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The First Indoor Radon Gas Measurement at Historical Places in Cappadocia, Nigde, Turkey

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ABSTRACT

The aim of this study is to determine the concentration of Radon and its annual effective dose at the Nigde Museum and in a number of historical places namely the Sungur Bey, the Alaeddin, the Disari mosque and the Ak Medrese Culture House in Cappadocia, Nigde, Turkey. Nuclear track detector CR-39 were used to ascertain how much Radon concentration affects the people who are working in or visiting such places. Nuclear track detectors CR-39 were used for measurement for 132 days at the Nigde Museum, and for 63 days in the historical places. The exposed nuclear track detectors were then sent to the Sarayköy Nuclear Research and Training Center (SANAEM) to determine of Radon-222. The average Radon concentration results obtained for the Nigde Museum, the Sungur Bey, the Alaeddin, the Disari mosques and the Ak Medrese Culture House were 13.0±2.94 Bq/m^3, 31.67±3.86 Bq/m^3, 52.0±5.72 Bq/m^3, 42.67±19.34 Bq/m^3 and 31.0±4.55 Bq/m^3 respectively. The average effective dose of Radon was calculated for the Nigde Museum, the Sungur Bey, the Alaeddin, the Disari mosques and the Ak Medrese Culture House in Nigde and was found to be approximately 0.137 mSv/y, 0.062 mSv/y, 0.103 mSv/y, 0.084 mSv/y and 0.327 mSv/y respectively.

Keywords: Radon, environmental radioactivity, track detectors, diffusion chamber, CR-39

1. INTRODUCTION

The natural decay of radioactive substances in a series of heavy nuclei is known to result in the radioactive isotopes of lead. There are four natural radioactive series to be found in nature (Th-232, Np-237, U-238 and U-235).

The three that naturally occur in a radioactive decay chain existing in nature can be summarized as:

$$^{232}_{92}U \xrightarrow{\alpha,\beta} {}^{222}_{86}Rn \xrightarrow{\alpha,\beta} {}^{206}_{82}Pb(stable)$$

$$^{232}_{90}Th \xrightarrow{\alpha,\beta} {}^{220}_{86}Rn \xrightarrow{\alpha,\beta} {}^{208}_{82}Pb(stable)$$

$$^{235}_{92}U \xrightarrow{\alpha,\beta} {}^{219}_{86}Rn \xrightarrow{\alpha,\beta} {}^{207}_{82}Pb(stable)$$

Rn-222, as part of the U-238 group, is the longest-lived isotope of Radon, with a half-life of approximately (3.825 days). Rn-222 can, therefore, represent a significant concentration in the atmosphere, a feature which invests an important role to Rn-222 for measuring radiation concentrations in nature. It must be stressed that Radon is one of the most dangerous radioactive elements in the environment in terms of radiation exposure: for instance, should Radon be inhaled into our lungs as we breathe in, it increases the risk of damage to the lung tissue; and is nowadays

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considered to be the second cause of lung cancer after cigarette smoking [1, 2, 3]. For this reason, Radon measurements play a critical role in monitoring human health and safety both in the home and workplace. Consequently, Radon is currently being widely measured throughout the world in natural environments as it can be a contributor to harmful health diseases [4].

Under normal temperature and atmospheric pressure, Radon is a colourless, invisible, tasteless and odourless gas that mixes with air in nature. Its atomic number is 86, its atomic weight is 222 g/mol and it has a neutron number of 136 in the nucleus. Radon gas results from the decay of the natural radioactive elements Uranium and Thorium. Uranium and Thorium-forming rock, present in the earth's crust, are found widely in soil, thus rendering it radioactive. Furthermore, Radon concentrations in soil are subject to many physical parameters such as soil structure, type of mineral, etc.

Radon gas measurements can be obtained by using active and passive measurement methods. The measurement of Radon using active-measurement techniques is performed in real time. In this technique, the concentration of Radon gas may be identified from an air sample to be determined by radiation counter; however, this not thought of as being preferable because Radon is greatly affected by external factors (humidity, pressure, air temperature, and so on). Consequently, the passive method is preferred for determining the average value of Radon concentration. By taking long-term measurements (daily, monthly, seasonal or annual), we can quantify the mean values of Radon concentrations over lengthy periods of time.

Radon is measured all over the world and limit for the Radon concentration for different countries are reported: USA-150 Bq/m^3, Germany-250 Bq/m^3, Australia-200 Bq/m^3, China-200 Bq/m^3, Denmark-400 Bq/m^3, France-400 Bq/m^3, India-150 Bq/m^3, UK-200 Bq/m^3, Ireland-200 Bq/m^3, Sweden-200 Bq/m^3, Canada-800 Bq/m^3, Luxemburg-250 Bq/m^3, Norway-200 Bq/m^3, Russia-200 Bq/m^3, Turkey-400 Bq/m^3, EU-400 Bq/m^3, ICRP-400 Bq/m^3 and WHO-100 Bq/m^3 [5].

