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Original Article

Health Risk Assessment of Natural Background Radiation in Residents of Khorramabad, Iran

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Abstract

Introduction
Radioactive materials naturally exist in the world**.** Indeed, approximately 82% of human-absorbed radiation doses, which are out of human control, arise from natural sources of radiation including cosmic, terrestrial, and exposure through inhalation or ingestion. Thus, the aim of the present study was to estimate health risk, as well as the effective and organ doses from naturally occurring background radiation in residents living in the vicinity of Khorramabad, Iran.
Materials and Methods
This cross-sectional study was carried out in Khorramabad, Iran. The measurements were performed using Geiger-Muller detector (RDS-110) during daylight from April to June, 2015. The natural gamma radiation measurements were made both indoor and outdoor across five regions of Khorramabad (north, south, west, east, and center).
Results
The estimated mean absorbed dose rate in outdoor and indoor zones were 0.09±0.024 and 0.117±0.032 $mSvy^{-1}$, respectively. Additionally, the mean annual effective dose was calculated as 0.69±0.19 $mSvy^{-1}$, while the estimated health risk probability was 0.0345%.
Conclusion
The average annual effective dose arising from gamma background radiation was higher than global values. Therefore, more studies are required to examine the relationship between radiation-induced effects and the natural background radiation level in Khorramabad.

Keywords: Effective Dose, Health Risk Assessment, Gamma, Radiation Measurement

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1. Introduction

Humans are frequently exposed to spontaneous emission of ionizing radiations including uranium, thorium, and potassium isotopes (238U, 232Th, and 40K). Radiations such as alpha, beta, and gamma are emitted from different radioactive materials, which differ in their attenuation and absorption coefficients. Prior to the emergence of artificial products such as medical and technological radioactive materials, fallout from nuclear weapons tests, radioactive releases from nuclear reactor operations, humans were merely exposed to radiations through natural radiation sources. Presently, natural sources are making a great contribution to the average annual background radiation [1]. Natural radioactivity is common in the rocks and soil constituting earth, water, and building materials. Thus, no place on earth is free from radioactive materials [2].

Environmental radioactivity measurements are required in order to assess the natural background radiation level coming from the terrestrial and cosmic radiations. The terrestrial component of background is due to the various radioactive nuclides that are present in air, soil, rock, water, and building materials whose abundance vary depending on the geological features of a region. The cosmic radiations originate from interstellar space, while their contribution to background vary mainly with elevation and latitude [3]. To assess the population-effective dose, several national [4-19] and international studies have attempted to estimate the terrestrial gamma dose rate [-20-29]. As a result, the present study aimed to estimate health risk along with the effective and organ doses arising from naturally emerging background radiations in residents living in the vicinity of Khorramabad, Iran.

2. Materials and Methods

This cross-sectional study was carried out during Spring 2015 in Khorramabad, Iran. Based on the topographic map of the area (Figure 1), Khorramabad (latitude: 33° 29´ N, longitude: 48°21´ E) with the population of more than 350.000 is located in Central Zagros Mountains (CZM) at the altitude of 1150 m above sea level.

The measurements were performed using Geiger-Muller detector (RADOS Technology Oy, P.O. Box 506, and FIN-20101 Turk) during daylight from April to June 2015. The detector is able to measure dose rates of radiation from 0.05 $\mu Sv/h^{-1}$ to 99.9 mSv/h^{-1}, where the calibration procedure is performed by Iran Secondary Standard Dosimetry Laboratory (ISSDL). The natural gamma radiation measurements were made both indoor and outdoor in five regions of the city (north, south, west, east, and center). In so doing, 10 buildings with similar masonry materials were randomly selected from each region. The outdoor radiation measurements were conducted by placing the detector at least 6 m away from any building or wall nearby and 1 m higher than the ground with the aim of reducing its effects on the measurement process. In the same vein, the indoor radiation measurements were performed by placing the detector 1 m higher than the ground in the buildings. Subsequently, the values of the outdoor and indoor absorbed dose rates were calculated. Since radio nuclides decay and cosmic radiation fluency vary slightly in time, the total exposure time of 1 h was taken into account in each measurement. Moreover, 100-120 measurements (indoor and outdoor) were performed in each building. The annual effective dose was also calculated as follows:

1) Indoors: $D_{in} \times T \times OF \times$ Conversion Coefficient /1000

2) Outdoors: $D_{out} \times T \times OF \times$ Conversion Coefficient /1000

Where D_{in} and D_{out} are the average indoor and outdoor absorbed dose rates in air, T is the time converter from hour to year (8760 h), and OF is the occupancy factor. According to the equation, the fraction of time people spends indoors and outdoors is 0.8 and 0.2, respectively. The conversion coefficient of 0.7 $SvGy^{-1}$ is defined by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [3] to convert the absorbed dose value in air to the effective dose received by adults. The organs and effective doses were calculated using the new tissue weighting factors [30]. Besides, the International Commission on Radiological Protection (ICRP) asserted that the risk of fatal carcinogenesis linked to the exposure to total body irradiation is 5% Sv^{-1} [30]. Therefore, the number of health risks can be calculated by the following equation:

Health risk probability = 0.05 collective effective dose

2.1. Statistical analysis

Mean and standard deviation of all the recorded data for each region was computed. Statistical analysis was carried out using SPSS, version 21.

