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Risk Assessment of Public Gamma Radiation in Some Provinces of Iran

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ABSTRACT

Introduction: Humans are continuously exposed to ionizing radiation. In order to evaluate health hazards, the measurements of background radiation in most countries have special importance.

Material and Methods: The measurements were carried out by an Ion Chamber Survey Meter (X5C plus), during daylight in 2016. The collected and reported data were based on two ways. Firstly, the measurements of gamma background radiation were performed directly in indoor and outdoor places of five areas, including north, south, west, center, and east, in 11 cities of South Khorasan province, Iran. Secondly, the related data of other studies were used for several provinces of Iran.

Results: According to the obtained results, the maximum and minimum of annual effective gamma dose were 0.72 and 0.34 $nSvh^{-1}$ in Asadabad and Tabas, Iran, respectively. The maximum and minimum of annual effective gamma dose were 0.84 and 0.27 $nSvh^{-1}$ in Hamedan, as well as Chaharmahal and Bakhtiari, Iran, respectively.

Conclusion: The average values of the annual effective dose and estimated excess lifetime cancer risk (ELCR) were 0.60 nSv and 2.11×10^{-3}, respectively, which were higher than the amounts of the world average. The calculated ELCRs for all Iran provinces were higher in comparison to the world average value of 0.25×10^{-3}.

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Introduction

Background radiation is the natural source of human exposure, and nowhere can be found without the presence of background radiation. This type of radiation leads to some concerns about the annual effective doses arising from indoor and outdoor background exposures for the governmental and international radiation protection communities [1]. Due to the above-mentioned concerns, it seems that the studies on background radiation have a crucial role in the field of radiation protection, and different studies were carried out around the world in this regard. The level of natural exposure usually varies around the world by a factor of about 3 [2].

Radioactive materials can be observed anywhere around the world, such as in sands, rocks, mineral waters, and body of living creatures. Therefore, in most studies, radium-226 concentrations in building materials are assessed because it is the most important radioisotope in the uranium-238 decay chain. The seventh generation of the uranium is radon emitting a gamma ray. The human beings can be exposed externally to direct gamma radiation and internally to radon that may come from natural radionuclides in building materials [3].

Due to the earth crust structure, the concentration of radioisotopes varies in deferent regions. In spite of the variations of background radiation among different regions, indoor exposure to gamma rays is often higher than outdoor exposure. Furthermore, the duration of occupancy for indoor exposure is more significant [4]. Since most people spend higher than 80% of their time inside the buildings, the determination of public exposure to building materials becomes very important [3].

Human tissues and all living organisms are affected by ionizing radiation from both manmade and natural radioactive sources. During the day and night, the body organs are influenced by cosmic rays that come from the space, solar surface, and terrestrial radionuclide. These kinds of radiation can lead to harmful effects on the body tissues, such as various types of cancer [5, 6]. Based on the experimental results, significant damage regarding chromosomal mutations and cellular death may be caused due to high and low levels of radiation doses to living organisms [6].

Atoms and molecules due to the process of ionization in the living matter, at least transiently, change or may damage the cell. The cellular damage

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may prevent the cell from surviving, reproducing, or performing its normal functions. Radiation cause long-term harm to the organs and tissues of the body from which the damage to deoxyribonucleic acid in the nucleus is the main initial event [2]. However, there is a potential for debate on the deleterious effects of very low doses of ionizing radiation; nevertheless, according to the linear no-threshold model, radiation in different doses and times of exposure can induce many responses in living organisms [6].

Background gamma radiation depends strongly on the earth crust structure, as well as geological and geographical characteristics, such as altitude and latitude, and utilized materials in the buildings of a region [7]. Therefore, the levels of background radiation may differ in various geographic locations [8]. The present study aimed to measure environmental gamma doses in South Khorasan province, Iran, and collect data from 17 provinces in Iran for the calculation of the annual effective dose and excess lifetime cancer risk (ELCR).

