A comprehensive analysis of health risk due to natural outdoor gamma radiation in southeast Haryana, India

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A systematic study of background radiation in southeast Haryana, India, i.e. the Jhajjar, Sonipat and Rohtak districts, was initiated to establish reliable baseline data on the background radiation level of the region. Worldwide many areas have been found with high background gamma radiation, leading to several types of disorders in human beings. So the present study was carried out as a precautionary step. There are two natural sources of ionizing radiation – cosmic and terrestrial. Isotopes of heavy elements and their decay products present in the Earth's crust are the major sources of terrestrial radiation. A radiation survey meter was used for the analysis of gamma radiation. In total, 50 locations were chosen for the survey. Gamma radiation showed variation from 82 to 184 nSv/h, with the mean value of 131.64 ± 5.56 nSv/h. An independent *t*-test at a significance level of 5% was applied for comparison. Annual effective dose and excess lifetime cancer risk were computed to determine the number of cancer cases due to outdoor radiation.

Keywords: Annual effective dose, cancer risk, cosmic rays, Gamma radiation, heavy metals.

THE natural terrestrial gamma radiation dose rate contributes significantly to the average total dose rate of the global population. Ionizing radiation from natural sources has always been a part of human life[1,2]. Radiation-level assessment provides us with baseline data to examine the effects of radiation on humans[3]. There are two types of radiation: natural and artificial. Natural radiation contributes significantly to the overall dose as it is responsible for up to 85% of the annual dosage of radiation received by humans. Background radiation has been widely studied around the world due to its significant contribution to human exposure[4]. As part of this effort, some studies have been carried out in various Iranian cities[5–9]. The surface has been exposed to many types of radiation from space and naturally occurring radionuclides that reside in the atmosphere, hydrosphere and the Earth's crust and circulate throughout the ecosystem. The dose rate varies depending on the geology and geographical conditions; it also has spatial variations[4,10,11]. Radiation due to the decay series of natural radionuclides such as U-238, Th-232 and K-40 is found in almost all materials originating from the Earth's crust. Their concentration is a function of multiple factors such as geology, topology and various environmental conditions. Due to direct gamma radiation and radon gas and its decay products, natural radionuclides are responsible for both exterior and interior radiation exposure[12]. According to the United Nations Scientific Commission on the Effects of Atomic Radiation (UNSCEAR), the population weight average of outdoor terrestrial radiation dose rate is 59 nSv/h (refs 13, 14). Aside from natural sources, artificial sources such as medical procedures, nuclear testing and accidents, among others, contribute to radiation exposure. Nuclear-weapon testing and accidents account for only 1% of all exposure to artificial sources[15]. So systematic quantification of outdoor gamma radiation is a key factor for analysing the health of the population. This study analyses the health risk of natural outdoor radiation in Southeast Haryana, India.

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Study area

Haryana, in the northwestern region of India is located between 27°39′–30°35′N lat. and 74°28′–77°28′ long. (ref. 16) (Figure 1). For the study of outdoor gamma radiation, 50 villages were selected from three districts in the southeast of Haryana, i.e. Jhajjar, Sonipat and Rohtak (Table 1). The region consists of old and new alluvium deposits of Quaternary to Recent age.

Materials and method

Garmin eTrex 10 was used to locate 50 different areas and record GPS information (Figure 1). A handheld radiation monitor (Polimaster PM 1405) was used to measure the outdoor gamma dose rate. This survey meter has a large energy-compensated GM tube that allows exact measurement of gamma radiation up to 100 mSv/h. The detection limit of the radiation meter is 1 nSv/h.

