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Risk assessment from the exposure of natural gamma radiation in the lesser Garhwal Himalayan part, India

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Abstract—Health issues due to exposure to natural radiation are a serious concern around the globe as it can damage cell DNA through direct or indirect processes. The present study aims to measure the indoor and outdoor gamma dose rates in different locations of the foothills of Garhwal Himalaya, Uttarakhand India. The average outdoor and indoor gamma dose rate were found 0.15 Sv/h and 0.17 Sv/h. The total annual effective dose equivalent (AEDE) and lifetime effective dose (LED) were found with the average value of 399.03 Sv/y and 25.94 mSv, respectively. Total AEDE was observed to be less than the global population-weighted average.

Keywords: *Gamma dose rate; Pocket Gamma Survey meter; AEDE; ELCR.*

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1. Introduction

Gamma radiation is part of the natural background radiation, and is largely due to terrestrial radionuclides in rocks and soils and to cosmic radiation that penetrates the Earth's atmosphere [1]. The terrestrial gamma radiation depends mainly on the amount and distribution of naturally occurring radionuclides, including ^{226}Ra, ^{232}Th, and ^{40}K, in the underlying geological formations, while cosmic radiation is mainly affected by altitude [2], [3]. Background gamma radiation is, therefore, spatially variable and is influenced by geological, geographical and environmental factors [4]. Radiation monitoring in the environment is essential for assessing environmental exposure for the public and for radiological baseline assessments as about 80% of the annual dose received by the public is due to natural radiation sources [5],[6],[7].

Even though the radiation that comes from the natural environment is not something that can be avoided, high levels of gamma radiation for extended periods of time can be a risk to adverse effects on the biology. For environmental surveillance, radiation protection and public health, therefore, systematic assessment of environmental gamma radiation and the associated radiological dose is important [8]. The absorbed dose rate from terrestrial gamma radiation is about 59 nGy h^{-1} and cosmic radiation contributes about 31 nGy h^{-1} at sea level [5].

The present study is intended to check up the background gamma dose rates and the radiological exposure inside and outside the center of the Maldevta region of Doon valley in Uttarakhand in the foothills of Garhwal Himalaya. The area is geologically complex due to its proximity to the Main Boundary Thrust (MBT) and often observes natural disasters almost every year, and hence, it is of great scientific and public health interest to establish baseline radiation data for this area. The study also calculates the annual effective dose equivalent (AEDE), lifetime effective dose (LED), and excess lifetime cancer risk (ELCR), in the radiological assessment.

2. Study Area

The study area lies in Doon Valley region of Dehradun district of lesser Garhwal Himalaya, India, in which MBT region represents the geological feature (Figure 1). There are three major fault lines in Garhwal Himalayas: Himalayan Front Fault (HFF), Main Boundary Thrust (MBT) and the Main Central Thrust (MCT) that passes through the Doon valley [9]. The Garhwal Himalaya can be categorized into four geological

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units: the Higher Himalaya, the Lower Himalaya, the Shivalik, and the Indo-Gangetic plain. The MBT (Main Boundary Thrust) acts as a separation between the lower Himalayas, which include rock formations such as infra-krol, tal, and pre-tertiary rocks (including krol), and the Shivalik, which is primarily composed of tertiary rocks. In the MBT region of the Doon Valley, various rock types like phosphorite, chert, carbonaceous shale, and siltstone form a sequence with tal above and underlying krol limestone and infra-krol rocks, all thrust over the Shivalik rocks. The upper section of the Shivalik consists of conglomerates and boulders, while the lower part is predominantly composed of clay and sandstone. These rocks have undergone significant compression and shearing, resulting in a thick layer of boulders and pebbles commonly referred to as the Doon gravel, representing the youngest geological layer in the region [10], [11].

3. Methods

A portable pocket radiation monitor ATOMTEX AT6130C (ATOMTEX, Minsk, Belarus) was used to measure the background gamma doses, and was factory calibrated before use, in both indoor and outdoor settings. It is used for measuring ambient gamma dose equivalent rates, and based on a Geiger–Müller detector, which records gamma radiation-induced electrical pulses as automatic conversion to a dose equivalent rate. The response of the energy compensation filter is almost independent of energy over a wide gamma energy range, and the data is processed, saved and displayed via built-in microprocessors. The AT6130C is widely employed in environmental radiation monitoring, in radiation protection and in radioecological studies, due to its portability, accuracy and broad operating range (https://atomtex.com/en/radiation-monitors/at6130-at6130a-at6130d-radiation-monitors). This work was carried out in the months of May-June in 2024.