Materials and Methods

The measurements were carried out by an Ion Chamber Survey Meter (X5C plus GRAETZ Strahlungsmeßtechnik GmbH, Germany) during daylight in 2016. The Ion Chamber Survey Meter was calibrated by the Secondary Standard Dosimetry Library of Iran. The collected and reported data were based on two ways. Firstly, the measurements of gamma background radiation were performed in indoor and outdoor places of five areas, including north, south, west, center, and east, in 11 cities of South Khorasan province (i.e., Birjand, Khusf, Sarbisheh, Asadabad, Qaen, Ferdows, Sarayan, Nehbandan, Tabas, Hajiabad, and Boshruyeh).

In each area, two buildings and two stations were randomly selected for indoor and outdoor measurements, respectively. In order to measure gamma background radiation, the survey meter was located on the top of a holder. According to the protocols, the device was placed with 1 m height above the ground, and the readings were preferentially performed in a grassy level for half an hour to minimize the effects of the ground and buildings on outdoor measurement. For indoor measurement, the device was approximately placed in the center of the room to satisfy the criteria of the indoor environment. The background dose rate was read every minute in each station for 30 min. Secondly, the related data of other studies on the measurements of background radiation were used for several provinces of Iran.

In the next step, all dose rates were recorded, and then, the annual effective absorbed dose and average of all the data in each station were calculated in this study. The background dose rates of other provinces of Iran were reported and calculated (Figure 1) for comparison. The annual effective dose of background radiation was estimated as follows [9, 10]:

$$E = (D_{out} \times OF_{out} + D_{in} \times OF_{in}) \times T \times f \quad (1)$$

where E (nSv) is the annual effective dose; D_{out} and D_{in} (nSv/h) are the mean values of outdoor and indoor absorbed dose rates; T (hour) is the year to hour conversion factor; OF_{out} and OF_{in} are the outdoor and indoor occupancy factors (20% and 80% for the outdoor and indoor, respectively); f is the age conversion coefficient. According to The United Nations Scientific Committee on the Effect of Atomic Radiation, the age conversion coefficients are 0.7, 0.8, and 0.9 for adults, children, and infants, respectively [11].

It is necessary to measure the ELCR due to gamma radiation. Based on the annual effective dose, the ELCR was calculated as follows [9, 12, 13]:

Figure 1. Included provinces of Iran in the study [14]

$$ELCR = E \times \text{mean duration of life (DL)} \times \text{risk factor (RF)} \quad (2)$$

where E indicates the annual effective dose; DL is the expectation of life (i.e., 70 years); RF is the risk factor (Sv^{-1}) coefficient of fetal cancer risk per sievert. For this risk factor, the International Commission on Radiological Protection used the value of 0.05 for public exposure [15].

Results

The calculated average of absorbed dose rates depends on altitude, latitude, and longitude for the outdoor and indoor as shown in Table 1. The findings of this study revealed that the maximum and minimum outdoor dose rates were reported as 104.75 and 49.93 $nSvh^{-1}$ for Sarbisheh and Tabas, respectively. On the other hand, the maximum and minimum indoor dose rates were 124.64 and 57.36 $nSvh^{-1}$, for Asadabad and Tabas, respectively, Furthermore, the average values of determined outdoor and indoor dose rates were 73.63 and 87.03 $nSvh^{-1}$, respectively. The maximum and minimum of effective dose rates were measured at 0.72 and 0.34 $nSvh^{-1}$ for Asadabad, respectively.

Table 1. Outdoor and indoor gamma radiation doses, annual effective dose, and excess lifetime cancer risk in cities of South Khorasan province, Iran