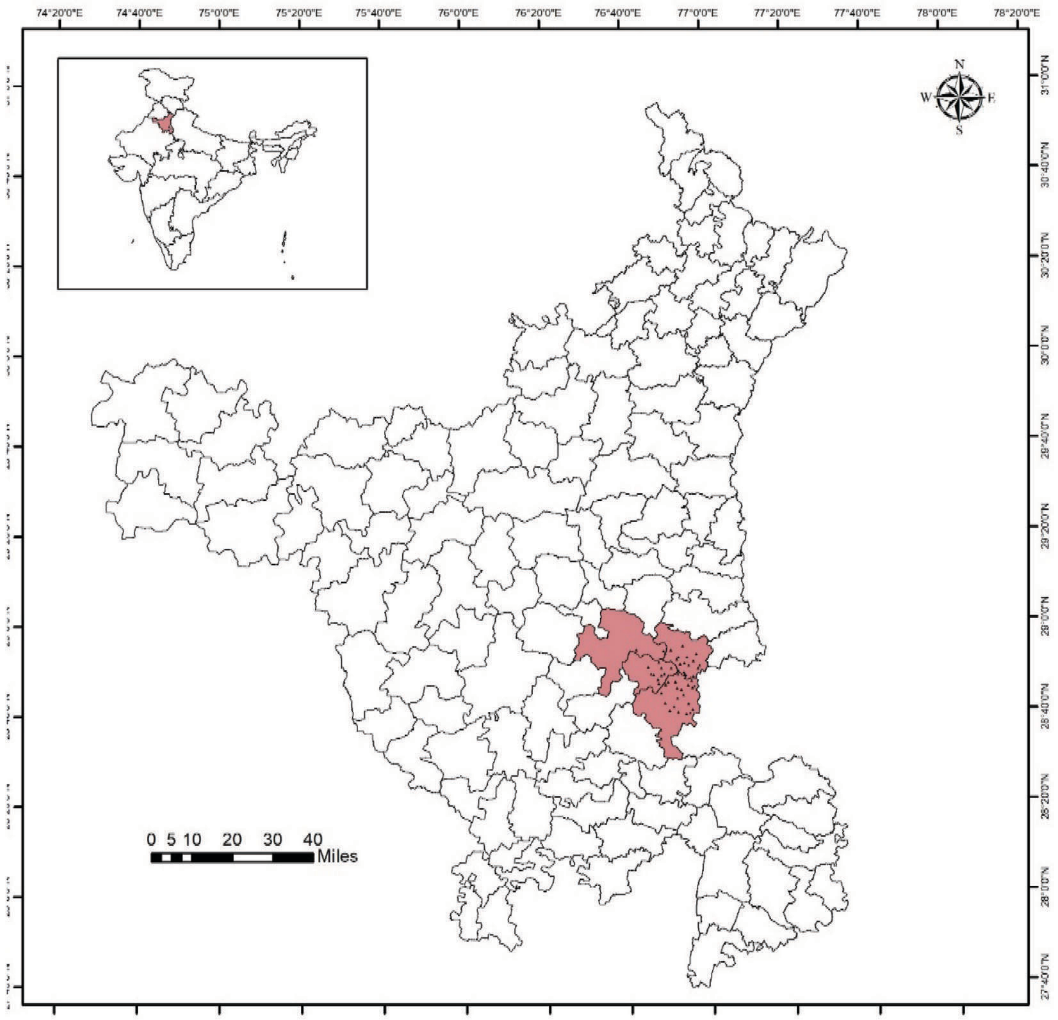

Figure 1. Map of the study area.

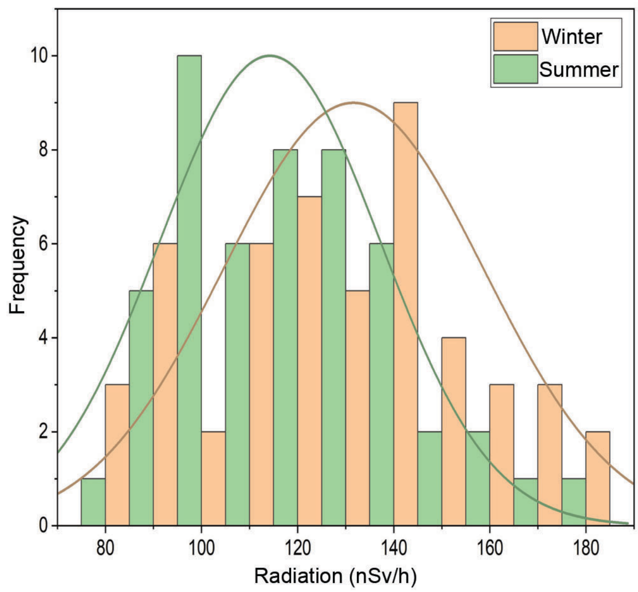

Figure 2. Normal distribution of outdoor gamma radiation in winter and summer.

