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Measurement of Indoor Radon Concentration Levels and Effective Dose Assessment in the Zanjan City, Iran

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Abstract With growing understanding of the role of radon and its daughter products as the major sources of radiation exposure, the importance of estimating radon concentration in various parts of the country has been realized. Indoor radon radioactivity in 200 houses in Zanjan city was measured using Durridge Rad 7. It is a portable, easy to use, and very sensitive device. Ten per cent of the houses had radon concentrations of above 100 Bq/m3, which is taken by WHO as the action level. The remained 90% had the concentration of less than this level. The average annual effective dose of the indoor radon was calculated, using the equation, which is introduced by the United Nations Scientific Committee on the Effects of Atomic Radiation.

Keywords: *indoor radon, environmental radioactivity, radon, dose calculation*

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1. Introduction

Radon is constantly generated all over the earth as the result of the decay of radium, which is available in crystal materials. The foremost motivation for initiating and carrying out the studies about radon has been to weigh up the potential risk to human population from indoor ^{222}Rn. It has been estimated that out of 98% of the average radiation dose received by human from natural sources, about 52% is due to breathing radon, thoron and progeny present in the dwellings [1,2]. Radon is a colorless, odorless, and tasteless noble gas. It has three isotopes with natural origin as ^{222}Rn, ^{220}Rn and ^{219}Rn, which have half-lives of 3.82 days, 55.6 s, and 3.96 s, respectively [3]. Atmospheric radioactivity at sea level generally occurs as a result of ^{220}Rn, ^{222}Rn and their decays. The main source of radon in air is the decay products of uranium in soil and rocks [3]. Radon enters the building construction through the leakages in the basement slab and causes the increased indoor radon concentrations inside the dwellings. This process leads to the increased concentrations of radon daughter products, and intensifies the risk of lung cancer [4]. Radon and its daughters are present in the atmosphere, especially in the places where the ventilation is the lowest like in the mines. Quantification of radon and their progeny, especially inside the dwellings, is essential when determining the background radiation level to the population [5,6]. The ventilation pattern, types of building materials, topography and meteorological parameters play very critical roles in the resultant concentration of radon in the dwellings. Also reported that ventilation and atmospheric pressure have definite influence on the levels of radon concentration [7]. Radon higher levels have been observed in igneous rocks, such as granite and lower radon levels in sedimentary rocks with some exceptions in shale and phosphate rocks [8]. Regarding the action level for radon, WHO has expressed that homeowners take actions when radon level exceeds 100 Bq/m^3. This is much more than the conservative figure declared by the Environmental Protection Agency (EPA), in which the action level is 148 Bq/m^3 [9]. This has been the USA standard for many years [10,11]. In this study, indoor radon concentration has been measured in 200 houses in Zanjan city. Zanjan is located in the northwest of Iran and one of the largest cities is after Tehran, the capital of Iran, with the fixed population of nearly 470 thousand. The city is located at 1663 meters above sea level with the geographical coordinates of 36° 66´ N, 48° 48´ E. From a geological point of view, in the north of Zanjan, the most important locations are Gerel ja, Zaker, Ghajar, Taleghan, Sialan and Alamo mountains and in the south, they are Ghaflankouh, Dagh, Mola dagh, Damirlo and Soltaniyeh mountains. The majority of the northern mountains are made of granite and in the south; they are mainly made of shale, basalt, and lime stones.The main purpose of this article, measurement of radon concentration in Zanjan city, and determine whether the people this city are exposed to dangerous or not.

2. Materials and Methods

DURRIDGE RAD7 was employed to measure indoor radon concentration. It is a portable, easy to use and very sensitive device. RAD7 is an electronic radon detector with real-time monitoring and spectral analysis. Which based on a solid-state detector and principle of operation is the electrostatic collection of alpha-emitters with spectral analysis, Passivated Ion-implanted Planar Silicon detector. This device by DURRIDGE Company, Incin Boston Road Billerica, MA, USA manufactured. RAD7 has a pump to send the air over the detection system in order to be able to operate with a constant flow rate of 1 l/min. The nominal sensitivity of this system in continuous mode is 0.5 counts/min/pCi/L. The measurements carried out in different areas in the Zanjan city, with the emphasis to cover almost the entire zones. Figure 1 shows the Zanjan location in Iran as well as the sampling sites. Radon concentration measurements were accomplished in 200 houses during spring of 2012. The houses with age of less than 25 years were selected, which were built from local materials. The measurements were performed based on EPA protocol. Therefore, 24 hours prior to the measurements, the windows and doors of the measurement places were closed, air conditioners were turned off, and the measurement points were set one meter above the ground and away from the walls in the center of the room. All the measurements were done in the rooms on the ground floor. Measurements have been done four times per house, around 7:00 a.m. to 10:00 a.m.

