ORIGINAL ARTICLE

# Assessment of Background Radiation, Annual Effective Dose and Excess Lifetime Cancer Risk in Gonabad City

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## Abstract

**Purpose:** Humans are always exposed to ionizing radiation from their environment, which can have destructive effects. This study aimed to measure background gamma radiation and estimate annual effective dose and excess cancer risk in Gonabad city.

**Materials and Methods:** The dose rate due to indoor and outdoor background radiation was measured by RDS-30 radiation survey meter at five zones on the map, including North, South, East, West, and center. Then, the annual effective dose and excess lifetime cancer risk were calculated by associated equations.

**Results:** Mean dose rates for outdoor and indoor spaces were 0.111 µSv/h and 0.139 µSv/h, respectively. The mean background dose rate of indoor space was significantly higher than that of outdoor space. Annual effective dose and excess lifetime cancer risk were obtained as 0.817 and $2.85\times10^{-3}$, respectively.

**Conclusion:** Background radiation dose, annual effective dose, and cancer risk for Gonabad city were higher than global ones. Further investigations are needed to encompass internal background radiation doses in annual effective dose.

**Keywords:** Annual Effective Dose; Background Gamma Radiation; Excess Lifetime Cancer Risk; Gonabad.


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## 1. Introduction

Humans are always exposed to ionizing radiation in their environment. In general, ionizing radiation sources are divided into two categories: natural resources and man-made resources [1-4]. The natural rays that living organisms always are naturally exposed to are called background rays [5-8]. The amount of absorbed dose due to natural radioactivity in humans is very important and plays a key role in determining the equivalent dose received by the world's population.

Natural background radiation includes cosmic rays and ground-based radioactive materials in building materials, water, air, etc. [9]. Human exposure to all of these sources can be external or internal. Internal irradiation is by swallowing or inhaling natural radioactive substances in the environment or any other method that leads to the entry of these substances into the body. Radiation from terrestrial radioactive materials is highly dependent on the location as well as radioactive materials in soil, water, building materials used in various houses and buildings, and decorative materials used in the building [10]. The average global effective dose due to gamma rays in the soil is 0.5 mSv. Meanwhile, the average radiation dose from all artificial sources, including nuclear explosions, nuclear accidents, normal operation of nuclear power plants, as well as diagnostic and therapeutic medical radiation is about 0.8 milliSievert per year [11, 12].

Radiation absorbed by the body can lead to stochastic or deterministic effects. The deterministic effect has a practical threshold dose and the intensity of the effect increases with increasing dose. While the stochastic effects of radiation exposure, which include hereditary and carcinogenic effects, do not have a threshold dose. In other words, there is no safe dose in this field and the mentioned effects can be created in each received dose and with increasing the received dose, the probability of their occurrence increases [13].

Due to mentioned effects of ionizing radiation, the importance of studies that determine the amount of background radiation in different geographical areas becomes more apparent. Therefore, extensive studies in this regard have been conducted in different parts of the world, the results of some of which show high background radiation in some areas, including certain parts of India and Brazil, as well as the city of Ramsar in Iran [14]. This study aims to measure background gamma radiation and estimate annual effective dose and excess cancer risk in Gonabad city.

## 2. Materials and Methods

This study was performed in the winter of 2020 in both indoor and outdoor spaces in Gonabad city (34.3396° N, 58.7030° E) located in the Khorasan Razavi province (Figure 1). Radiation dose measurements were done with a Geiger-Muller-based radiation survey meter with the trademark of RDS-30 (Mirion, Finland). This survey meter detects ionizing photons ranging from 48 KeV to 1.3 MeV. For this instrument, the measurement range of the dose rate is 0.01 µSv/h to 100 mSv/h.