Estimation of annual effective dose

The annual effective dose (AED) from the outdoor gamma radiation was computed. It was used to analyse the impact of radiation on humans. The following equation was used to compute AED[17,18]

$$\text{AED (mSv/year)} = \{D(\text{nSV}/h) \times T \times \text{conversion coefficient} \times \text{occupancy factor}\},$$

Table 1. Location details of sampling sites

Sample	Village	Latitude	Longitude
S-1	Bahadurgarh	28.6826	76.9316
S-2	Mandothi	28.7067	76.8205
S-3	Nuna majra	28.6725	76.8735
S-4	Sankhol	28.7035	76.9149
S-5	Rohad	28.7437	76.8058
S-6	Balour	28.6684	76.9212
S-7	Dahkora	28.7746	76.8229
S-8	Jasour Kheri	28.7858	76.8627
S-9	Nilothi	28.8134	76.8746
S-10	Ladrawan	28.789	76.9289
S-11	Kulasi	28.7722	76.9148
S-12	Kanonda	28.7635	76.9313
S-13	Barahi	28.7366	76.8955
S-14	Asoudha Siwan	28.7559	76.8867
S-15	Asoudha Todran	28.7615	76.8687
S-16	Bhainsru Khurd	28.8095	76.8068
S-17	Bhainsru Kalan	28.8147	76.8183
S-18	Mahandipur	28.6787	76.8384
S-19	Rohana	28.8512	76.8834
S-20	Barona	28.8541	76.9006
S-21	Gopalpur	28.8456	76.9175
S-22	Sohati	28.8035	76.9369
S-23	Pai	28.8206	76.8977
S-24	Kuranmpur	28.8258	76.8758
S-25	Kirholi	28.8116	76.902
S-26	Lohar Kheri	28.785	76.8336
S-27	Tandaheri	28.6922	76.8569
S-28	Dattaur	28.8142	76.7639
S-29	Gijhi	28.8109	76.7757
S-30	Naya bass	28.7936	76.7927
S-31	Mor kheri	28.8589	76.7968
S-32	Samchana	28.836	76.807
S-33	Garhi sisana	28.8909	76.8232
S-34	Humayupur	28.8989	76.8171
S-35	Hassangarh	28.8357	76.846
S-36	Sisana	28.9033	76.8453
S-37	Matindu	28.8691	76.87
S-38	Chhinoli	28.8755	76.8775
S-39	Pipli	28.8623	76.9369
S-40	Kheri Sampla	28.7781	76.7949
S-41	Kundal	28.8346	76.9559
S-42	Saidpur	28.8449	76.9628
S-43	Kharkhoda	28.8749	76.9108
S-44	Jakhoda	28.7249	76.8698
S-45	Khairpur	28.7675	76.9407
S-46	Bhalaut	28.9047	76.705
S-47	Thana Kalan	28.8863	76.9506
S-48	Khanda	28.9187	76.8949
S-49	Atail	28.8403	76.753
S-50	Naya Gaon	28.6663	76.9059

where D and T denote the outdoor gamma dose rate and time conversion factor (8760) respectively, the conversion coefficient is 0.700 Sv/Gy (ref. 14) and the occupancy factor for outdoor exposure is 0.200.

Estimation of excess lifetime cancer risk

The excess lifetime cancer risk (ELCR) includes the potential consequences such as the probability of cancer incidence in a population during a certain lifespan[12,19]. It can be calculated as follows

$$\text{ELCR} = \text{AED} \times \text{ALD} \times \text{RF},$$

where ALD is the average life duration which is taken 65.8 years for India[19] and RF denotes the risk factor of 0.057 (ref. 20).

Results

Table 2 shows outdoor gamma radiation, AED and ELCR in 50 locations in southwest Haryana during winter and summer. Figure 2 shows the frequency distribution of outdoor gamma radiation for both seasons[21]. Gamma radiation ranged from 85.46 to 184.22 nSv/h with a mean value of 131.64 nSv/h for winter, and from 78 to 178 nSv/h with a mean value of 114.26 nSv/h for summer (Figure 3). The gamma radiation exposure was found to be within the normal range of 20–200 nSv/h for all sampling locations in both seasons, as reported by UNSCEAR[14]. In different parts of India, identical values for outdoor gamma radiation exposure rates have been reported[22,23]. At 50% of sampling locations during winter and 48% during summer, the gamma dose was higher than the mean value in both seasons. The radionuclides in parental rocks increased the background radiation level in the area, resulting in increased outdoor gamma radiation levels. The southwest districts of Haryana are dominated by quaternary Gangetic alluvium, which shows higher natural radioactivity[24,25]. A comparison of radiation during both seasons has been shown in Figure 4 as a box plot[26]. It was observed that the mean gamma dose rate in winter was higher than in summer. For statistical comparison, a independent t-test was applied and it was found that outdoor radiation during both seasons was significantly different at $P < 0.05$ (refs 27, 28). This might be due to the precipitation of radionuclides such as ^{214}Bi and ^{214}Pb (ref. 29). These radionuclides are brought to the ground due to rainfall[30]. An increase in the gamma dose rate due to precipitation has also been reported[31–33].