3.1 Assessment of Annual Effective Dose Equivalent (AEDE)

The values of Annual effective dose equivalent (AEDE) corresponding to outdoor and indoor environment of the study area were calculated by using outdoor and indoor gamma dose rates, respectively. Further, biological effects on humans due to radiations are evaluated on the basis of AEDE(13). AEDE was estimated by using the following equation:

$$A(indoor/outdoor) = D_{ind/out} \times C \times O.F \times T \quad (1)$$

where, d_i is gamma dose rate in indoor (Sv/h), d_o is absorbed gamma dose rate in outdoor (Sv/h) and t is Time (h). In above equation, O.F represents the occupancy factor that reported by UNSCEAR for indoor and outdoor environment was assumed to be 0.8 and 0.2, respectively; and C is taken as conversion coefficient for an adult and it was reported 0.7(3). However, the values are about 10% and 30% higher for children and infants, respectively(3). Therefore, above formula become as:

$$A(indoor) = d_i \times 8760 \times 0.7 \times 0.8 \quad (2)$$

$$A(outdoor) = d_o \times 8760 \times 0.7 \times 0.2 \quad (3)$$

The total annual effective dose equivalent was obtained by summing the outdoor and indoor contributions:

$$TotalAEDE(A_t) = A(indoor) + A(outdoor) \quad (4)$$

3.2 Calculation of Lifetime Effective Dose (LED)

Based on the literature, the Lifetime effective dose calculated by taking total AEDE values and duration of life in order to quantify risk assessment and it is given by following relation(15):

$$LED = totalAEDE \times L \quad (5)$$

where L represents the average lifetime (65 years). Calculation of Excess Lifetime Cancer Risk (ELCR) The excess lifetime cancer risk (ELCR) was calculated to estimate the risk of developing cancer from continued background gamma radiation exposure. ELCR was determined by multiplying the lifetime effective dose value by the nominal value of the fatal cancer risk coefficient (RF) recommended by the International Commission on Radiological Protection (ICRP) [16]. A risk coefficient of 0.05 Sv−1 was used for the general public [13]:

$$ELCR = LED \times R_f \quad (6)$$

4. Results and Discussion

Result of Indoor and outdoor gamma dose rate, AEDE and lifetime effective dose from foothills of lesser Garhwal Himalaya, Uttarakhand are presented in Table1and displayed in Figure 1.

4.1 Indoor and outdoor gamma dose rate

Table1 represents the measured levels of indoor and outdoor gamma dose rate, annual effective dose equivalent for indoor and outdoor exposure and total annual effective dose equivalent in the study area. In the current study, the outdoor and indoor gamma dose rate were obtained in between 0.01±0.002 Sv/h to 0.24±0.01 Sv/h and 0.06±0.01 Sv/h to 0.28±0.03 Sv/h with an average of 0.15 (±0.04SD) Sv/h and 0.17 (±0.04SD) Sv/h, respectively. The high gamma dose rate was observed for indoor settings from the locations G3, G26, G28, G32, G46, G48 and G52(Fig. 2). The indoor of these locations have the value more than 0.20 Sv/h. In the outdoor surroundings locations G3, G26, G32, G46 and G48 showing value more than 0.20 Sv/h. Location G17 showing the