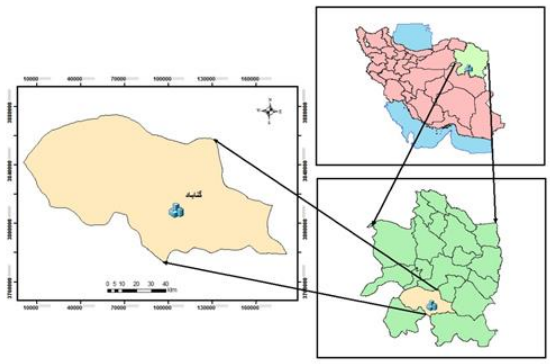

**Figure 1.** Geographical location of Gonabad city on the map of Iran

In this study, the dose rate due to indoor and outdoor natural background radiation was measured at five zones on the map, including North, South, East, West, and center. For outdoor background radiation measurements, in each zone, 40 points were selected randomly, and fifteen readings (once every two minutes) were performed at each point at a height of one meter. For indoor, 35 residential homes in each zone were entered randomly into the study, and fifteen readings (once every two minutes) were performed at each point at a height of one meter.

After measuring background gamma radiation as dose rate, the annual effective dose can be calculated by following Equations 1-3 [15]:

$$E_{in} = D_{in} \times OF_{in} \times T \times f \quad (1)$$

$$E_{out} = D_{out} \times OF_{out} \times T \times f \quad (2)$$

$$E = E_{out} + E_{in} \quad (3)$$

Where E, $E_{in}$, and $E_{out}$ are annual effective dose, indoor and outdoor effective doses, respectively. $D_{in}$ and $D_{out}$ are indoor and outdoor dose rates, respectively. In order to convert time from year to hour (8760 h), the T factor was used. $OF_{out}$ and $OF_{in}$ are occupancy factors to which the values of 0.2 and 0.8 are assigned, respectively [16, 17]. The f coefficient is 0.7 for the adults, which transforms the absorbed dose in the air to the effective dose [18].

Excess Lifetime Cancer Risk (ELCR) related to background gamma radiation can be calculated by the following Equation [17]:

$$ELCR = E \times LD \times RF \qquad (4)$$

Where LD is life duration (70 years) and RF is the risk factor for stochastic effects and the value of 0.05 $Sv^{-1}$ was assign to it [19].Measured dose rates in each zone are expressed as mean and standard deviation. One-way ANOVA test was utilized for comparison of background radiation among zones and student's t-test for comparing indoor and outdoor dose rates. $P<0.05$ was considered statistically significant.

## 3. Results

Table 1 shows dose rates measured by RDS-30 for different zones of indoor and outdoor spaces. For indoor space, measured dose rates with unit of µSv/h were as follows: Center (0.125 ± 0.046), North (0.133 ± 0.004), South (0.15 ± 0.021), East (0.145 ± 0.022), and West (0.144 ± 0.011). Statistical analysis showed no significant difference between background radiation in different zones of indoor space ($P>0.05$). Background dose rates for outdoor space are: Center (0.090 ± 0.0137), North (0.112 ± 0.008), South (0.120 ± 0.026), East (0.104 ± 0.02), and West (0.132 ± 0.013). In indoor space, the west zone had a statistically significant and higher background dose than of some other zones ($P<0.05$).

Mean background dose rates and effective dose for indoor and outdoor spaces, and annual effective dose are listed in Table 2. The mean dose rates for outdoor and indoor spaces were 0.111 µSv/h and 0.139 µSv/h, respectively. The mean background dose rate of indoor space was significantly higher than that of outdoor space ($P<0.05$). Using Equations 1, 2 and 3, the outdoor and indoor effective dose and annual effective dose were obtained as 0.136, 0.681, and 0.817, respectively. According to the annual effective dose and Equation 4, a value of $2.85\times10^{-3}$ was obtained for ELCR.

## 4. Discussion

Stochastic effects of ionizing radiations due to background gamma radiation is one of the important health hazards. In this study, we measured background dose with RDS-30 radiation survey meter in five zones of outdoor and indoor spaces of Gonabad city. The number of measurement points was enough in such that to satisfy good coverage of all regions of the city.