Indoor Radon concentrations were also measured in different cities from Turkey. For example Radon concentration was measured in Sakarya as 40±5 Bq/m3 [6], in Adana as 37 Bq/m3 [7], in Ardahan as 53-736 Bq/m3, in Artvin as 21-321 Bq/m3 [8], in İzmir as 210 Bq/m3 [9], in Kilis, Osmaniye, Antakya as 5-171, 6-209, 4-135 Bq/m3 respectively [10], and in Sivas as 56 Bq/m3 [5]. The aritmetic mean of the indoor Radon concentrations are reported as 81 Bq/m^3 for Turkey of 81 provinces in Turkey [11] and the worldwide indoor Radon concentration was measured as 46 Bq/m^3 [12].

The present study aimed to determine indoor Radon concentrations using CR-39 (a polycarbonate structure 500 micron thick) in diffusion chamber nuclear track detectors for selected areas where people are working or visiting, such as the Nigde Museum and certain selected historical places in Nigde, the Sungur Bey mosque (the mosque was constructed in 1335), the Alaeddin mosque (completed in 1223), the Disari (Celebi Husamettin) mosque (despite having no precise indication in the building, but it is supposed to have been built in the XVI century), and the Ak Medrese Culture House (finished in 1409). Nigde is a large town in the southern part of the Central Anatolian region of Turkey and is also part of Cappadocia, resulting in its attracting tourists to its historical sites. As well as these historical places, the Nigde Museum was chosen particularly in order to measure Radon concentrations from historical items within the museum and also to supervise the annual effective dose from these places.

2. MATERIALS AND METHODS

CR-39 plastic nuclear track detectors are widely used for Radon measurement in a natural environment and are favoured because of their availability, low-price, sensitivity and practical usage since they do not need any signal processing or power source during the measurement of radiation concentrations [13]. They prove to be one of the most useful nuclear track detectors for measuring indoor and outdoor Radon concentrations in any research areas. They also have high detection efficiency in identifying alpha particles emitted by Radon and its daughters.

CR-39 detectors were placed in the Nigde Museum for 132 days and at the Sungur Bey mosque, the Alaeddin mosque, the Disari (Celebi Husamettin) mosque and at the Ak Medrese Culture House) for 63 days, during which time the alpha particles produced from Rn-222 would leave tracks on the detectors. These tracks or images used in the analysis of traces of alpha on detectors under the Linux operating system employee carries out a programme called the Radosys processing set [14]. The detectors counting traces of unwanted marks on the purified by a chemical etching process and within this process any real trace of alpha becomes observable. The counting process of alpha tracks was done through a film scanner and an image-processing program. All images were monitored and counted by the Radosys programme. The analysis of the tracks and the estimation of track density are automatically effected with the Radosys equipment. All Radon concentration measurements for CR-39 detectors which were bought from TAEK (Turkish Atomic Energy Agency) collected and sent to SANAEM at TAEK for analysis.

In this study, a total of 15 pieces of CR-39 detectors were placed at different places in Nigde: in the Nigde Museum (3) for 132 days, and in other selected historical places in Nigde, for 63 days: in the Sungur Bey mosque (3), in the Alaeddin mosque (3), in the Disari (Celebi Husamettin) mosque (3), and in the Ak Medrese Culture House (3 pieces of CR-39). Photographs of one-piece of the CR-39 detector placed in the Sungur Bey Mosque (a), the Alaeddin mosque (b), the Disari (Celebi Husamettin) mosque (c) and in the Ak Medrese Culture House (d) are shown in Figure 1.

Figure 1. Photograph of located one-piece of a CR-39 detector cup in the Sungur Bey mosque (a), the Alaeddin mosque (b), the Disari (Celebi Husamettin) mosque (c) and in the Ak Medrese Culture House (d) here in Nigde.

3. RESULTS

In this study, we present the results of indoor Radon concentration in spring-summer season employing CR-39 detectors at the Nigde Museum as well as in the Sungur Bey, Alaeddin and Disari (Celebi Husamettin) mosques and in the Ak Medrese Culture House in Nigde; these can be seen in Table 1 shows the Radon concentration and annual effective dose for each of these areas. Figure 2 shows average radon concentration of each location with standart deviation. The average Radon concentration measured in the Nigde Museum and at the Sungur Bey, the Alaeddin, the Disari (Celebi Husamettin) mosques and at the Ak Medrese Culture House in Nigde, were found to be 13.0±2.94 Bq/m^3, 31.67±3.86 Bq/m^3, 52.0±5.72 Bq/m^3, 42.67±19.34 Bq/m^3 and 31.0±4.55 Bq/m^3 respectively.