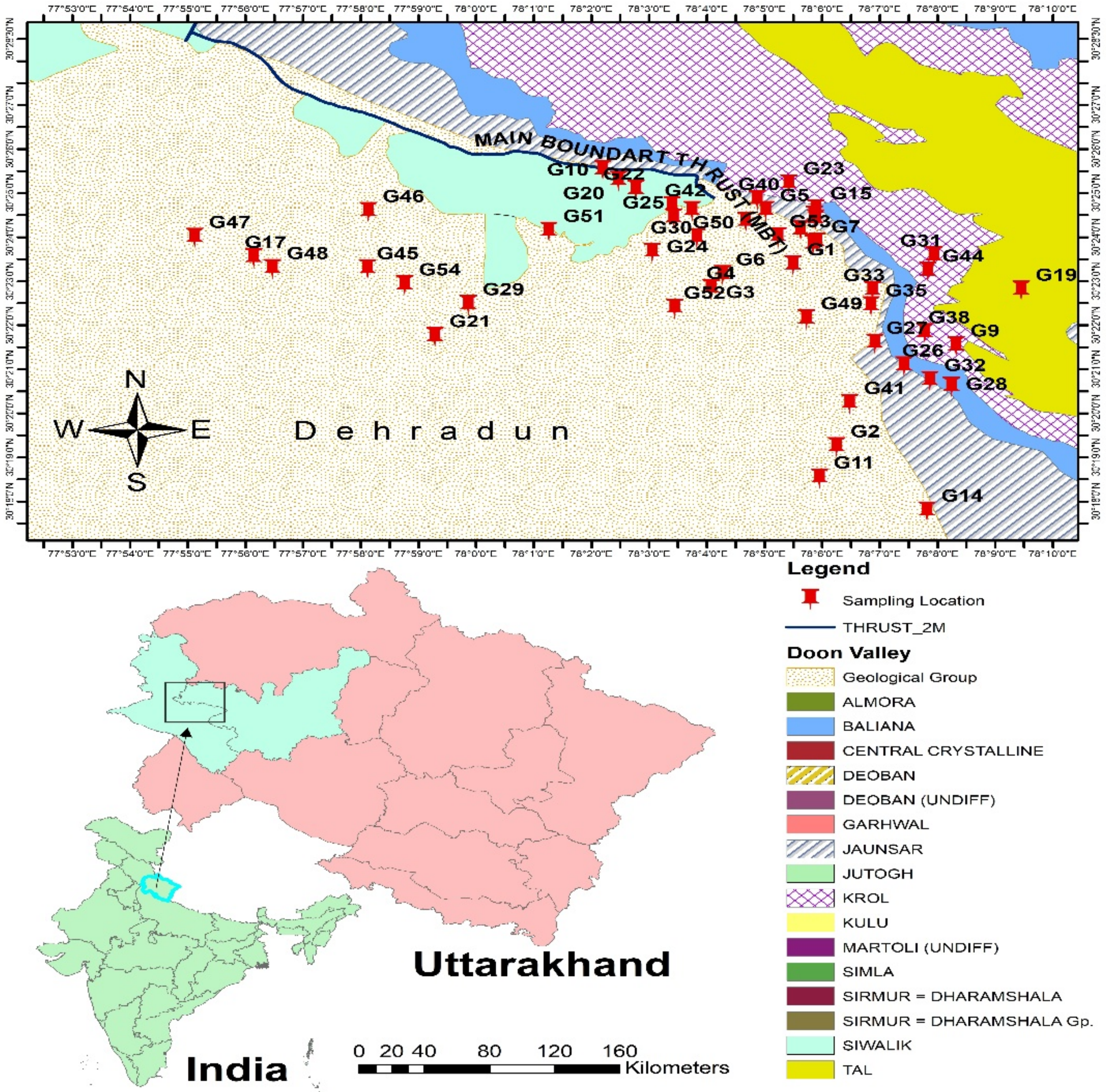

Figure 1: Study area map showing sampling points.

Table 1: Indoor and Outdoor Gamma dose rate (d), Annual effective dose equivalent (A) for indoor and outdoor and lifetime effective dose (LED) derived from total AEDE (A_t) calculated over the study area.

Parameters	Minimum	Maximum	Average	Std. D.	Geomean	Skewness
d_i (Sv/h)	0.06	0.28	0.17	0.04	0.17	0.09
d_o (Sv/h)	0.01	0.24	0.15	0.04	0.14	-0.82
A (indoor) (Sv/y)	73.58	343.49	210.08	49.00	203.83	0.09
A (outdoor) (Sv/y)	12.26	294.34	188.96	52.22	176.61	-0.82
A_t (Sv/y)	85.85	625.46	399.03	99.20	383.38	-0.44
LED (mSv)	5.58	40.66	25.94	6.45	24.92	-0.44
ELCR ($\times 10^{-3}$)	0.28	2.03	1.30	0.32	1.25	-0.44

