SEASONAL VARIATION OF INDOOR AND OUTDOOR GAMMA DOSE RATES OF REASI DISTRICT OF JAMMU AND KASHMIR

by

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In the present study, the indoor gamma dose rate has been studied seasonally and the outdoor gamma dose rate was also measured in and around the 24 dwellings of 10 villages of Reasi district of Jammu and Kashmir, India, at about one meter above the ground surfaces by using Dosimeter-Radiometer MKS-03 (SARAD). The study was carried out to assess the annual equivalent dose rate for the inhabitants of the dwellings. The survey was designed in such a way so as to obtain a uniform and representative distribution of measurements locations. The indoor to outdoor dose ratio was calculated as 1.8, which indicated that the indoor gamma dose rate as compared to outdoor gamma dose rate has elevated levels of radon exposure due to confined space and poor ventilation. The average indoor gamma dose rate for three seasons such as winter, summer, and rainy were 0.18 0.02, 0.12 0.03, and 0.15 0.03 Svh^{-1}, respectively. It was observed that the indoor gamma dose rate during the winter season is higher than those for rainy and summer seasons. The indoor and outdoor annual equivalent dose rate was also measured from the health hazard point of view and it varied from 771 210 to 1402 280 Svy^{-1} and 105 53 to 315 105 Svy^{-1}. These results revealed that the outdoor equivalent dose rate levels in all of the locations were below the 1000 Svy^{-1} maximum permissible limit for the public set by International Commission on Radiological Protection, except the few locations of indoor equivalent dose rate.

Key words: indoor and outdoor gamma exposure, dosimeter-radiometer, equivalent dose rate, seasonally variation

INTRODUCTION

The knowledge of distribution of radionuclides and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and extra-terrestrial sources. Radioisotopes present in soil significantly affect terrestrial gamma radiation levels. The majority of human exposure to ionizing radiation occurs from natural sources including cosmic rays and terrestrial radiation [1]. The terrestrial gamma rays derive essentially from ^{40}K and the radio-nuclides in the ^{238}U and ^{232}Th radioactive decay series, and these radionuclides are widely dispersed in the earth crust. The origin of these materials is the earth crust, but they find their way into building materials, air, water, food and human body itself.

The presence of terrestrial radiations due to naturally occurring radioactive materials (NORM) in the environment may result to an external and internal dose received by a population through the ingestion or inhalation pathways. The external radiation exposure is caused by the gamma emitting radionuclides, which in the uranium series mainly belong to the decay chain segment starting with ^{226}Ra. The internal (inhalation) radiation exposure is due to ^{222}Rn, and marginally to ^{220}Rn, and their short lived decay products, exhaled from building materials into the room air [2]. The worldwide average value for outdoor gamma absorbed dose rate in air due to terrestrial sources is 54 nGyh^{-1} and the relative contributions of ^{40}K, ^{238}U, and ^{232}Th to this dose are about 35 %, 25 %, and 40 %, respectively [3].

Therefore the measurement of terrestrial radiations is important since they may have a significant contribution to the collective dose (1-10 mSv) of the population [4]. Great variations have been observed in environmental radiation levels and several studies have been done on characterizing gamma dose rates both in outdoor and indoor environments [5-7].

As a preliminary study in this direction, the environmental gamma radiation measurement has been carried out in this area. This type of work has not been

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carried out so far, in this part of the country and hence happens to be the first of its kind. The main objective of this study was to obtain the seasonal variation of the indoor gamma dose rate and to measure the outdoor gamma dose rate in and around 10 villages of Reasi district, Jammu and Kashmir, India, and to calculate the annual effective dose (AED) received by the inhabitants of the study area. These studies were part of our effort to set up baseline data for environmental radiations in Reasi district. In the initial phase of our project, indoor radon levels, were measured in Jammu district of the state of Jammu and Kashmir, India [5]. The values obtained were compared with that of the world average as well as with the other values reported in literature.

