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Quantification of outdoor gamma radiation level and consequent health hazards assessment in Panipat district of Haryana, India

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Abstract

The radiation dose due to natural terrestrial gamma radiations is an important contribution to the average total dose rate received by world's population. Therefore, in this study, a systematic measurement of outdoor gamma radiations has been done using radiation monitor, based on Geiger-Muller technique, in Panipat district of Haryana. The gamma dose rate was found to be in the range from 85 ± 4.250 nSv/h – 216 ± 10.800 nSv/h. The annual effective dose (AED) due to outdoor gamma radiation in Panipat district was computed to be in the range of 0.104 ± 0.005—0.265 ± 0.010 mSv/year. The value of excess lifetime cancer risk (ELCR) was found to be in the range of 0.391×10^{-3}—0.994×10^{-3}.

Keywords AED · ELCR · Geiger-Muller technique · Health Hazard · Outdoor gamma radiation

Introduction

The knowledge of radionuclides and their consequent radiation level in our surroundings is important to study the effect of radiation exposure. The radiation exposure due to ionizing radiation is inescapable and majorly occurs from natural sources consisting of cosmic and terrestrial radiations. The radiation exposure due to natural sources accounts for 87% of radiation dose, received by living beings on earth. The background radiation level at any location depends on the radionuclides present in surroundings such as rocks, soil, air, water etc., which is mainly contributed by ^{238}U, ^{232}Th series, and ^{40} K [1]. The relative contribution of radionuclides ^{238}U, ^{232}Th series, and ^{40} K in background gamma radiation level is 25%, 40% and 35% respectively [2, 3].

The cosmic radiation level varies with the latitude and altitude in reference of mean sea level so that polar and mountain inhabitants as well as aircrew and frequent air travelers are more prone to receive higher cosmic radiations exposure but terrestrial radiation level does not fluctuate with the heights [4]. However, the variation in terrestrial gamma radiation dose rate is higher as compared to cosmic and former one also contributes higher to the total background radiation level [5]. The United Nation of Scientific Commission on Effect of Atomic Radiation (UNSCEAR) has reported the radiation dose rate due to cosmic radiation at mean sea level is 32 nSv/h and population weight average of outdoor terrestrial radiation dose rate is 59 nSv/h [6, 7]. The annual effective dose due to terrestrial as well as cosmic gamma radiation is 0.870 mSv/year collectively [6, 7].

Radon is the significant source of radiation in indoor environment; but in outdoor environment, the gamma radiation dose rate significantly contributed by the radionuclides present in earth's crust (primordial), rocks, soil, air and water and even human body itself. In addition to natural sources, the artificial sources such as medical, nuclear testing and accidents etc. contribute to the radiation exposure. So, it is quite obvious that human beings encounter a number of health problems due to continuous exposure of natural as well as artificial radiations. At certain level of exposure, radiations interact with human cells and destroy their structure that leads to a set of health problems or cancer in human body [8]. The radiation interaction causes damage in cells, that results in cell death and modifications which leads to malfunction of the organs and tissues and ends with stochastic health effects

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(cancerous and hereditary effects) [6]. The damage to DNA of the nucleus is the main initiating step by which the radiation causes long term effects to the organs and tissues of the body. The mutation caused by radiation interaction with genes is reflected in the form of several disorders and cancer [6]. As the dose to the tissue increases, from a low level, the more and more cells are prone to get damaged and probability of stochastic effects occurring increases. As per the present study, the outdoor gamma radiation dose rate has a positive correlation with malignant tumor in humans [9]. Therefore, it becomes necessary to evaluate the outdoor gamma radiation levels people are exposed to and keep them under observation on a regular basis. Therefore, in recent years, various studies have been conducted to evaluate the gamma radiation dose rate and the factors which affect its level in the environment [2, 4, 5, 10–12]. Therefore, in this study systematic quantification of outdoor gamma radiation dose was employed. The human health risk due to the exposure of gamma radiation was assessed by computing annual effective dose (AED) and excess lifetime cancer risk (ELCR). The seasonal variation in gamma radiation level and their possible factors were studied.