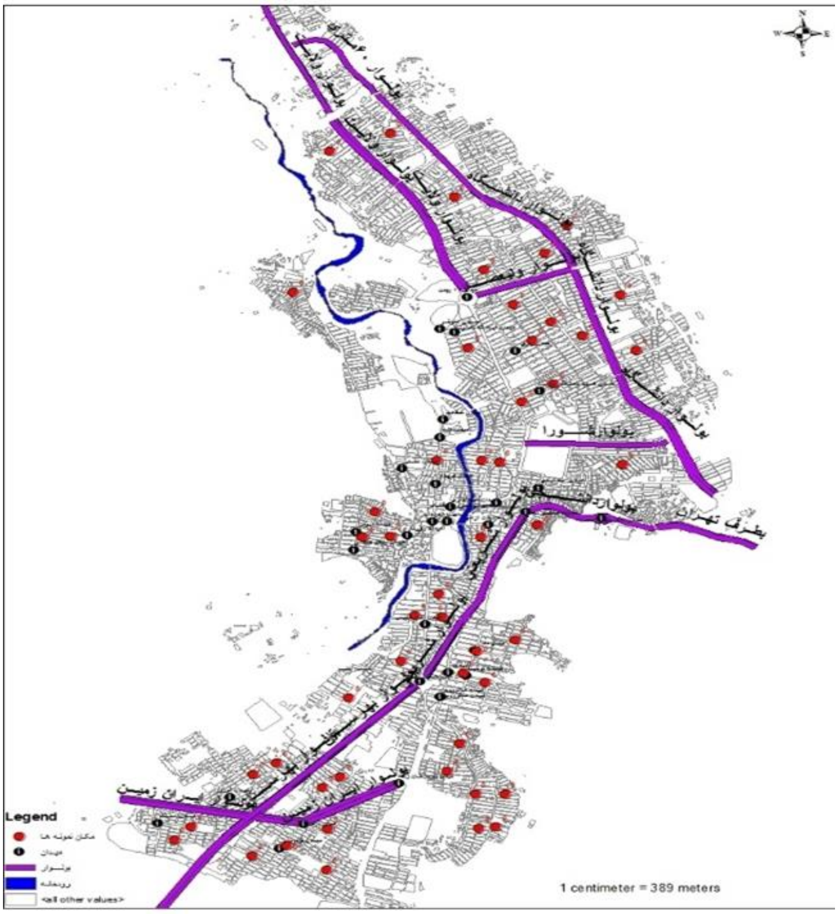

Figure 1. Khorramabad map of the selected regions (red dots)

3. Results

Table 1 represents the dose rate of gamma radiation absorbed in air (indoor and outdoor) across five regions of Khorramabad. Each value is the mean in those areas. As shown, the highest and lowest outdoor absorbed dose rates were in the south and west, while the highest and lowest indoor values were in the south and west regions, respectively.

Table 2 demonstrates the outdoor and indoor mean absorbed dose rates, according to which the mean absorbed dose rate in outdoor and indoor regions were 0.09±0.024 $mSvy^{-1}$ and 0.117±0.032 $mSvy^{-1}$, respectively. Furthermore, outdoor and indoor effective dose rates, annual effective dose, and indoor/outdoor ratios are tabulated, as well.

Depending on tissue weighting factors, the effective and total effective doses for the critical organs involved are shown in table 3.

Table 1.The outdoor and indoor absorbed dose rate in selected regions

Region	Mean±SD(μSvh^{-1})		Min		Max		Median		1st quartile		3th quartile	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
South	0.132±0.04	0.095± 0.031	0.06	0.04	0.28	0.32	0.12	0.09	0.10	0.07	0.15	0.11
North	0.122±0.26	0.088±0.20	0.05	0.04	0.19	0.16	0.12	0.09	0.10	0.07	0.14	0.1
Center	0.120±0.032	0.094±0.024	0.05	0.05	0.2	0.15	0.11	0.09	0.08	0.08	0.13	0.11
West	0.104±0.024	0.084±0.018	0.06	0.01	0.2	0.15	0.1	0.08	0.09	0.07	0.12	0.09
East	0.115±0.027	0.091±0.023	0.05	0.05	0.22	0.18	0.11	0.09	0.1	0.07	0.13	0.1

Table 2. The mean absorbed dose rates, effective doses and annual effective dose in selected regions