MATERIALS AND METHODS

Detailed of the study area

Reasi district lies between latitude 33°05'56.58" N and longitude 74°42'26.88" E, at a distance of 64 km from Jammu and is bounded by Tehsil Gool-Gulabgarh in the north, Tehsil Sunderbani and Kalakote of District Rajouri in the west, Udhampur District in the east, Tehsils Jammu and Akhnoor of District Jammu at the south (fig. 1). Geologically, the district is underlained by rock formations which range in age from Pre-Cambrian of Sirban limestone to Quaternary period of Murree Group. The Sirban Limestone is also known as great limestone or Reasi limestone. It occurs in a chain of inliers in the tertiary rock formations. The Murree group of rocks of late Eocene-Early Miocene age is disconformably underlain by the rocks of Subathu formation in Jammu & Kashmir. The district in general shows the conspicuous physiographic variations comprising of moderately high hills, isolated hillocks and alluvial tract.

Based on the variation in hydrogeological characters of the rocks and the hydrogeological characters of the rock formations, the study area may be divided as Fissured formation and Porous formation. Former includes hard rock formation comprising mainly of granites, gneisses, quartzite, limestone, sandstone etc. These are generally massive and consolidated and devoid of any primary porosity. Main Boundary Thrust (Mandi-Kishanpur thrust), Tanhal thrust, Muree thrust, Mudum thrust, *etc*., some important weaker zones are present in the area. Porous formation comprises of terrace deposit of Recent to sub-Recent age in the area. All along the Chenab river and its tributaries from Arnas to Akhnoor and from Katra to Jhajhar Nala, alluvial terraces of varying dimensions are deposited.

Gamma dose rate

In the selected villages of Reasi district, ambient indoor and outdoor gamma dose rates [8] have been measured by using Dosimeter-Radiometer MKS-03D [5, 9] gamma detector meter, at about one meter above the ground surface. It is a GM tube based survey meter with digital display. It can detects the gamma radiation ranged between 0.05-3.0 MeV, with 15 % accuracy and can detects the ambient gamma radiations dose rate ranged between 0.01 μSvh^{-1}-0.1 Svh^{-1}. Due to the random nature of the radioactive decay, the radiation exposure rate changes rapidly with time. In order to average out the exposure level of given locations, 10 to 15 readings were taken for 10-15 min. Results of the measurements of ambient gamma dose rate in the environmental air are reported in units of micro Sievert per hour (μSvh^{-1}).

Estimation of annual equivalent dose rate

The annual equivalent dose rate (AED) resulting from the gamma-ray emission attributed to the radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) is obtained using following formula [1, 10-12]

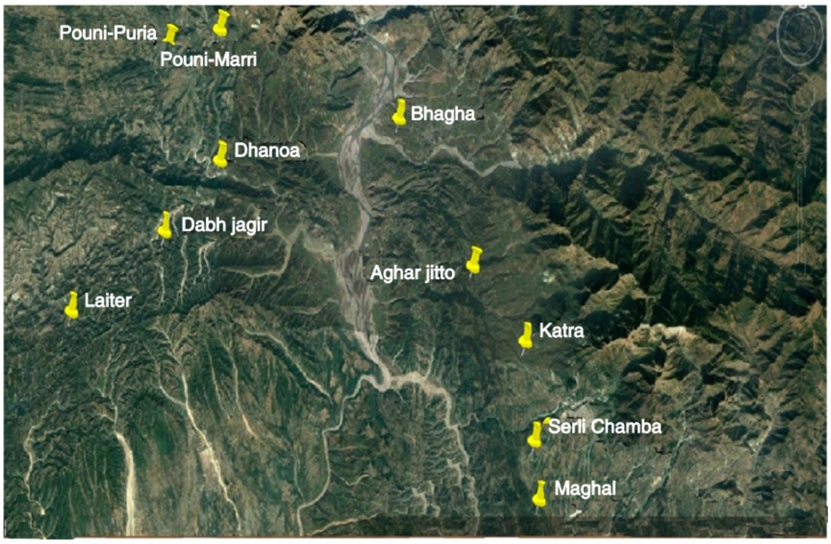

Figure 1. Map shows the studied location of Reasi district

$$\mathrm{AED_{In}}\ (\mu\mathrm{Svy}^{-1}*) = \text{Indoor equivalent dose rate}\ (\mu\mathrm{Svh}^{-1})\ T_{\mathrm{exp}}\ \mathrm{OF_{int}} \quad (1)$$