AED and ELCR

The AED due to outdoor gamma radiation was found to be between 0.104 ± 0.003 and 0.225 ± 0.011 mSv/year

Table 2. Absorbed dose rate, annual effective dose (AED) and excess lifetime cancer risk (ELCR) at the study locations

	Radiation (nSv/h)		AED (mSv/year)		ELCR	
Sample	Winter	Summer	Winter	Summer	Winter	Summer
S-1	143 ± 4.05	96 ± 5.76	0.175 ± 0.005	0.118 ± 0.007	0.658 ± 0.019	0.442 ± 0.026
S-2	98 ± 6.71	90 ± 4.78	0.120 ± 0.008	0.110 ± 0.006	0.451 ± 0.031	0.414 ± 0.022
S-3	85 ± 5.46	98 ± 7.88	0.104 ± 0.007	0.120 ± 0.010	0.391 ± 0.025	0.451 ± 0.036
S-4	94 ± 5.5	102 ± 5.67	0.115 ± 0.007	0.125 ± 0.007	0.432 ± 0.025	0.469 ± 0.026
S-5	122 ± 6.82	102 ± 5.73	0.150 ± 0.008	0.125 ± 0.007	0.561 ± 0.031	0.469 ± 0.026
S-6	135 ± 8.13	120 ± 6.25	0.166 ± 0.010	0.147 ± 0.008	0.621 ± 0.037	0.552 ± 0.029
S-7	176 ± 7.75	145 ± 4.56	0.216 ± 0.010	0.178 ± 0.006	0.810 ± 0.036	0.667 ± 0.021
S-8	115 ± 3.02	90 ± 7.88	0.141 ± 0.004	0.110 ± 0.010	0.529 ± 0.014	0.414 ± 0.036
S-9	129 ± 4.23	115 ± 8.54	0.158 ± 0.005	0.141 ± 0.010	0.593 ± 0.019	0.529 ± 0.039
S-10	184 ± 5.22	167 ± 8.99	0.226 ± 0.006	0.205 ± 0.011	0.846 ± 0.024	0.768 ± 0.041
S-11	121 ± 3.87	110 ± 4.67	0.148 ± 0.005	0.135 ± 0.006	0.557 ± 0.018	0.506 ± 0.021
S-12	165 ± 3.25	125 ± 5.79	0.202 ± 0.004	0.153 ± 0.007	0.759 ± 0.015	0.575 ± 0.027
S-13	112 ± 4.32	87 ± 4.23	0.137 ± 0.005	0.107 ± 0.005	0.515 ± 0.020	0.400 ± 0.019
S-14	139 ± 4.25	122 ± 6.23	0.170 ± 0.005	0.150 ± 0.008	0.639 ± 0.020	0.561 ± 0.029
S-15	154 ± 6.77	135 ± 5.87	0.189 ± 0.008	0.166 ± 0.007	0.708 ± 0.031	0.621 ± 0.027
S-16	123 ± 5.64	178 ± 7.24	0.151 ± 0.007	0.216 ± 0.009	0.566 ± 0.026	0.819 ± 0.033
S-17	121 ± 5.05	85 ± 3.45	0.148 ± 0.006	0.106 ± 0.004	0.557 ± 0.023	0.391 ± 0.016
S-18	96 ± 4.08	102 ± 6.34	0.118 ± 0.005	0.125 ± 0.008	0.442 ± 0.019	0.469 ± 0.029
S-19	139 ± 4.25	156 ± 7.35	0.170 ± 0.005	0.131 ± 0.009	0.639 ± 0.020	0.718 ± 0.034
S-20	130 ± 3.04	101 ± 5.78	0.159 ± 0.004	0.124 ± 0.007	0.598 ± 0.014	0.465 ± 0.027
S-21	141 ± 5.09	112 ± 8.67	0.173 ± 0.006	0.137 ± 0.011	0.649 ± 0.023	0.515 ± 0.040
S-22	150 ± 8.55	126 ± 6.13	0.184 ± 0.010	0.155 ± 0.008	0.690 ± 0.039	0.580 ± 0.028
S-23	107 ± 3.54	95 ± 4.54	0.131 ± 0.004	0.117 ± 0.006	0.492 ± 0.016	0.437 ± 0.021
S-24	117 ± 6.55	134 ± 6.43	0.143 ± 0.008	0.164 ± 0.008	0.538 ± 0.030	0.616 ± 0.030
S-25	115 ± 6.76	110 ± 5.74	0.141 ± 0.008	0.135 ± 0.007	0.529 ± 0.031	0.506 ± 0.026