Name	Altitude (m)	Latitude (degree)	Longitude (degree)	Outdoor mean dose (nSv/h)	Indoor mean dose (nSv/h)	Annual effective dose (nSv)	Standard deviation	Excess lifetime cancer risk (×10-3)
Birjand [9]	1461	32.86	59.22	71.85	82.00	0.49	0.14	1.71
Sarbisheh	2002	32.50	59.65	104.75	116.39	0.67	0.21	2.45
Asadabad	1459	31.66	60.04	86.68	124.64	0.72	0.25	2.51
Khusf	1311	32.78	58.89	69.37	88.36	0.52	0.14	1.82
Nehbandan	1189	31.54	60.03	70.58	78.39	0.47	0.12	1.65
Qaen	1455	33.72	59.17	76.04	82.51	0.49	0.13	1.74
Hajiabad	1037	33.60	59.99	68.73	83.97	0.49	0.14	1.73
Bushruyeh	881	33.86	57.42	58.86	66.75	0.40	0.11	1.40
Sarayan	1436	33.85	58.51	77.61	85.40	0.51	0.13	1.80
Ferdows	1281	34,02	58.17	75.54	91.65	0.54	0.15	1.90
Tabas	663	33.60	56.93	49.93	57.36	0.34	0.10	1.20

Table 2. Outdoor and indoor gamma radiation doses, annual effective dose, and excess lifetime cancer risk in some reported provinces of Iran

Name	Altitude (m)	Latitude (degree)	Longitude (degree)	Outdoor mean dose (nSv/h)	Indoor mean dose (nSv/h)	Annual effective dose (nSv)	Standard deviation	Excess lifetime cancer risk (×10-3)
South Khorasan	1483	32.5	59.10	73.63	87.03	0.52	0.17	1.82
Ardabil [8]	1332	38.27	48.31	284	277	0.34	0.11	1.19
Ilam [16]	1382	33.63	46.41	85.7	107	0.63	0.16	2.21
Lorestan [17]	1496	33.58	48.39	113	119	0.72	0.21	2.52
Zanjan [18]	1699	36.68	48.50	127	146	0.82	0.27	2.87
Kermanshah [19]	1341	34.32	47.07	99.96	118.6	0.70	0.22	2.45
Bushehr [8]	498	28.76	51.51	51.6	60	0.36	0.09	1.26
Hamedan [20]	1818	34.79	48.51	137	-	0.84	0.24	2.94
Gilan [5]	2	37.28	49.59	94	-	0.57	0.18	1.99
Kordestan [21]	1927	35.95	47.13	111	138	0.79	0.30	2.77
Kerman [6]	2009	29.48	57.64	90	-	0.55	0.16	1.93
Azerbaijan [6]	1909	37.90	46.26	112.9	-	0.69	0.19	2.42
Hormozgan [6]	715	27.13	55.13	49.4	-	0.3	0.12	1.05
Razavi Khorasan [6]	1146	35.10	59.10	90.5	-	0.56	0.20	1.96
Mazandaran [6]	989	36.22	52.53	91.3	-	0.56	0.17	1.96
Yazd [22]	1425	32.10	54.43	101.4	122	0.72	0.19	2.52
Chaharmahal and Bakhtiari [23]	1839	31.99	50.66	44	-	0.27	0.10	0.95

Discussion

The measurement of background radiation in most countries has special importance [5]. Therefore, background gamma dose rates (outdoor and indoor), corresponding annual effective dose, and ELCR were determined for South Khorasan province and compared with those reported for other provinces of Iran. In addition, all the measurements were reported as a whole. The results of this study showed that the annual effective dose of background gamma radiation in South Khorasan province (0.52 nSv) was slightly higher than the global level (0.48 nSv). As reported, Table 2 tabulates that the obtained results for south Khorasan are lower than the values of some provinces, such as Ilam, Lorestan, Zanjan, Kermanshah, Hamedan, Kordestan, Kerman, Azerbaijan, Razavi Khorasan, Yazd, and Mazandaran, Iran. Moreover, the results are higher than those reported for some other provinces, such as Ardabil, Bushehr, and Hormozgan, Iran.

Two determining factors of background radiation level are altitude and latitude [8]. The amount of background radiation doubles by altitude increasing for each 1,500 m [5]. The altitude of the studied cities was reported within the range of 2 to 2,009 m. According to the obtained data of the present study, figures 2 and 3 show the variation of altitude with outdoor mean dose, indoor mean dose, and annual effective dose. As illustrated in figures 2 and 3, with a good approximation, the variation of altitude was linear as a function of annual effective dose, and it was higher at a higher altitude. This might be due to higher cosmic rays and expected to be about one-third of the measured values. It is clear that people living in higher altitudes receive slightly more radiation than those living in lower altitudes.