$$\mathrm{AED_{Out}}\ (\mu\mathrm{Svh}^{-1}) = \text{Outdoor equivalent dose rate}\ (\mu\mathrm{Svy}^{-1})\ T_{\mathrm{exp}}\ \mathrm{OF_{ext}} \quad (2)$$

where T_{exp} is the exposure duration per year *i. e.* 8760 hy^{-1}, and $\mathrm{OF_{ext}}$ and $\mathrm{OF_{int}}$ are occupancy factor for outdoor (0.2) and indoor (0.8) effective dose [13] for environmental exposures to gamma ray, respectively.

RESULTS AND DISCUSSION

The seasonally measured indoor gamma dose rate in 10 villages of Reasi district, Jammu & Kashmir, India are presented in tab. 1. The indoor gamma dose rate was varied in the range of 0.08   0.01 $\mu\mathrm{Svh}^{-1}$ to 0.19   0.02 $\mu\mathrm{Svh}^{-1}$, with geometric mean value of 0.12 $\mu\mathrm{Svh}^{-1}$ for the summer season; 0.10   0.01 $\mu\mathrm{Svh}^{-1}$ to 0.20   0.03 $\mu\mathrm{Svh}^{-1}$, with geometric mean value of 0.14 $\mu\mathrm{Svh}^{-1}$ for the rainy season; 0.15   0.03 $\mu\mathrm{Svh}^{-1}$ to 0.21   0.04 $\mu\mathrm{Svh}^{-1}$, with the geometric mean value of 0.18 $\mu\mathrm{Svh}^{-1}$ for the winter season, respectively. The value of indoor gamma dose rate was found to be maximum in the winter season as shown in fig. 2. This may be due to the poor ventilation and more accumulation of radio-active gases in the winter season as compared to the summer and the rainy seasons. The value of indoor gamma dose rate for the rainy season is higher than for the summer season but lower than the value for the winter season, due to the reason that during the rainy season the soil pores are partially filled with water which resists the entry of gamma radiations form soil to indoor air.

* Svy^{-1} means   Sv per year

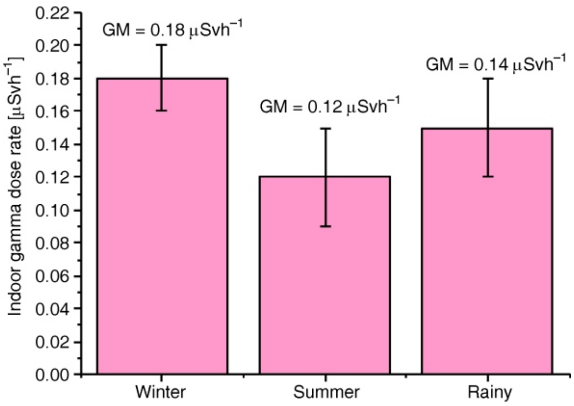

Figure 2. Seasonal variation of indoor gamma dose rate [$\mu\mathrm{Svh}^{-1}$]

The median of indoor gamma dose rate for the summer, rainy and winter seasons are 0.12, 0.15, and 0.18, respectively. The Kruskal-Wallis test [14] was applied under the null hypothesis that the median of indoor gamma dose rate for different seasons are the same. But the test showed a statistically significant difference amongst the medians of the indoor gamma dose rate for different seasons, with test static of 12.82 at 98 % confidence level ($p = 0.02$).

The results of experimentally determined values of indoor and outdoor gamma dose rates, indoor and outdoor annual equivalent doses and indoor to outdoor dose ratio, observed in selected 24 dwellings of 10 villages, are sum-

