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ORIGINAL ARTICLE

Assessment of Gamma Dose Rate in Indoor Environments in Selected Districts of Ardabil Province, Northwestern Iran

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ABSTRACT

Gamma rays pose enough energy to remove electrons from atoms of absorbing material including human body and adversely affect human health. The external exposure of human beings to natural environmental gamma radiation normally exceeds that from all man-made sources combined. Therefore, we monitored gamma dose rate in indoor environments and estimated corresponding annual effective dose in selected districts of Ardabil Province, Iran. Indoor environmental gamma dose rates were measured using an Ion Chamber Survey Meter, FLuke-451b, in 88 selected dwellings (One in city center and the remaining in cardinal and ordinal directions with an appropriate distance from each other) in Ardabil, Sar Ein, Germy and Kosar. The measurements of gamma radiation dose rate were performed at 20 and 100 cm above the ground for a period of one hour. Average absorbed dose rate (i.e. arithmetic average of dose rate at 20 and 100 cm above the ground) inside buildings for Ardabil, Sar-Ein, Germy, and Kosar were 238, 221, 402, and 361 $nSvh^{-1}$, respectively. The respective corresponding values for annual affective absorbed dose rate due to indoor environments for the studied area were 1.17, 1.08, 1.97, and 1.77 mSv, respectively. Calculated annual effective doses for selected districts of Ardabil Province were appreciably higher than the population weighted average exposure to environmental gamma radiation worldwide as well as the average estimated value for Iran.

Keywords: *Gamma radiation, Effective dose, Ionizing radiation, Iran*

INTRODUCTION

Ionizing radiation, in the form of electromagnetic or particles, has sufficient energy to eject one or more orbital electrons from atoms and hence break chemical bonds through nonthermal process [1]. Ionizing radiation is emitted because of radioactivity of radionuclides naturally occurring in the environment. Radionuclides are unstable atoms that undergo spontaneous nuclear transformations and release excess energy in the form of ionizing radiation. Gamma rays as an electromagnetic ray often accompany the emission of alpha or beta particles from a nucleus.

The majority of human exposure to ionizing radiation occurs from natural sources (i.e. cosmic rays and terrestrial radiation) [2]. Cosmic rays from space include energetic protons, electrons, gamma ray, and x-ray. The exposure to cosmic radiation depends mostly on altitude, latitude, and solar activity [1, 3]. Terrestrial radiation is originated from naturally occurring radioactive nuclides in the earth's crust. Naturally occurring primordial radionuclides mainly include 238U, 235U, and 232Th series and 40K [3, 4], which present at trace levels in all environmental compartments.

Gamma ray accounts for the majority of external human exposure to radiation from all source types due to its high penetration ability [1, 5]. Physical and chemical processes occurring following the radiation

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Table 1. Indoor absorbed dose rates ($nSvh^{-1}$) in selected districts

	Ardabil	Sar-Ein	Germy	Kosar
Average	238	221	402	361
SD	86	60	105	80
Minimum	110	110	215	240
25^{th} percentile	167	185	310	304
Median	236	233	415	353
75^{th} percentile	300	262	475	399
95^{th} percentile	389	302	560	501
Maximum	460	313	610	510

Table 2. Estimated annual effective absorbed dose rates due to indoor gamma radiation in selected districts of Ardabil Province

	Absorbed dose rate ($nSvh^{-1}$)	Annual effective absorbed dose rates (mSv)
Ardabil	238	1.17
Sar-Ein	221	1.08
Germy	402	1.97
Kosar	361	1.77

exposure involve successive changes at the molecular, cellular, tissue and whole body levels that may lead to a wide range of health effects varying from simple irritation, radiation-induced cancer, and hereditary disorders to immediate death [1].

Indoor exposure to gamma rays is often greater than outdoor exposure if earth materials are used as construction materials. When the duration of occupancy taken into account (i.e. typically people spend more than 80% of their time indoors), indoor exposure becomes even more significant [6, 7].

High levels of environmental gamma radiation are expected in Ardabil Province, in northwestern Iran, due to high altitude from the sea level and presence of natural hot springs across the state. Environmental gamma dose rate has been measured in a number of locations across the country [8-10]; however, surveys of absorbed dose rates in air inside buildings are not as complete as outdoor surveys. Although recent studies have found relatively high concentration of radon and uranium series in indoor air and water resources including springs, wells, rivers and lakes in Ardabil province [11,12], however; less is known about indoor gamma dose rate in Ardabil Province. In addition, the prevalence of gastric adenocarcinoma in Ardabil is much higher than those of other countries [13, 14]. In order to characterize gamma dose rate (both terrestrial and cosmic) and estimate corresponding effective dose; gamma dose rate were monitored in indoor environments in selected districts of Ardabil Province, Iran.