S-26	177 ± 7.42	124 ± 7.4	0.217 ± 0.009	0.152 ± 0.009	0.814 ± 0.034	0.570 ± 0.034
S-27	128 ± 6.76	86 ± 3.98	0.157 ± 0.008	0.105 ± 0.005	0.589 ± 0.031	0.396 ± 0.018
S-28	146 ± 2.97	135 ± 6.58	0.179 ± 0.004	0.166 ± 0.008	0.672 ± 0.014	0.621 ± 0.030
S-29	141 ± 4.07	116 ± 7.46	0.173 ± 0.005	0.142 ± 0.009	0.649 ± 0.019	0.534 ± 0.034
S-30	115 ± 5.97	97 ± 5.47	0.141 ± 0.007	0.119 ± 0.007	0.529 ± 0.027	0.446 ± 0.025
S-31	87 ± 7.95	94 ± 8.98	0.107 ± 0.010	0.115 ± 0.011	0.400 ± 0.037	0.432 ± 0.041
S-32	92 ± 5.82	90 ± 6.93	0.113 ± 0.007	0.110 ± 0.008	0.423 ± 0.027	0.414 ± 0.032
S-33	167 ± 6.13	88 ± 4.92	0.205 ± 0.008	0.108 ± 0.006	0.768 ± 0.028	0.405 ± 0.023
S-34	148 ± 3.17	113 ± 5.47	0.182 ± 0.004	0.139 ± 0.007	0.681 ± 0.015	0.520 ± 0.025
S-35	140 ± 4.01	123 ± 4.74	0.172 ± 0.005	0.151 ± 0.006	0.644 ± 0.018	0.566 ± 0.022
S-36	163 ± 7.89	109 ± 7.45	0.200 ± 0.012	0.134 ± 0.009	0.750 ± 0.036	0.501 ± 0.034
S-37	145 ± 8.02	134 ± 5.89	0.178 ± 0.010	0.164 ± 0.007	0.667 ± 0.037	0.616 ± 0.027
S-38	95 ± 8.76	94 ± 5.24	0.117 ± 0.011	0.115 ± 0.006	0.437 ± 0.040	0.432 ± 0.024
S-39	156 ± 4.45	132 ± 6.55	0.191 ± 0.005	0.162 ± 0.008	0.718 ± 0.020	0.607 ± 0.030
S-40	145 ± 3.45	104 ± 4.74	0.178 ± 0.004	0.128 ± 0.006	0.667 ± 0.016	0.478 ± 0.022
S-41	181 ± 8.71	155 ± 7.86	0.222 ± 0.011	0.190 ± 0.010	0.833 ± 0.040	0.713 ± 0.036
S-42	175 ± 6.46	148 ± 4.38	0.215 ± 0.008	0.182 ± 0.005	0.805 ± 0.030	0.681 ± 0.020
S-43	103 ± 7.5	86 ± 5.92	0.126 ± 0.009	0.105 ± 0.007	0.474 ± 0.034	0.396 ± 0.027
S-44	128 ± 4.13	115 ± 4.83	0.157 ± 0.005	0.141 ± 0.006	0.589 ± 0.019	0.529 ± 0.022
S-45	137 ± 4.56	122 ± 6.21	0.168 ± 0.006	0.150 ± 0.008	0.630 ± 0.021	0.561 ± 0.029
S-46	119 ± 6.88	125 ± 5.28	0.146 ± 0.008	0.153 ± 0.006	0.547 ± 0.032	0.575 ± 0.024
S-47	89 ± 5.76	78 ± 7.93	0.109 ± 0.007	0.096 ± 0.01	0.096 ± 0.026	0.359 ± 0.036
S-48	156 ± 3.06	133 ± 5.45	0.191 ± 0.004	0.163 ± 0.007	0.718 ± 0.014	0.612 ± 0.025
S-49	148 ± 4.87	117 ± 4.34	0.182 ± 0.006	0.143 ± 0.005	0.681 ± 0.022	0.538 ± 0.020
S-50	90 ± 7.45	92 ± 8.35	0.110 ± 0.009	0.113 ± 0.010	0.414 ± 0.034	0.423 ± 0.038
Mean	131.64 ± 5.56	114.26 ± 6.11	0.161 ± 0.007	0.140 ± 0.007	0.606 ± 0.026	0.526 ± 0.028
Maximum	184 ± 8.76	178 ± 8.99	0.225 ± 0.011	0.218 ± 0.011	0.846 ± 0.04	0.819 ± 0.041
Minimum	85 ± 2.97	78 ± 3.45	0.104 ± 0.003	0.095 ± 0.004	0.391 ± 0.014	0.359 ± 0.015