Table 1. Seasonal variation of indoor gamma dose rate

Villages	Statistical factors	Seasonally indoor gamma dose rate [$\mu\mathrm{Svh}^{-1}$]		
		Summer	Rainy	Winter
Laiter (2)	A. M. SD	0.14 0.02	0.11 0.03	0.21 0.03
	G. M. (GSD)	0.13 (1.1)	0.11 (1.4)	0.21 (1.3)
Dabh jagir (2)	A. M. SD	0.13 0.04	0.17 0.04	0.18 0.01
	G. M. (GSD)	0.12 (1.3)	0.16 (1.2)	0.18 (1.1)
Pouni-Mari (2)	A. M. SD	0.10 0.03	0.16 0.02	0.18 0.04
	G. M. (GSD)	0.10 (1.4)	0.15 (1.1)	0.17 (1.2)
Pouni-Puria (3)	A. M. SD	0.11 0.04	0.12 0.05	0.17 0.02
	G. M. (GSD)	0.10 (1.4)	0.11 (1.3)	0.17 (1.5)
Dhanoa (3)	A. M. SD	0.10 0.06	0.15 0.02	0.16 0.04
	G. M. (GSD)	0.09 (1.8)	0.15 (1.1)	0.15 (1.2)
Bhagha (2)	A. M. SD	0.19 0.02	0.20 0.03	0.20 0.04
	G. M. (GSD)	0.19 (1.1)	0.19 (1.2)	0.18 (1.1)
Aghar Jitto (2)	A. M. SD	0.14 0.05	0.17 0.01	0.21 0.04
	G. M. (GSD)	0.13 (1.4)	0.17 (1.0)	0.20 (1.3)
Katra (2)	A. M. SD	0.09 0.01	0.13 0.01	0.16 0.02
	G. M. (GSD)	0.08 (1.1)	0.12 (1.0)	0.16 (1.2)
Serli Chamba (3)	A. M. SD	0.12 0.03	0.14 0.02	0.16 0.03
	G. M. (GSD)	0.11 (1.2)	0.14 (1.1)	0.15 (1.3)
Maghal (3)	A. M. SD	0.08 0.01	0.10 0.01	0.15 0.03
	G. M. (GSD)	0.08 (1.0)	0.10 (1.1)	0.15 (1.2)
Median		0.12	0.15	0.18

Table 2. Statistical parameters of gamma and absorbed dose rate and their contribution to annual equivalent dose rate in the villages of Reasi district, Jammu and Kashmir, India

Villages	Statistical parameters	Averaged gamma dose rate [μSvh^{-1}]		Annual equivalent dose rate [μSvy^{-1}]		Indoor to outdoor dose ratio
		Indoor	Outdoor	AED_{In}	AED_{Out}	
Laiter	A. M. SD	0.15 0.04	0.06 0.03	1051 280	105 53	2.5
	G. M. (GSD)	0.15 (1.3)	0.05 (1.7)	1051 (1.3)	88 (1.7)	
Dabh Jagir	A. M. SD	0.16 0.02	0.18 0.06	1121 140	315 105	0.9
	G. M. (GSD)	0.16 (1.2)	0.17 (1.4)	1121 (1.2)	298 (1.3)	
Pouni-Mari	A. M. SD	0.15 0.03	0.07 0.04	1051 210	123 70	2.1
	G. M. (GSD)	0.14 (1.3)	0.05 (1.8)	981 (1.2)	88 (1.8)	
Pouni-Puria	A. M. SD	0.13 0.03	0.08 0.05	911 210	140 88	1.6
	G. M. (GSD)	0.13 (1.2)	0.06 (2)	911 (1.2)	105 (2)	
Dhanoa	A. M. SD	0.14 0.03	0.08 0.04	981 210	140 70	1.8
	G. M. (GSD)	0.13 (1.2)	0.07 (1.7)	911 (1.2)	123 (1.7)	
Bhagha	A. M. SD	0.20 0.04	0.10 0.06	1402 280	175 105	2
	G. M. (GSD)	0.20 (1.02)	0.08 (2)	1402 (1.0)	140 (2)	
Aghar Jitto	A. M. SD	0.17 0.03	0.06 0.03	1191 210	105 53	2.8
	G. M. (GSD)	0.17 (1.2)	0.05 (1.7)	1191 (1.2)	88 (1.7)	
Katra	A. M. SD	0.13 0.03	0.08 0.03	911 210	140 53	1.6
	G. M. (GSD)	0.12 (1.3)	0.07 (1.4)	840 (1.3)	123 (1.4)	
Serli Chamba	A. M. SD	0.14 0.02	0.06 0.03	981 140	105 53	2.3
	G. M. (GSD)	0.14 (1.1)	0.05 (1.7)	981 (1.1)	88 (1.7)	
Maghal	A. M. SD	0.11 0.03	0.11 0.06	771 210	193 105	1
	G. M. (GSD)	0.11 (1.3)	0.09 (1.8)	771 (1.3)	158 (1.8)	
G. M. (GSD)		0.15 (1.2)	0.08 (1.4)	1024 (1.2)	145 (1.4)	1.8 (1.4)