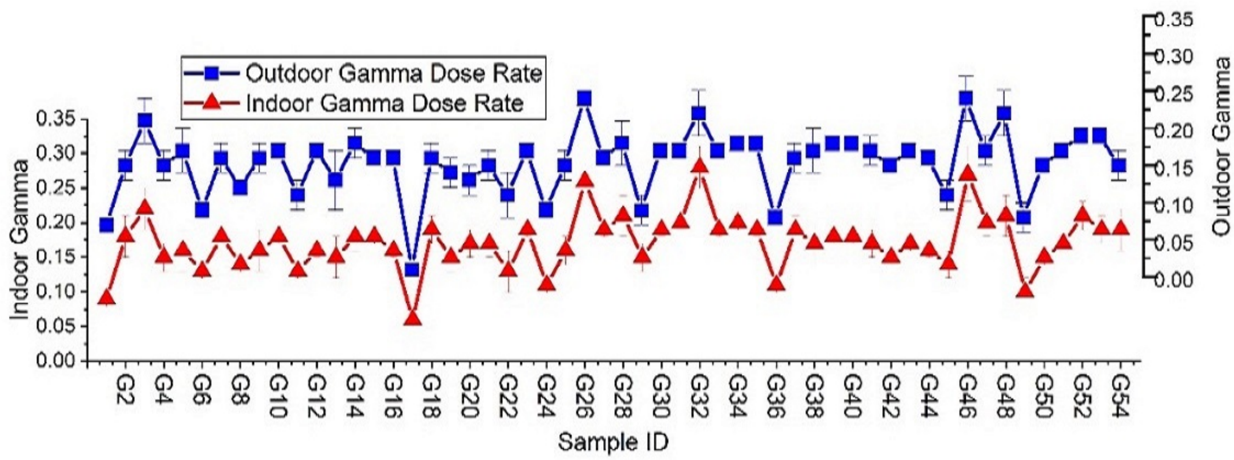

Figure 2: Measured indoor and outdoor gamma dose rates.

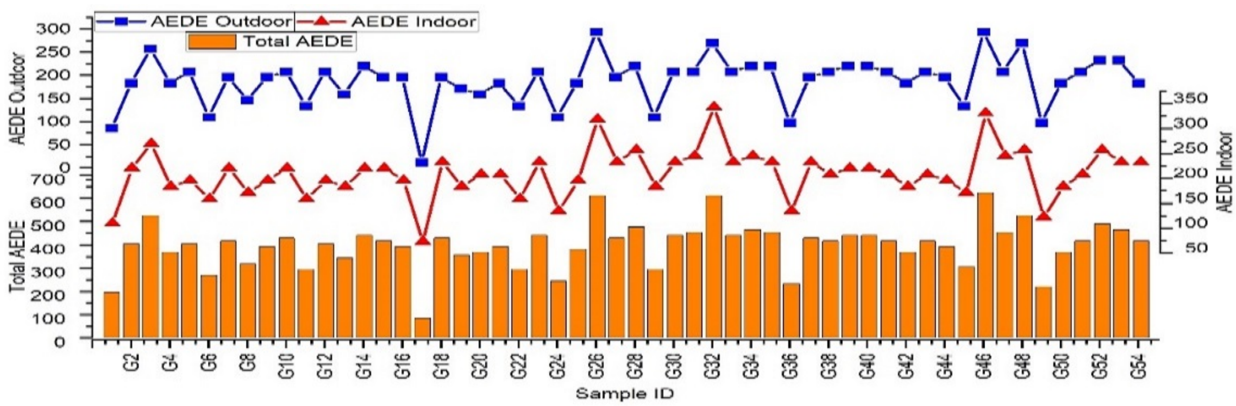

Figure 3: Calculated indoor, outdoor and total annual effective dose equivalent (µSv/y) in study area.

minimum indoor as well as outdoor gamma dose rate, However UNSCEAR reported gamma dose rate varies from 0.02 to 0.20 Sv/h. A previous radon-related study conducted in this region reveals the presence of significant natural radiation levels [9].