with a mean value of 0.161 ± 0.007 mSv/year during winter. However, during summer, AED was found to be between 0.095 ± 0.004 and 0.218 ± 0.11 mSv/year with a mean value of 0.140 ± 0.007 mSv/year (Table 2 ad Figure 5). AED was higher in winter than in summer due to higher levels of gamma radiation[30–33]. AED for all the sampling locations for both seasons was higher than the average worldwide value of 0.070 mSv/year (Figure 5)[14]. AED due to gamma radiation dose at all the sampling locations for both seasons was below the permissible limit of 1.000 mSv/year, according to International Commission on Radiological Protection (ICRP)[20].

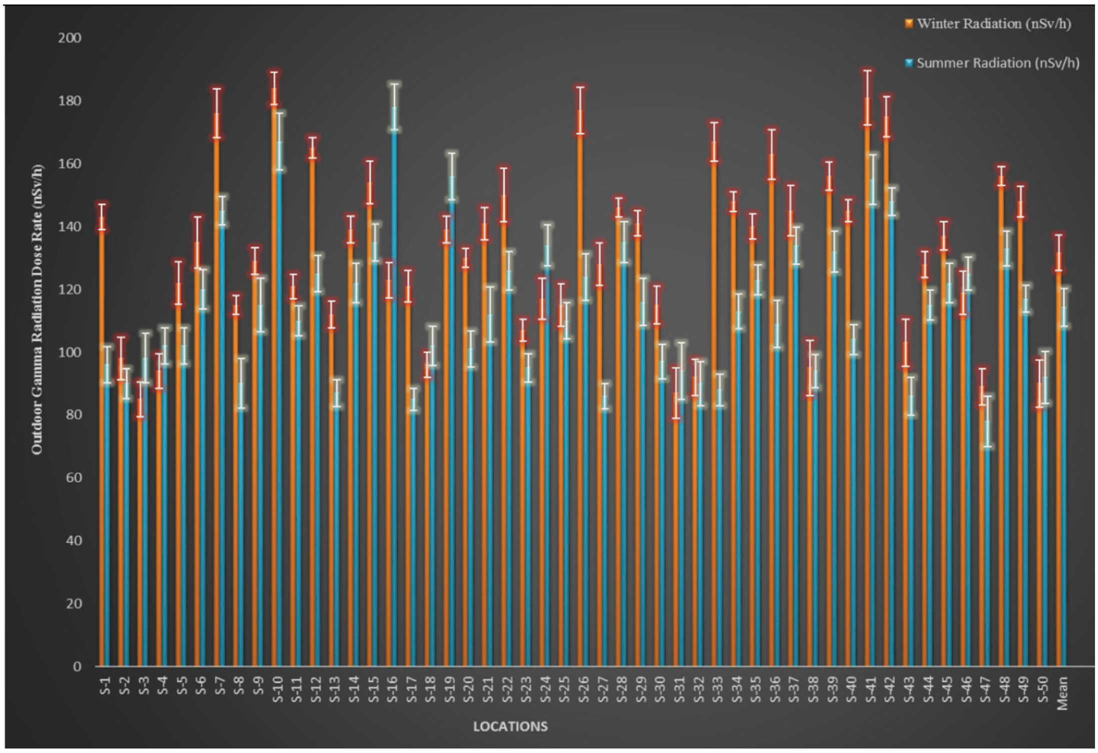

Figure 3. Outdoor gamma radiation dose rate during winter and summer.

