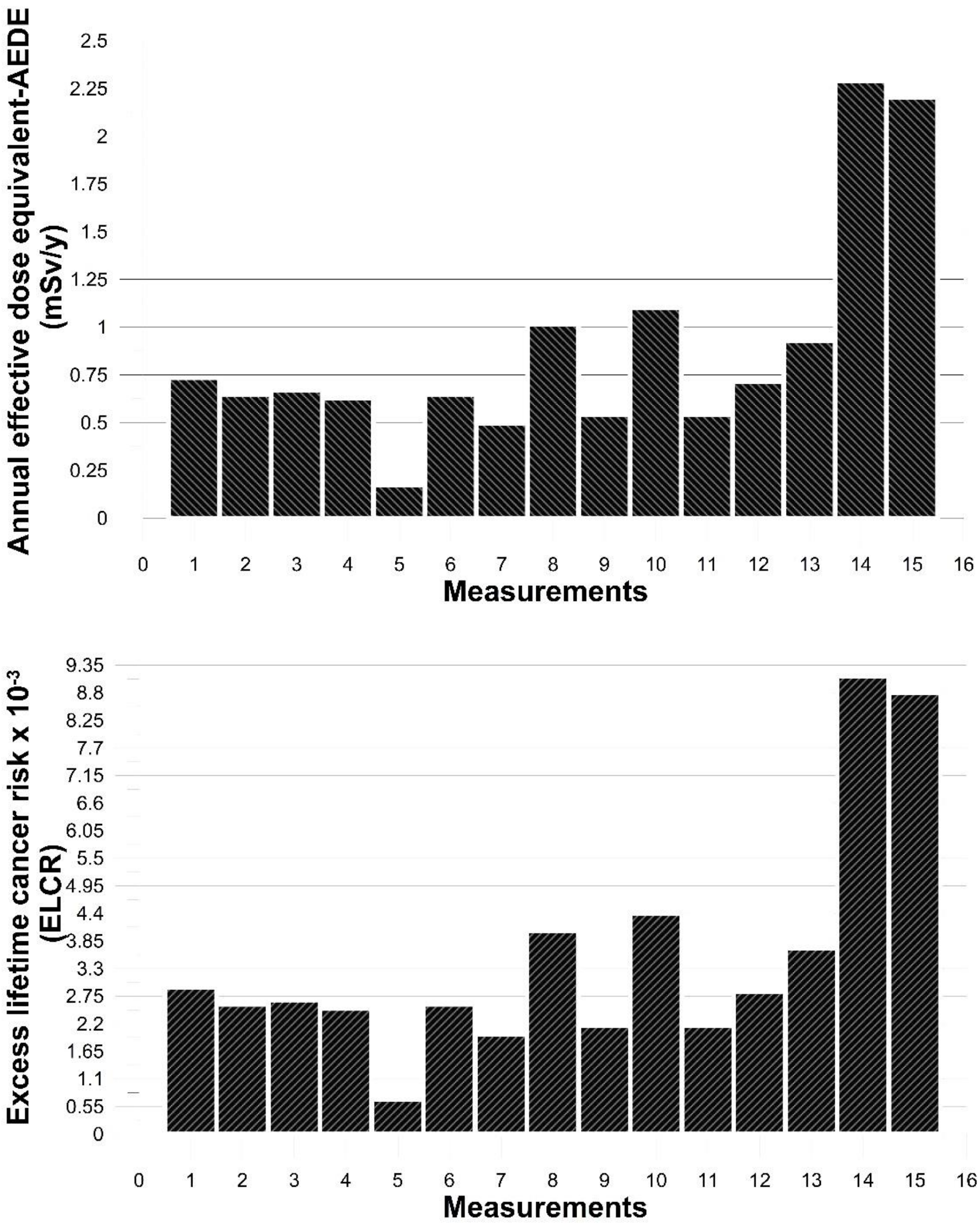


Figure 3*. Display of annual effective dose equivalent and excess lifetime cancer risk.*

When Table 1 and Figure 3 are examined; annual effective dose equivalent (AEDE) between 0.173 (1st floor) and 2.290 (4th floor) mSv/y, excess lifetime cancer risk (ELCR) values between 0.692 and 9.136 appears to have changed.

According to TENMAK, the external irradiation dose originating from the earth (inside the building) is 0.41 mSv/y, depending on the mixture of soil and building materials. In addition to this value, the respiratory irradiation dose depending on the radon gas concentration is 1.15 mSv/y. Depending on both factors in the office rooms where measurements are taken, the total dose (limit value) is calculated as 1.56 mSv/y.

It is seen that AEDE values in offices 2 (2.290 mSv/y) and 3 (2.203 mSv/y) on the 4th floor of the faculty building are above the 1.56 mSv/y limit value. The average value of AEDE was calculated as 0.889 mSv/y. The average value is below the limit value and the calculated values are generally found to be risk-free. When ELCR values are examined, it is seen that the overall risk of cancer is not high.

4 CONCLUSION

It was determined that the radon-222 activity concentration level (average 41.13 Bq/m^3) measured in the Bitlis Eren University Faculty of Science and Letters building was below the limit values determined both in our country and in other countries. Since the measured radon activity concentration values are below the limit values, it shows that there is no risk to health. Radon activity concentration values were determined by measuring on various floors of the faculty building. According to the measured results, it was determined that the radon activity concentration value did not change depending on the floors. According to this study, it was observed that radon activity concentration values were not affected much by atmospheric parameters such as temperature, pressure and relative humidity.

It was observed that AEDE values were not alarming considering the limit value (1.56 mSv/y). However, it can be said that ELCR values do not pose a risk.

Ventilating offices periodically will reduce the radon gas that naturally accumulates in the office, and in this way, an important precaution will be taken in terms of health.

Conflict of interest

There is no conflict of interest between the authors.

Authors Contributions

Writing the article, processing and reviewing the data, and calculations were made by Sultan ŞAHİN BAL. Radon measurements were made by Yonca DERVİŞOĞLU KOÇ.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

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