4.2 Indoor and outdoor annual effective dose Equivalent

Based on the observed gamma dose rate values, annual effective dose equivalent (AEDE) for outdoor and indoor gamma radiation exposure were calculated and it ranges between 12.26 Sv/y to 294.36 Sv/y and 73.58 Sv/y to 343.49 Sv/y with an average of 188.96 Sv/y (±52.22SD) and 210.08 Sv/y (±49SD), respectively (Fig. 3). The total AEDE was found to be from 85.85 Sv/y to 625.46 Sv/y with average value 399.03 Sv/y (±0.04SD) in the study area. The indoor AEDE values were found to be higher than the outdoor AEDE. The higher value of indoor AEDE because people spend most of time inside as compare to outside. The total AEDE in the study area was observed below than world population weighted average report (870 Sv/year) [5]. Figure 3 revealing the location wise annual effective dose equivalent. Out of 54 locations 32 showing the total AEDE values higher than mean values. Locations having higher value of AEDE lies along the MBT line in the study area.

4.3 Lifetime Effective Dose (LED) and Excess Lifetime Cancer Risk (ELCR)

The probability of the incidence of cancer and the potentially carcinogenic effect of gamma dose rate during a specific lifetime is calculated by ELCR. Figure 4 represents the frequency distribution of LED and ELCR. Lifetime effective dose calculated by total AEDE values the dose value varies from 5.58 mSv to 40.66 mSv with the mean value of 25.94 mSv (±6.45SD), Figure 3 reveals that 27 locations out of total 54 ranging between 25-30 mSv. Excess lifetime cancer risk (ELCR) was also calculated from obtain result. The possibility of the incident of cancer and the potentially carcinogenic effect from gamma dose rate during a particular lifetime can be evaluated by ELCR(15). The ELCR ranges from 0.28×10-3 to 2.03×10-3 with the average value of 1.30×10^{-3}(±0.32SD), 19 locations showing the ELCR between the value of 1.2×10-3 -

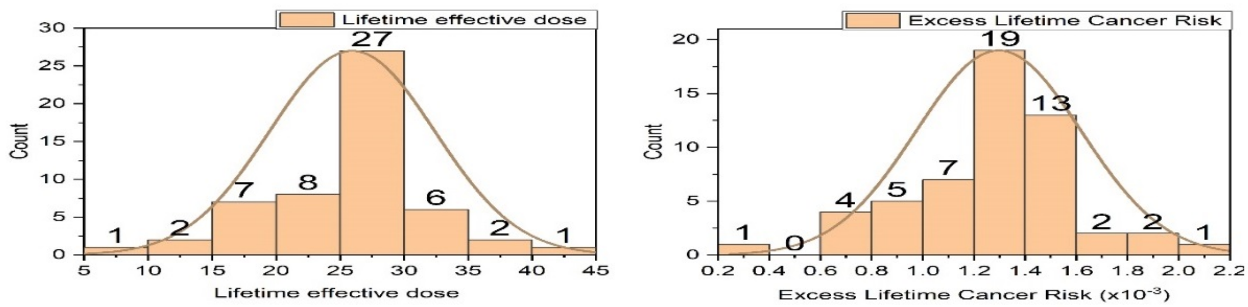

Figure 4: Frequency distribution graph of calculated LED (mSv) and ELCR.

1.4×10-3. The present study shows that the ELCR values are less than the recent study [15].

5. Conclusion

The study was conducted to measure the gamma radiation level in the foothills of lesser Garhwal Himalaya (Doon valley), Uttarakhand, India. As result obtained the indoor environment were highly affected by the gamma radiation. We can imply that terrestrial radiation may be the main cause of gamma radiation level than the cosmic radiation. The study reveals that the gamma dose rate and annual effective dose equivalent for indoor environment was higher as compared to outdoor. The MBT line is an easy pathway to emanate terrestrial radiation as Dehradun situated in lower Himalayan region and MBT line passes through the District. Mean value of total AEDE for the current study is lower than the world population weighted average value. This study is important for understanding the impact of climatic or terrestrial radiation on human beings and results show gamma radiation could influence human well-being. It can provide a base data for the evaluation of further radiation hazards and can be adopted in a future study on natural radioactivity mapping.

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CONFLICT OF INTEREST

Authors declare that there is no any competing interest among them that could have appeared to effect the work reported in this research paper.

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