Materials and Methods

Selection of the measurement sites: Gamma dose rates were measured inside buildings situated in 4 selected districts (Ardabil, Sar-Ein, Germy, and Kosar) of Ardabil Province, northwestern Iran from 2009 to 2010. For each district, the city center was assumed as a reference point and additional sites were selected in both cardinal and ordinal directions with an appropriate distance from each other (Fig. 1). Based on the size of the districts, 33, 17, 21, and 17 buildings were monitored in Ardabil, Sar-Ein, Germy, and Kosar, respectively.

Dose rate measurement: Indoor environmental gamma dose rates were measured using an Ion Chamber Survey Meter, FLuke-451b, in 88 dwellings. The measurements were performed at 20 and 100 cm above the ground for a period of one hour. A minimum distance of 100 cm from sidewalls of the room was kept for each measurement campaign. A well-designed stand was employed to obtain the above-mentioned measuring heights. The instrument was calibrated in an Iranian Atomic Energy Agency accredited laboratory using ^{137}Cz prior to gamma dose rate measurement and a calibration factor of 1 was obtained for the dosimeter. Slide of the dosimeter was kept closed during the measurement campaign in order to prevent the effect of other ionizing particles (e.g. alpha and beta) on recorded dose rates.

Calculation of Effective absorbed dose rate in indoor environments: Biological effects of ionizing radiation on human are evaluated based on the effective absorbed dose rate. Annual effective absorbed dose were determined using algorithm below:

$$HE_{In} = T \times {}^{\circ}D_{In} \times C_C \times OF_{In} \times 10^{-6}$$

HE_{In} = Annual effective absorbed dose rate in indoors in $mSvy^{-1}$

T= Time in hours (8760 hours for a year)

${}^{\circ}D_{In}$ = absorbed dose rate in indoor in $nSvh^{-1}$

C_C = Correction coefficient (0.7 for adult)

OF_h = Occupancy factor (80% for indoor)

SPSS version 13.0 for windows was used to perform all statistical analysis in this study. T-test was applied to elucidate any similarities or differences in the dose rates measured in different locations.

Results

The absorbed dose rates measured in selected districts are summarized in Table 1. The highest dose rate was observed in Germy and the lowest in Sar-Ein with respective values of 402 and 238 $nSvh^{-1}$.

The determined absorbed dose rates at 20 and 100 cm above the ground for each district are shown in Fig. 2.

Estimated annual effective absorbed dose rates due to indoor gamma ray are presented in Table 2.

Discussion

Average absorbed dose due to gamma radiation at 100 cm above the ground were slightly higher than that of 20 cm for majority of the locations studied, however,

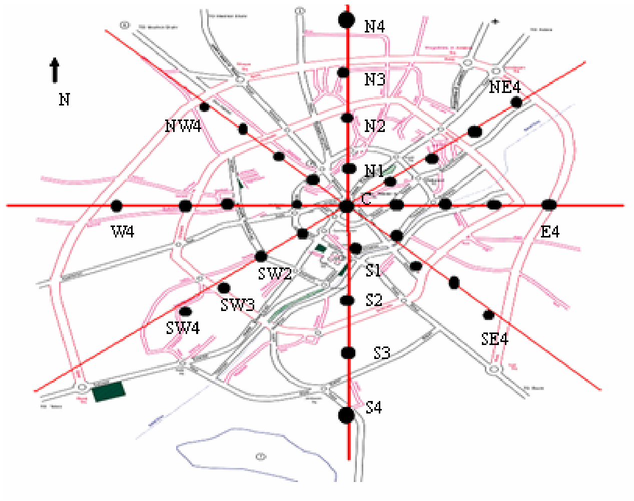

Fig 1. Selection of the measurement sites in Ardabil district

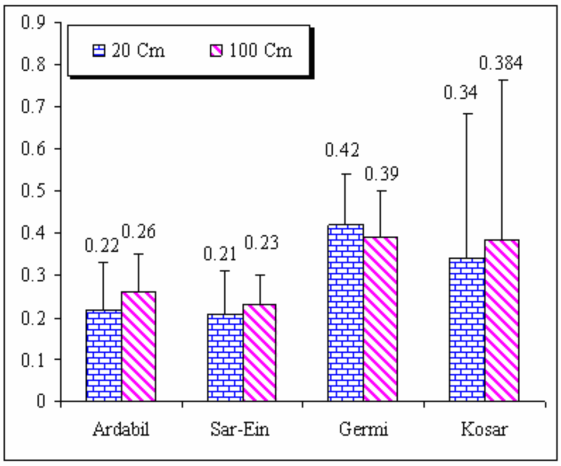

Fig 2. The average absorbed dose rates ($nSvh^{-1}$) at 20 and 100 cm above the ground for selected districts