Study area

Panipat district of Haryana was selected for this study. It is an agricultural as well as industrial district of Eastern Haryana, India. Its geographical extent lies from 29°10′15″ to 29°30′25″ in North to 76°38′30″ to 77°90′15″ in East. It occupies an area of nearly 1263 km^2. The study area is the semi-arid type and receives maximum rainfall during July to September i.e. monsoon period, with an average rainfall of 680 mm. The surface water resources in the region are usually perilous and they do not receive water for agricultural activities in the non-monsoon season. Therefore, the local population mostly uses groundwater obtained from privately owned wells for domestic, irrigation and industrial purposes [13]. Panipat district is completely covered by old and new alluvium deposits of quaternary to recent age, consisting majorly of clay and sand. The alluvial deposits of quaternary age covered the whole district which majorly comprises of recent alluvial deposits of the vast Gangetic alluvial plains. The investigation area and measurement locations of gamma radiation dose rate of Panipat district is shown in Fig. 1.

Methodology

A systematic measurement of gamma dose rate was employed by dividing the district into grids having size of 6×6 km^2. Total 45 locations were investigated in winter and summer season and GPS coordinates were recorded using Garmin 78S. The outdoor gamma dose rate was measured using handheld Polimaster PM 1405 Radiation monitor. This instrument is based on Geiger-Muller technique and measures terrestrial as well as cosmic radiation dose rate. Five measurements per grid were done by holding the monitor 1 m above from the ground and mean dose rate was taken to get concordant dose rate. The energy range of the monitor to measure gamma radiation is 0.050 – 3.000 MeV and its detection limit for gamma dose rate is from 0.010 μSv/h to 100 mSv/h. It has measurement accuracy of $\pm(20+K/H)$ % where K is coefficient, taken as 1 nSv/h and H is dose rate in nSv/h [14]. The locations were pointed in Panipat map using Arc GIS 10.7 software.

Calculation of annual effective dose (AED)

The annual effective dose due to outdoor gamma radiation was calculated. The effect due to ionizing radiation on human beings was evaluated using annual effective dose. The AED was calculated using the following equation:

$$\text{AED (mSv/year)} = \left\{ \begin{array}{l} \text{D (nSv/h)} \times \text{T} \\ \times \text{ conversion coefficient } \times \text{ occupancy factor} \end{array} \right\} \tag{1}$$

where D is the outdoor gamma dose rate in nSv/h, T is the time conversion factor which was taken as 8760 (365×24), the conversion coefficient was taken as 0.700 Sv/Gy [6] and the occupancy factor for outdoor exposure was taken as 0.200.

Calculation of excess lifetime cancer risk (ELCR)

The cancer risk estimates the potential carcinogenic effects involving the probability of cancer incidence in population for specific lifetime. Therefore, lifetime excess cancer risk was calculated using the following equation:

$$\text{ELCR} = (\text{AED} \times \text{ALD} \times \text{RF}) \tag{2}$$

where AED is the annual effective dose, ALD is the average life duration in India which was taken as 65.8 [11] years and RF is the risk factor and its suggested value by ICRP is 0.057 [15].