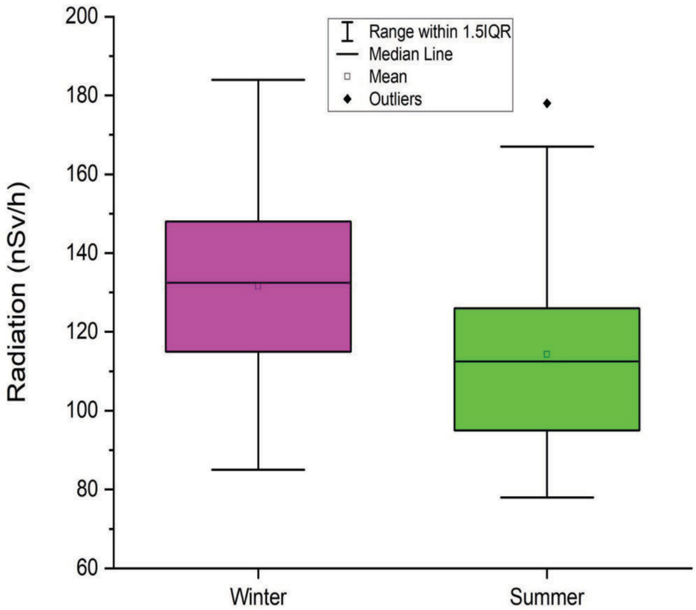

Figure 4. Outdoor radiation dose during winter and summer.

During winter, ELCR ranged from 0.391×10^{-6} to 0.846×10^{-6}, while during summer, it ranged from 0.359×10^{-6} to 0.819×10^{-6} (Table 2 and Figure 6). The mean value of ELCR for both seasons was lower than the average worldwide value of 0.290×10^{-3}. Exposure to low levels of radiation is found to have a good effect on human health as it accelerates the DNA repair mechanism, reducing genetic instability and enhancing overall immune response[34–37]. It also reduces lymph gland inflammation, provides relief from arthritis, and helps in the healing of wounds and treatment of various infections[38,39]. It has been reported that the chance of cancer cases is six per million of the population in the affected area[19].

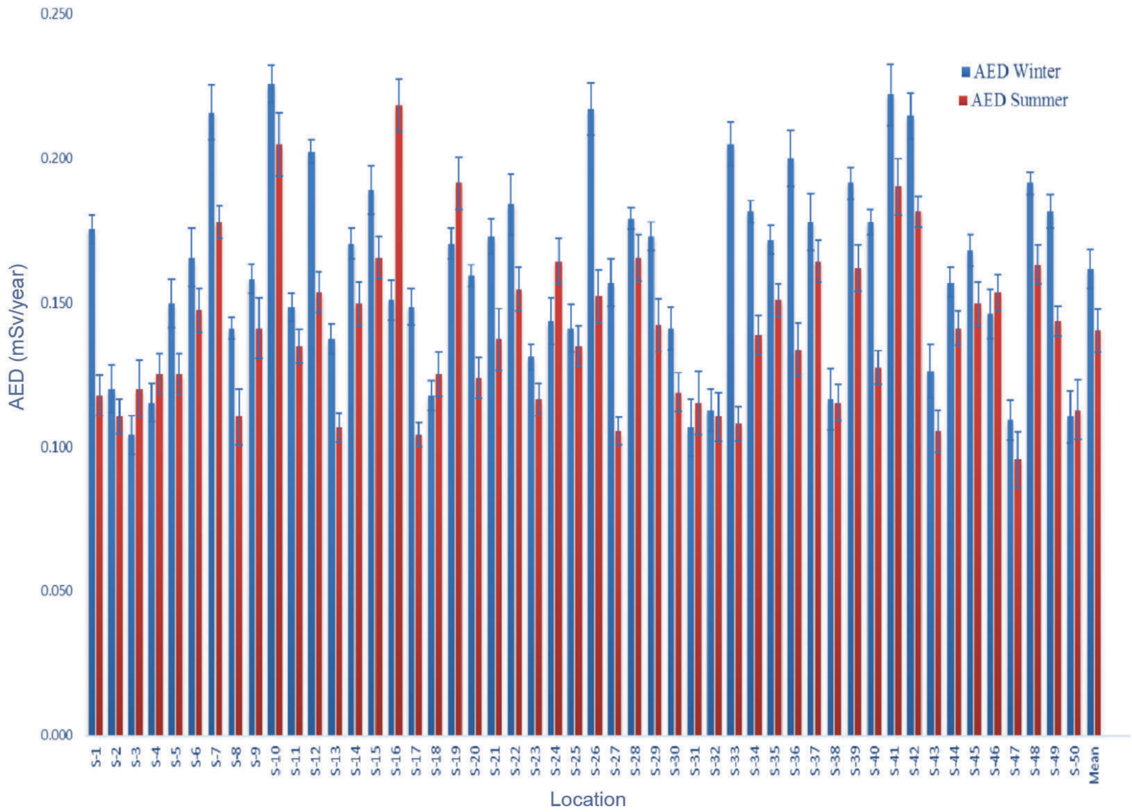

Figure 5. Annual effective dose (AED) in different locations.