The aritmetic mean of indoor Radon concentrations values in these places ranged from 13.0±2.94 Bq/m^3 to 52.0±5.72 Bq/m^3, which is lower than the aritmetic mean of indoor Radon concentrations for Turkey (81 Bq/m^3) [11] and obatined to be arround for the world value as (46 Bq/m^3) [12].

The annual average effective dose for indoor Radon is calculated using parameters introduced in the report by UNSCEAR [15]. From the measured Radon concentration, the annual effective dose of Radon was calculated with $E=C_{Rn}\times F\times t\times d$, equation.

E: Effective dose
C_{Rn}: The indoor Radon concentration (Bqm^{-3})
F: The equilibrium factor between Radon and its decay product equal to 0.4
t: The average indoor occupancy time for a person (y^{-1})
d: The dose conversion factor for Radon exposure is 9 nSv (Bqhm^{-3})$^{-1}$

The Sungur Bey, the Alaeddin and the Disari (Celebi Husamettin) mosques are used daily by people at prayer times with an average occupancy-time for prayer being defined as 1.5 hours per day; this totals 548 hours per year. For the Ak Medrese Culture House and the Nigde Museum, daily activities have been found to total 8 hours, meaning that working or visiting time per year comes to 2920 hours. The average effective dose of Radon was calculated at the Nigde Museum, the Sungur Bey, the Alaeddin, the Disari (Celebi Husamettin) mosques and the Ak Medrese Culture House together with historical places in Nigde and found to be approximately 0.137 mSv/y, 0.062 mSv/y, 0.103 mSv/y, 0.084 mSv/y and 0.327 mSv/y respectively.

Table 1. The measured indoor Radon concentration and effective dose collected from the Nigde Museum and other historical places in Nigde.

Number of detectors and areas	Date of buildings	Height from floor	Radon concentration (Bq/m^3)	Annual effective dose (mSv/y)
1. Nigde Museum	1997	1.25 meter	10	0.105
2. Nigde Museum		1.20 meter	12	0.126
3. Nigde Museum		1.15 meter	17	0.179
1. Sungur Bey mosque	1335	2.80 meter	30	0.059
2. Sungur Bey mosque		3.70 meter	28	0.055
3. Sungur Bey mosque		4.0 meter	37	0.073
1. Alaeddin mosque	1223	1.80 meter	49	0.097
2. Alaeddin mosque		1.50 meter	47	0.093
3. Alaeddin mosque		1.70 meter	60	0.118
1. Disari mosque	XVI century	1.30 meter	70	0.138
2. Disari mosque		10 cm	30	0.059
3. Disari mosque		2.0 meter	28	0.055
1. Ak Medrese Culture House	1409	2.0 meter	30	0.315
2. Ak Medrese Culture House		2.0 meter	37	0.389
3. Ak Medrese Culture House		3.10 meter	26	0.273

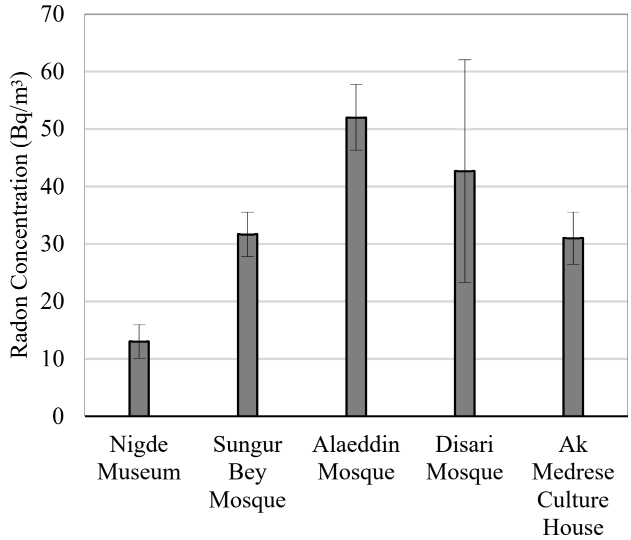

Figure 2. Average Radon concentration of each location.

4. CONCLUSION

The measurement of average Radon concentrations and its annual effective dose using CR-39 detectors at the Nigde Museum, the Sungur Bey mosque, the Alaeddin mosque, the Disari (Celebi Husamettin) mosque and at the Ak Medrese Culture House in Nigde, were shown to be lower than the limits recommended not only by the ICRP for indoor Radon concentrations, which is about 300 Bq/m^3 (the annual mean concentration) and limit values for annual effective dose is about 10 mSv/y [16] but also by TAEK. For Turkey, the upper value for Radon concentration within dwellings is known to be 400 Bq/m^3 and annual effective dose of 5 mSv [17].

In natural surroundings, there are many parameters involving the effect Radon levels for indoor dwellings such as temperature climate, heat conversion and ventilation equipment, etc.

The present measured Radon concentration and the annual effective dose both showed that no action needs to be taken at these places and measurements indicated that values are reasonably lower than the levels recommended by both ICRP and TAEK.

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