these differences were only statistically significant for Ardabil (t-test, $p<0.04$) and Kosar (*t*-test, $p<0.001$) districts. The exact reason for these differences is unknown but might imply the differences in concentrations of radiation sources (i.e. radionuclides emitting gamma ray) in air, walls, ceilings, and roofs of the buildings and scattered rays from surrounding. This is in line with the elevated concentration of radon found in air inside of dwellings in Ardabil and Sar-Ein [11], which has a short half-life (3.85 days) and decay to isotopes of solid elements through emitting gamma ray.

Average absorbed dose (i.e. arithmetic average of dose rate at 20 and 100 cm above the ground) inside buildings for Ardabil, Sar-Ein, Germy, and Kosar were 238, 221, 402, and 361 $nSvh^{-1}$, respectively. Wide variation was observed in gamma dose rates quantified in different buildings ranging from 110 to 610 $nSvh^{-1}$.

Since the cosmic and cosmogenic radiations are expected mostly to be absorbed by roofs of the buildings, these differences might imply that the material used in construction of building differs in origin and consequently in strength of the radiation sources. Other speculation would be the differences in natural ventilation rate of buildings that would alter the concentrations of gamma emitting radioneulides (e.g. Radon and Thoron) inside dwellings [6]. In order to put in context, the results obtained in this study along with the values reported for some other locations are provided in Table 3.

Gamma absorbed dose rates found in Ardabil Province are appreciably higher than those reports from other provinces of Iran (e.g. Yazd and Zanjan) as well as the countries like USA, Italy, Malaysia, Sweden, India, and UK, where dose rates were determined in a range of 38 to 157 $nGy\ h^{-1}$ indicating preponderance of wood frame houses. Gamma absorbed dose rate in indoor environments studied are appreciably higher than those of UNSCEAR estimations for population weighted average of world and Iran. However, gamma dose rates obtained for Ardabil and Sar-Ein are

Table 3. Indoor gamma dose rates ($nGyh^{-1}$) reported for selected locations worldwide

Location	Dose Rate ($nGyh^{-1}$)	Reference
USA	38	[2]
Hong Kong	200	
Malaysia	96	
Sweden	110	
UK	60	
Italy	105	
Coimbatore, India	157.3	[15]
Ramsar, Iran	50000	[15]
Yazd, Iran	122	[16]
Zanjan, Iran	128	[8]
Ardabil	238	This study
Sar-Ein	221	
Germy	402	
Kosar	361	
Iran (Population Weighted Average)	115	[2]
World Population Weighted Average	84	

relatively similar to the value reported for Hong Kong but much lower than the dose rates recorded for Ramsar, where high levels of gamma dose rates have been reported (Table 3).

The exact reason for higher dose rate recorded in this study is unknown; however, it is speculated to be related to application of stone or masonry materials used in building constructions [11]; as it was the case for Hungary, Malaysia, China, Albania, Portugal, Australia, Italy, Spain, and Sweden [2].

Although the effective environmental gamma dose rates due to outdoor have not been included in the results presented in Table 2, however these are appreciably higher than the values estimated for world average (i.e. 0.87 $mSvy^{-1}$). If we assume the similar dose rate for outdoor and recalculate the total annual effective absorbed dose rate, then the people living in Ardabil Province receive from 1.5 to 2.4 times higher environmental gamma radiation than the world population weighted average. These relatively high gamma dose rates found in this study strongly recommend further investigations on concentrations of gamma emitting radionuclides in soil of Ardabil Province.

CONCLUSION

People living in Ardabil Province receive appreciably higher gamma ray than other provinces in Iran as well as the most of the other countries. Among the districts studied Germy had the greatest indoor exposure while Sar-Ein had the least. The high indoor exposure might propose a possible risk factor for high rate of gastric cancer in Ardabil.

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