marized in tab. 2. The averaged values of gamma dose rate have been varied from 0.11 0.03 μSvh^{-1} to 0.20 0.04 μSvh^{-1}, with the geometric mean value of 0.15 μSvh^{-1} for indoor and from 0.06 0.03 μSvh^{-1} to 0.18 0.06 μSvh^{-1}, with the geometric mean value of 0.08 μSvh^{-1} for outdoor, respectively, as given in tab. 2. The results revealed that the value of indoor gamma dose rate was found to be higher than outdoor gamma dose rate.

The values of indoor and outdoor annual equivalent dose rate have been varied from 771 210 μSvy^{-1} to 1402 280 μSvy^{-1} with geometric mean value of 1024 μSvy^{-1} and 105 53 μSvy^{-1} to 315 105 μSvy^{-1}, with geometric mean value of 145 μSvy^{-1}, respectively (tab. 2). All the values of outdoor equivalent dose rate were found below the ICRP recommended limit of 1000 μSvy^{-1} [13]. However, 50 % values of indoor equivalent dose rate were found to be higher than the ICRP recommended limit of 1000 μSvy^{-1} [13]. The higher value of indoor annual equivalent dose rate in the studied locations may be due to high natural radioactivity levels in soil and building materials existing in this region and the presence of main boundary thrust in this region [15].

Figure 3 shows the comparison between the indoor and the outdoor annual equivalent dose rates. The indoor annual equivalent dose rate was found to be higher than the outdoor annual equivalent dose rate maybe be due to the indoor-outdoor pressure difference which is caused by temperature difference, wind, barometric pressure and unbalanced mechanical ventilation, as shown in fig. 3. The outdoor radionuclides concentration is far below compared to the indoor

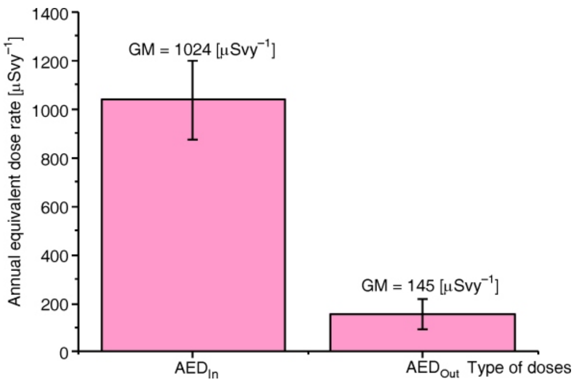

Figure 3. Comparison of indoor and outdoor annual equivalent dose [μSvy^{-1}]

radionuclide concentration, because the radiation exhaled from the ground is rapidly diffused over vast atmosphere, but buildings and structures may prevent this dilution. This results in accumulation of radionuclides inside the buildings, emerging from the floor and wall materials, but also depends on the house-to-house variability, even for areas with low exhalation rates from the ground [16].

The ratio of indoor to outdoor doses was observed in the range 0.9 to 2.8 for all the studied locations, with the geometric mean value of 1.8, particularly in houses which have cemented floors and concrete walls and ceilings [17]. The linear correlation analysis between the indoor and outdoor gamma dose rate is shown in fig. 4, with a slope of 0.06. A weak positive correlation of 0.01 has been observed between indoor and outdoor gamma dose rates. The