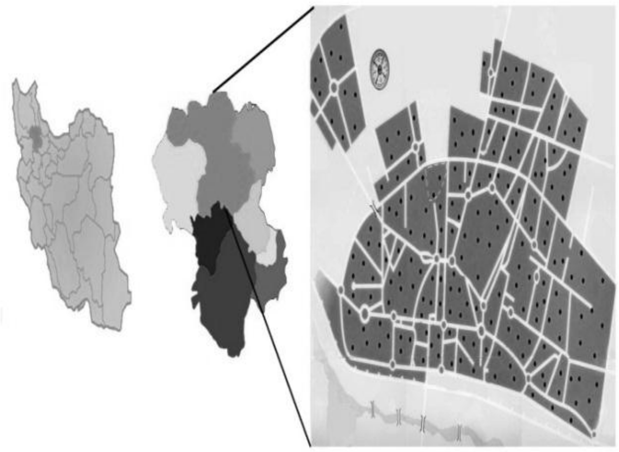

Figure 1. The map of Iran (the left hand side picture) and the Zanjan state (the middle picture). The orange area is the city of Zanjan and the bold points (dots) show the sampling sites

3. Results and Discussion

The average of four readings was considered as the mean value of radon concentration in each house. The distribution of indoor radon levels among 200 houses in Zanjan is revealed in Figure 3. Radon concentrations in 111 of the houses were lower than 60 Bq/m^3, in 77 were between 61 and 120 Bq/m^3, and in 12 of them were between 120 and 160 Bq/m^3. As illustrated in Figure 2, approximately 180 of the houses have radon level lower than 100 Bq/m^3, which is taken as the action level by WHO (2009) and only in 20 samples of indoor radon concentration were more than 100 Bq/m^3. According to the obtained data, the minimum and maximum radon concentrations in houses were 8.8 and 157.4 Bq/m^3, respectively, with an arithmetic mean of 56.95 Bq/m^3. In addition, it is worthwhile to mention that the mean outdoor radon level was 7.3 Bq/m^3 in that period.

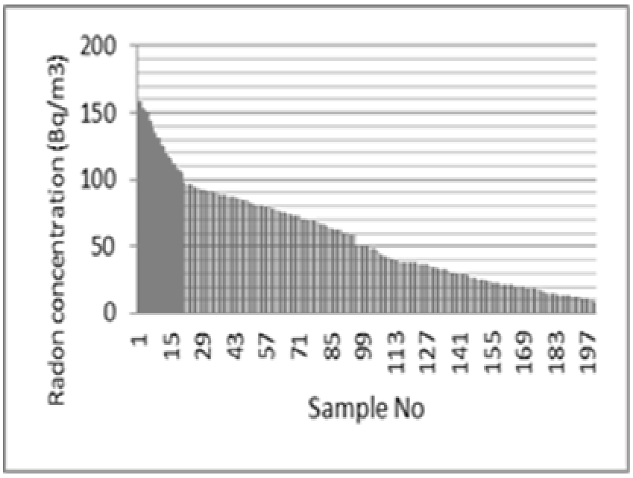

Figure 2. The histogram of annual effective dose of 200 houses

3.1. Radon Effective Dose Assessment

It is necessary to calculate the radon dose from radon concentration because radon effective dose value describes the harmful effects of radon on the human body [12]. In our calculation, UNSCEAR's radon dose conversion factor was applied as it lies between dosimetric and epidemiological dose conversions [10,13]. UNSCEAR suggests that in estimation of the effective doses, the following factors are applied [13]:

- An indoor radon decay product equilibrium factor, Ef = 0.4
- A radon effective dose coefficient factor, Cf = 9 nSv/(Bq h m−3)
- An indoor occupancy factor is of = 0.8, which is the fraction time that people spend indoors, but not essentially at their homes. It means, during a year (T = 365 × 24 h), people spend about 7,008 hours in indoor spaces like homes and offices. Hence, the equation for annual effective dose (Dy) due to radon concentration is as the below:

Dy = Ef Cf Of QRnT (1). Where QRn is the radon concentration in Bq/m3. By using this equation, annual radon effective dose has been calculated. It should be noted that houses were classified into three groups: 1) with radon concentration from the outdoor measured level to half of the WHO action level; 2) from half of the action level to the action level; 3) more than the action level [11] (Table 1). Furthermore, the histogram presentation of dose ranges against the frequency is shown in Figure 3.

4. Conclusion

In this article, indoor radon concentration level in Zanjan was determined in a total of 200 houses. Average indoor radon concentrations are above the global average (40.3 Bq/m^3). The measurements results demonstrate that 90% of the houses have radon level of less than 100 Bq/m^3. This level has been advised as the action level by WHO, and 10% have higher radon concentration. Annual effective doses are higher than the global average (1.094 mSv/y) in Zanjan.

The main factors for low radon concentration in houses refer to geological characteristics and types of construction and architecture styles. These geological situation and construction characteristics make the situation unique with respect to the concentrations of indoor radon, making these houses radiologically safe. In this way, the risk of lung cancer due to indoor radon inhalation becomes less probable for the inhabitants.

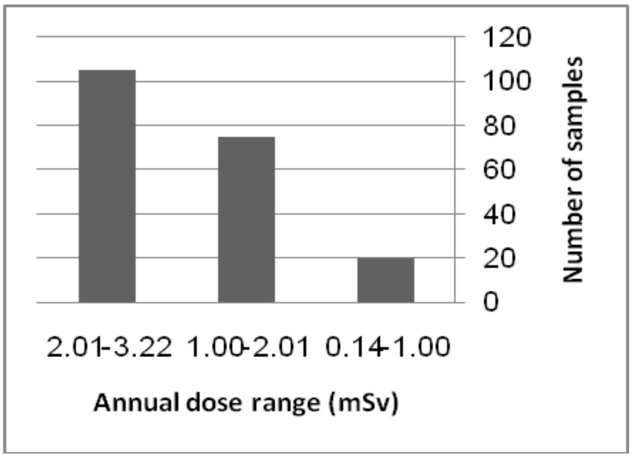

Figure 3. The histogram of indoor radon concentration

Table 1. Annual radon effective dose assessment in 200 houses in Zanjan

Indoor radon Concentration range (Bq/m3)	Number of houses	Annual effective dose range (mSv)
7-50	105	0.14-1.00
50-100	75	1.00-2.01
100-160	20	2.01-3.22

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