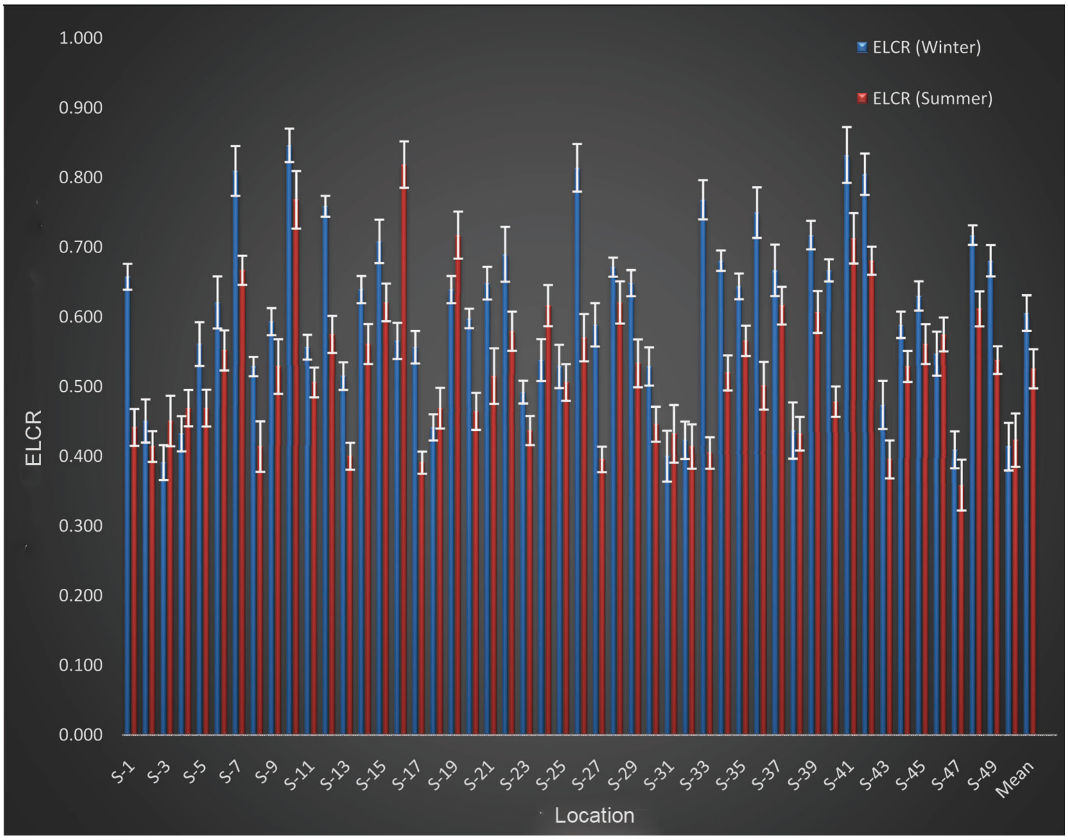

Figure 6. Excess lifetime cancer risk (ELCR) at different locations.

Conclusion

The gamma dose rate was higher than its mean value in 50% of winter sampling sites and 48% of summer sampling sites. The radiation dose rate measured at all locations was within the UNCSEAR reported gamma dose rate range of 20–200 nSv/h. ELCR was also found to be lower than the world average. The risk of cancer cases owing to radiation was found to be six cases per million population on average. So chances of cancer due to radiation are very low. Hence it can be concluded that the radiation level measured in the present study poses a low health risk. Furthermore, radiation value below 100 mSv/h has been claimed to have therapeutic effects in various conditions, including tumour development prevention[40], wound healing, lymph gland inflammation reduction, arthritis relief[41] and the treatment of numerous infections. Further research and epidemiological surveys are required to establish the reality of a possible health effect areas with high levels of radiation.

Conflict of interest: The authors declare that there is no conflict of interest.

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ACKNOWLEDGEMENT. We thank the Department of Environmental Science, M. D. University, Rohtak for providing instrumental access.

Received 2 January 2022; accepted 4 May 2022

doi: 10.18520/cs/v123/i2/169-176