Latitude against the mean dose rates of outdoor and indoor was also examined in this study. Figures 4 and 5 depict that the overall trend of the mean dose rates of outdoor and indoor, as well as the annual effective dose rates, are increasing with the latitude. The magnetic field of the earth is another main reason for this phenomenon which increases by latitude to the optimum value at poles. This happens due to the effect of the magnetic field of the earth on slow-moving charged particles that can divert to the poles [8].

The ELCRs for all Iran provinces, compared to the global ELCR, are shown in Figure 6. The calculated ELCRs for all Iran provinces were higher in comparison to the world average value of 0.25×10^{-3} due to terrestrial nuclear radiation [9].

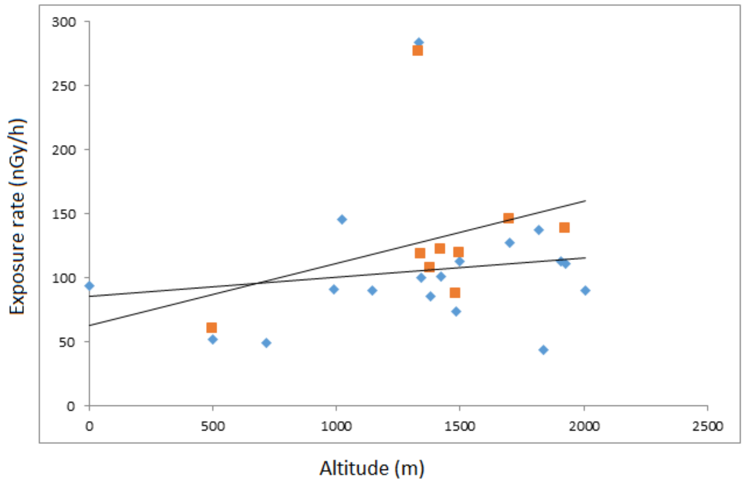

Figure 2. Relation between altitude and exposure of gamma dose rate for provinces of Iran

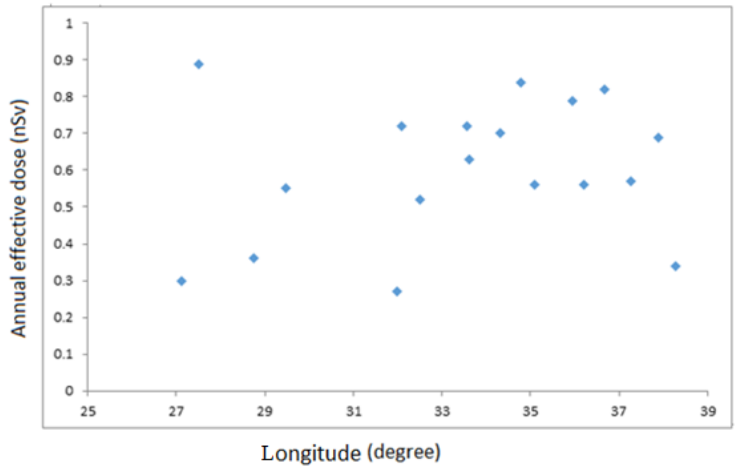

Figure 3. Correlation between longitude and annual effective dose for provinces of Iran

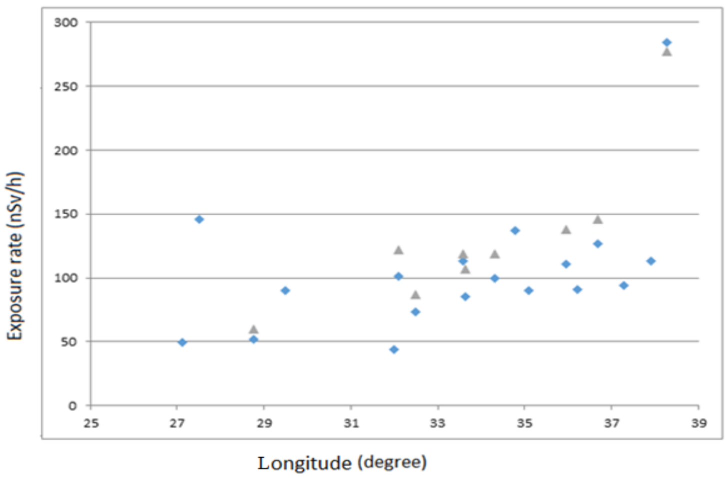

Figure 4. Correlation between longitude and exposure of gamma dose rate for provinces of Iran