Region/dose	Mean±SD	Min	Max	Median	1st quartile	3th quartile	Indoor/Out door ratio
absorbed dose rate(Outdoor)	0.09± 0.024	0.01	0.32	0.09	0.07	0.10	
absorbed dose rate (Indoor)	0.117±0.032	0.05	0.28	0.11	0.09	0.13	1.3
Outdoor effective dose (mSvy^{-1})	0.11±0.03	0.02	04	0.11	0.09	0.13	
Indoor effective dose (mSvy^{-1})	0.58±0.16	0.25	1.38	0.54	0.45	0.64	
annual effective dose (mSvy^{-1})	0.69±0.19	0.27	1.78	0.65	0.54	0.77	

Table 3. Effective and total effective dose in some critical organs

Tissue or organ	Tissue weighting factor, ω_T	Effective dose (mSvy^{-1})	Total (equivalent) Effective dose (mSvy^{-1})
Bone- Marrow (red), colon, lung, stomach, breast, reminder tissues[a]	0.12	0.117	0.703
Gonads	0.08	0.078	0.078
Bladder, esophagus, liver, thyroid	0.04	0.039	0.156
Bone surface, brain, salivary glands, skin	0.01	0.0097	0.0391

[a]Remainder tissues: Adrenals, extrathoracic (ET) region, gall bladder, heart, kidney, lymphatic nodes, muscle, oral mucosa, prostate, small intestine, spleen, thymus, uterus/cervix

4. Discussion

In recent years, studies on background radiation measurements are gaining great importance both at global and country level [3-8, 20-29]. In this regard, although in our prior investigation [3] we made gamma radiation dose measurement across all cities of Lorestan, in the present study, we measured gamma background radiation in five zones of Khorramabad with higher precision due to the great importance of human health.

As shown in the red dots, the samples were collected approximately from all parts of the city (Figure 1). Therefore, the results and the risk assessment seem to be accurately representative.

According to Table 1, the mean and standard deviations of both indoor and outdoor absorbed dose rates of each region are shown, distinctively. In fact, among the five regions, the highest and lowest indoor absorbed dose rates were found in south and west (0.132±0.04 and 0.104±0.024 μSvh^{-1}), respectively. However, the highest and lowest outdoor absorbed dose rates were found in south and west regions (0.095±0.031 and 0.084±0.018 μSvh^{-1}), respectively. Table 2 presents the mean absorbed dose rates (outdoor and indoor), based on which the mean outdoor absorbed dose rate was 0.09±0.024 μSvh^{-1}. Indeed, the value is higher than the mean absorbed dose rate reported by UNSCEAR 2000 (with the mean of 59 $nSvh^{-1}$ and range of 18 to 93 $nSvh^{-1}$). Although the mean absorbed dose rate was lower than the values reported in some cities of Iran [5, 10], it exceeded the values reported in other cities [7, 11, 12].

The indoor mean absorbed dose rate was 0.117±0.032 μSvh^{-1}, which was higher than the mean absorbed dose rate measured by UNSCEAR 2000 (with the mean of 84 $nSvh^{-1}$ and range of 20 to 200 $nSvh^{-1}$). The highest values reported in some countries can be explained by the wide use of stone or masonry materials in buildings [20]. The outdoor and indoor effective doses were 0.11±0.03 and 0.58±0.16 $mSvy^{-1}$, respectively (Table 2). Finally, the average annual effective dose was 0.69±0.19 $mSvy^{-1}$, which was greater than the global guide levels (0.48 $mSvy^{-1}$) [3].

In its 1990 recommendations [29], the International Commission on Radiological Protection (ICRP) defined the quantity of the effective dose as the tissue-weighted sum of the equivalent doses in all the specified tissues and organs of the human, which is shown by a tissue weighting factor (w_T). Values of w_T were revised in the new recommendations depending on the obtained data on the risks of cancer induction and stochastic effects. In this respect, awareness of receiving proper background gamma radiation dose for the assessment of the deterministic and stochastic effects of low radiation doses is required. As discussed earlier, to calculate the organs-effective doses, we used the new tissue weighting factors based on ICRP recommendations [30].

Regarding the tissue weighting factors (Table 3), the highest and total effective doses or the equivalent effective dose is calculated in tissues, including bone marrow (red), colon, lungs, stomach, and breast. However, the lowest effective doses were detected in bone surface, brain, salivary glands, and skin. As mentioned above, the average annual effective dose in Khorramabad was greater than the global guide levels with the health risk probability of 0.0345%. Therefore, further epidemiological and experimental studies are needed to derive accurate correlations between health risk and quantity of natural background radiation.

5. Conclusion

The average annual effective dose arising from gamma background radiation was 0.69 $mSvy^{-1}$, which is higher than the global values. As a result, more studies are required to examine the relationship between radiation-induced effects and the amount of natural background radiation level in Khorramabad.

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