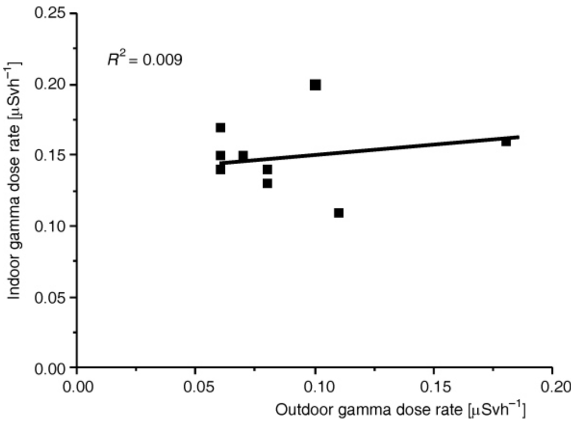

Figure 4. Correlation between indoor and outdoor gamma dose rate [μSvh^{-1}]
(indoor gamma dose rate = 0.06 outdoor gamma dose rate + 0.14)

computed value of correlation coefficient was 0.009. The average indoor to outdoor radiation dose rate in the study area was found to be 1.9 0.6 and was found comparable with the world average ratio of 1.4 [1].

CONCLUSIONS

The median of indoor gamma dose rate for the summer, rainy, and winter seasons are 0.12, 0.15, and 0.18 Svh^{-1}, respectively. The value of indoor gamma dose rate was found to be maximum in the winter season as compared to the rainy and the summer seasons. The averaged values of gamma dose rate have been varied from 0.11 0.03 μSvh^{-1} to 0.20 0.004 μSvh^{-1}, with the geometric mean value of 0.15 μSvh^{-1} for indoor and from 0.06 0.03 μSvh^{-1} to 0.18 0.06 μSvh^{-1}, with the geometric mean value of 0.08 μSvh^{-1} for outdoor, respectively. The indoor annual equivalent dose rate was found to be higher than the outdoor annual equivalent dose rate which may be due to indoor-outdoor pressure difference. All values of outdoor and 50% values of indoor annual equivalent dose rate were found to be below than the recommended limit given by ICRP [13].

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AUTHORS' CONTRIBUTIONS

The field work and experimental studies was done by M. Kaur and A. Kumar. The data analysis and preparation of paper was done by A. Kumar, M. Kaur, R. Mehra, and R. Mishra.

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СЕЗОНСКЕ ВАРИЈАЦИЈЕ ЈАЧИНЕ ДОЗЕ ГАМА ЗРАЧЕЊА У ЗАТВОРЕНОМ И ОТВОРЕНОМ ПРОСТОРУ ОБЛАСТИ РЕАСИ У ЏАМУ И КАШМИРУ

У овом раду сезонски је праћена јачина дозе гама зрачења у затвореном простору унутар 24 стамбена објекта у 10 села у области Реаси у Џаму и Кашмиру у Индији, и на отвореном простору око ових објеката. Мерења су вршена на висини од једног метра изнад тла коришћењем Radiometer MKS-03 (SARAD) дозиметра. Студија је обављена како би се проценила годишња доза за становништво у овим објектима. Испитивање је спроведено тако да се обезбеди униформна и репрезентативна расподела мерних локација. Однос јачине доза у затвореном и на отвореном простору износио је 1.8, што указује да је јачина дозе гама зрачења у затвореном простору повишена у односу на отворени простор услед затворености и лоше вентилације. Просечне јачине доза гама зрачења у затвореном простору током три годишња доба, зиме, лета и кишне сезоне, биле су 0.18   0.02, 0.12   0.03 и 0.15   0.03   Svh^{-1}, респективно. Уочено је да је јачина дозе гама зрачења током зиме већа него током лета и кишне сезоне. Са становишта здравственог ризика измерене су и годишње јачине еквивалентне дозе у затвореном и отвореном простору, у опсегу од 771   210 до 1402   280   Sv по години и 105   53 до 315   105   Sv по години. Ови резултати показују да је јачина еквивалента дозе на отвореном простору, на свим локацијама, испод максималне дозвољене границе за становништво од 1000   Sv по години, донете од стране Међународне комисије за радиолошку заштиту, осим на неколико затворених локација.

Кључне речи: излагање гама зрачењу у затвореном и на отвореном простору, сезонска варијација, радиометар-дозиметар, јачина еквивалентне дозе