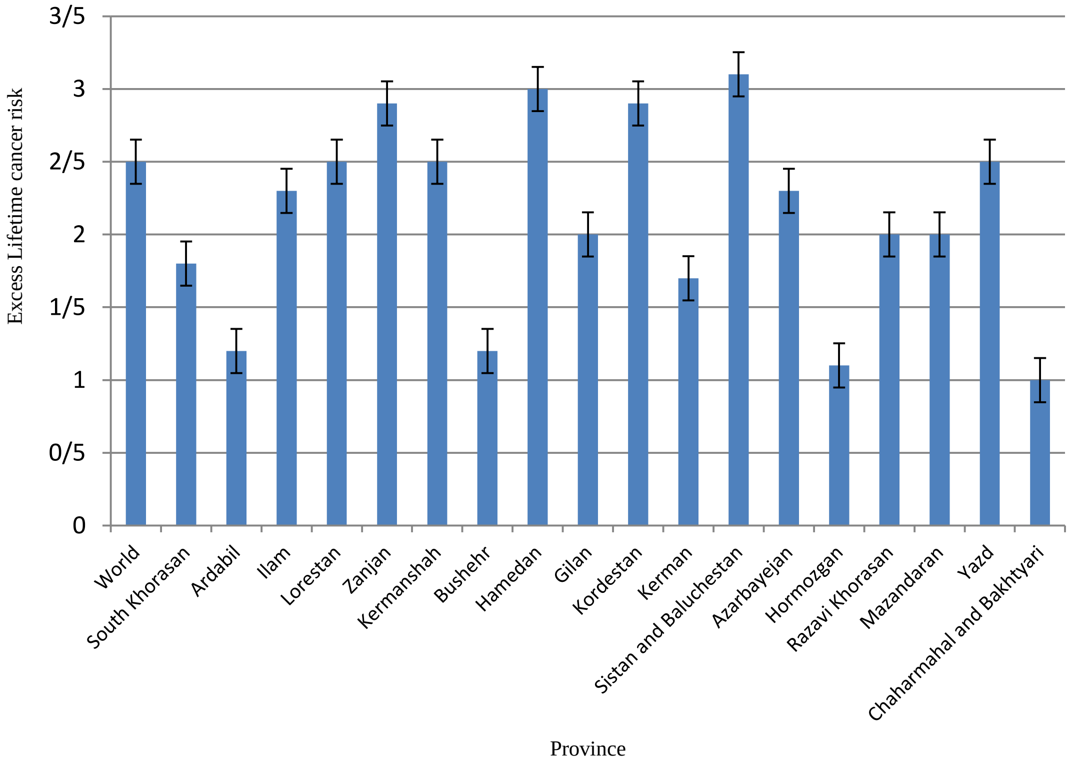

Figure 5. Comparison of Iran provinces and the World regarding excess lifetime cancer risk

Conclusion

To evaluate health hazards, the measurements of background radiation in most countries have special importance. The obtained findings of South Khorasan and 16 other provinces of Iran regarding the dose rates were computed and reported in this study. The maximum and minimum of effective gamma doses were reported as 0.84 and 0.27 nSvh^{-1} in Hamedan, as well as Chaharmahal and Bakhtiari, respectively. The average values of the annual effective dose and estimated ELCR were reported as 0.60 nSv and 2.11×10^{-3}, respectively, which were higher than the amounts of the global average. Therefore, it is suggested to carry out epidemiological studies to investigate the prevalence of chronic diseases related to exposure among the residents of the cities with high level radition.

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