The results of present study showed that mean indoor and outdoor background radiation dose rate and annual effective dose were 0.139 µSv/h, 0.111 µSv/h, and 0.817 mSv/y, respectively. The mean indoor and outdoor background radiation dose rates and annual effective dose of Gonabad city (0.139 µSv/h, 0.111 µSv/h and 0.817 mSv/y) are lower than some other cities in Iran, such as Kashan (0.186, 0.155.4 µSv/h and 1.1 mSv/y), Ardabil (0.277, 0.284 µSv/h and 1.73 mSv/y), Urmia (0.154, 0.114 µSv/h and 0.89 mSv/y), Tabriz (0.147, 0.114 µSv/h and 0.86 mSv/y) [16, 20-22] and higher than some other cities such as Birjand (0.082, 0.071 µSv/h and 0.49 mSv/y), and Khorramabad (0.117, 0.09 µSv/h and 0.69 mSv/y) [17, 23].

**Table 1.** Measured dose rates by RDS-30 for different zones of indoor and outdoor spaces

| Zone | Indoor dose rate (µSv/h) | Min-Max | Outdoor dose rate (µSv/h) | Min-Max |
|---|---|---|---|---|
| **Center** | 0.125 ± 0.046 | 0.091 - 0.200 | 0.090 ± 0.014 | 0.080 - 0.132 |
| **North** | 0.133 ± 0.004 | 0.122 - 0.183 | 0.112 ± 0.008 | 0.101 - 0.130 |
| **South** | 0.150 ± 0.021 | 0.142 - 0.177 | 0.120 ± 0.026 | 0.111 - 0.132 |
| **East** | 0.145 ± 0.022 | 0.139 - 0.181 | 0.104 ± 0.020 | 0.090 - 0.142 |
| **West** | 0.144 ± 0.011 | 0.141 - 0.190 | 0.132 ± 0.013 | 0.122 - 0.151 |

**Table 2.** Mean dose rate and effective dose for indoor and outdoor spaces, and calculated annual effective dose

| Dose rate/effective dose | Mean |
|---|---|
| **Outdoor dose rate (µSv/h)** | 0.111 |
| **Indoor dose rate (µSv/h)** | 0.139 |
| **Outdoor effective dose (mSv/y)** | 0.136 |
| **Indoor effective dose (mSv/y)** | 0.681 |
| **Annual effective dose (mSv/y)** | 0.817 |

Global average dose rate for outdoor space (0.059 µSv/h) (range 0.018-0.093 µSv/h), for indoor space (0.084 µSv/h) (range 0.02-2 µSv/h), global annual effective dose (0.48) mSv/y and global ELCR ($1.45\times10^{-3}$) were reported [24]. Mean indoor and outdoor background radiation dose rates (0.139, 0.111 µSv/h) in Gonabad city were nearly 1.65 and 1.88 times of average global ones, respectively. Furthermore, the annual effective dose and ELCR (0.817 mSv/y, $2.85\times10^{-3}$) in Gonabad city were nearly 1.7 and 1.77 times of global ones, respectively. Further studies are needed to evaluate the relationship between this excess risk and cancer incidence in this city.

The value of dose rate in the outdoor space depends on factors such as altitude, latitude, and soil and rock type of the geographical area, among which the soil and rock type of the area is more important. Therefore, in Gonabad city, the high mean background dose rate in the outdoor space can be justified according to the above factors. Also, the higher mean background dose rate of indoor space compared to outdoor space in all measuring points, despite the attenuation of cosmic radiation by the materials used in the walls and roof of buildings, indicates the performance of each wall, roof, and floor as the sources of radioactivity due to the presence of radioactive nuclei which are naturally present in soil and rock.

One limitation of this study is that the results are limited to external background doses (Cosmic and earthy gamma radiations) and not consisted of internal ones (inhalation and ingestion), which needs future investigations.

## 5. Conclusion

Mean indoor and outdoor background radiation dose rate and annual effective dose for Gonabad city were 0.139 µSv/h, 0.111 µSv/h, and 0.817 mSv/y, respectively, which are higher than global ones. Excess lifetime cancer risk ($2.85\times10^{-3}$) in Gonabad city was nearly 1.77 times of global one. Further investigations are needed to encompass internal background radiation doses in annual effective dose.

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