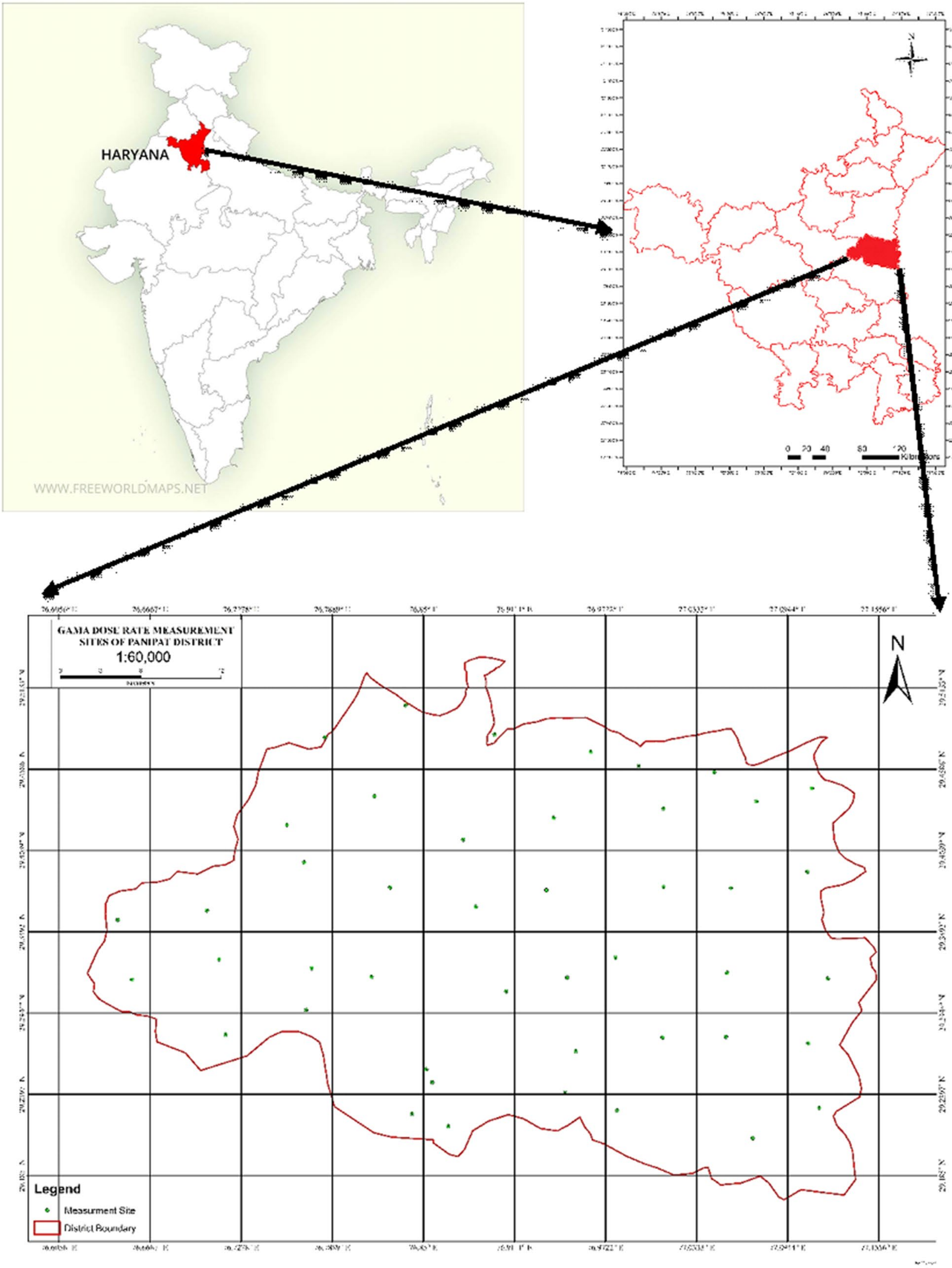

Fig. 1 Grid Map showing district locations and measurement sites of Panipat district

Table 1 Represents the gamma radiation dose rate, annual effective dose, and excess lifetime cancer risk in winter and summer seasons

Sample code	Gamma radiation level (nSv/h)		AED (mSv/year)		Excess lifetime cancer risk (ELCR)×10E-3	
	Winter	Summer	Winter	Summer	Winter	Summer
P-1	177±8.850	159±7.950	0.217±0.011	0.195±0.010	0.814×10E-3	0.731×10E-3
P-2	132±6.600	98±4.900	0.162±0.008	0.120±0.006	0.607×10E-3	0.451×10E-3
P-3	182±9.100	98±4.900	0.223±0.011	0.120±0.006	0.837×10E-3	0.451×10E-3
P-4	165±8.250	120±6.000	0.202±0.010	0.147±0.007	0.759×10E-3	0.552×10E-3
P-5	168±8.400	103±5.150	0.206±0.010	0.126±0.006	0.773×10E-3	0.474×10E-3
P-6	136±6.800	85±4.250	0.167±0.008	0.104±0.005	0.626×10E-3	0.391×10E-3
P-7	118±5.900	98±4.900	0.145±0.007	0.120±0.006	0.543×10E-3	0.451×10E-3
P-8	147±7.350	94±4.700	0.18±0.009	0.115±0.006	0.676×10E-3	0.432×10E-3
P-9	145±7.250	91±4.550	0.178±0.009	0.112±0.006	0.667×10E-3	0.419×10E-3
P-10	138±6.900	97±4.850	0.169±0.008	0.119±0.006	0.635×10E-3	0.446×10E-3
P-11	125±6.250	94±4.700	0.153±0.008	0.115±0.006	0.575×10E-3	0.432×10E-3
P-12	145±7.250	93±4.650	0.178±0.009	0.114±0.006	0.667×10E-3	0.428×10E-3
P-13	158±7.900	88±4.400	0.194±0.010	0.108±0.005	0.727×10E-3	0.405×10E-3
P-14	170±8.500	176±8.800	0.208±0.010	0.216±0.011	0.782×10E-3	0.810×10E-3
P-15	177±8.850	117±5.850	0.217±0.011	0.143±0.007	0.814×10E-3	0.538×10E-3
P-16	122±6.100	98±4.900	0.150±0.007	0.120±0.006	0.561×10E-3	0.451×10E-3
P-17	165±8.250	126±6.300	0.202±0.010	0.155±0.008	0.759×10E-3	0.580×10E-3
P-18	173±8.650	112±5.600	0.212±0.011	0.137±0.007	0.796×10E-3	0.515×10E-3
P-19	174±8.700	112±5.600	0.213±0.011	0.137±0.007	0.800×10E-3	0.515×10E-3
P-20	144±7.200	104±5.200	0.177±0.009	0.128±0.006	0.662×10E-3	0.478×10E-3
P-21	150±7.500	98±4.900	0.184±0.009	0.120±0.006	0.690×10E-3	0.451×10E-3
P-22	176±8.800	147±7.350	0.216±0.011	0.180±0.009	0.810×10E-3	0.676×10E-3
P-23	190±9.500	153±7.650	0.233±0.012	0.188±0.009	0.874×10E-3	0.704×10E-3
P-24	183±9.150	114±5.700	0.224±0.011	0.140±0.007	0.842×10E-3	0.524×10E-3
P-25	169±8.450	126±6.300	0.207±0.010	0.155±0.008	0.777×10E-3	0.580×10E-3
P-26	189±9.450	113±5.650	0.232±0.012	0.139±0.007	0.869×10E-3	0.520×10E-3
P-27	160±8.000	105±5.250	0.196±0.010	0.129±0.006	0.736×10E-3	0.483×10E-3
P-28	131±6.550	109±5.450	0.161±0.008	0.134±0.007	0.603×10E-3	0.501×10E-3
P-29	170±8.500	105±5.250	0.208±0.010	0.129±0.006	0.782×10E-3	0.483×10E-3
P-30	192±9.600	102±5.100	0.235±0.012	0.125±0.006	0.883×10E-3	0.469×10E-3
P-31	191±9.550	115±5.750	0.234±0.012	0.141±0.007	0.879×10E-3	0.529×10E-3
P-32	158±7.900	103±5.150	0.194±0.010	0.126±0.006	0.727×10E-3	0.474×10E-3
P-33	175±8.750	98±4.900	0.215±0.011	0.120±0.006	0.805×10E-3	0.451×10E-3
P-34	158±7.900	107±5.350	0.194±0.010	0.131±0.007	0.727×10E-3	0.492×10E-3
P-35	164±8.200	103±5.150	0.201±0.010	0.126±0.006	0.754×10E-3	0.474×10E-3
P-36	175±8.750	122±6.100	0.215±0.011	0.150±0.008	0.805×10E-3	0.561×10E-3
P-37	143±7.150	98±4.900	0.175±0.009	0.120±0.006	0.658×10E-3	0.451×10E-3
P-38	117±5.850	103±5.150	0.143±0.007	0.126±0.006	0.538×10E-3	0.474×10E-3
P-39	138±6.900	157±7.850	0.169±0.008	0.193±0.010	0.635×10E-3	0.722×10E-3
P-40	162±8.100	178±8.900	0.199±0.010	0.218±0.011	0.745×10E-3	0.819×10E-3
P-41	216±10.800	118±5.900	0.265±0.013	0.145±0.007	0.994×10E-3	0.543×10E-3
P-42	135±6.750	121±6.050	0.166±0.008	0.148±0.007	0.621×10E-3	0.557×10E-3
P-43	135±6.750	99±4.950	0.166±0.008	0.121±0.006	0.621×10E-3	0.455×10E-3
P-44	142±7.100	116±5.800	0.174±0.009	0.142±0.007	0.653×10E-3	0.534×10E-3
P-45	148±7.400	131±6.550	0.182±0.009	0.161±0.008	0.681×10E-3	0.603×10E-3
Average	158.40±7.92	113.42±5.67	0.194±0.010	0.139±0.007	0.729×10E-3	0.522×10E-3
Minimum	117±5.850	85±4.250	0.143±0.007	0.104±0.005	0.538×10E-3	0.391×10E-3
Maximum	216±10.800	178±8.900	0.265±0.013	0.218±0.011	0.994×10E-3	0.819×10E-3

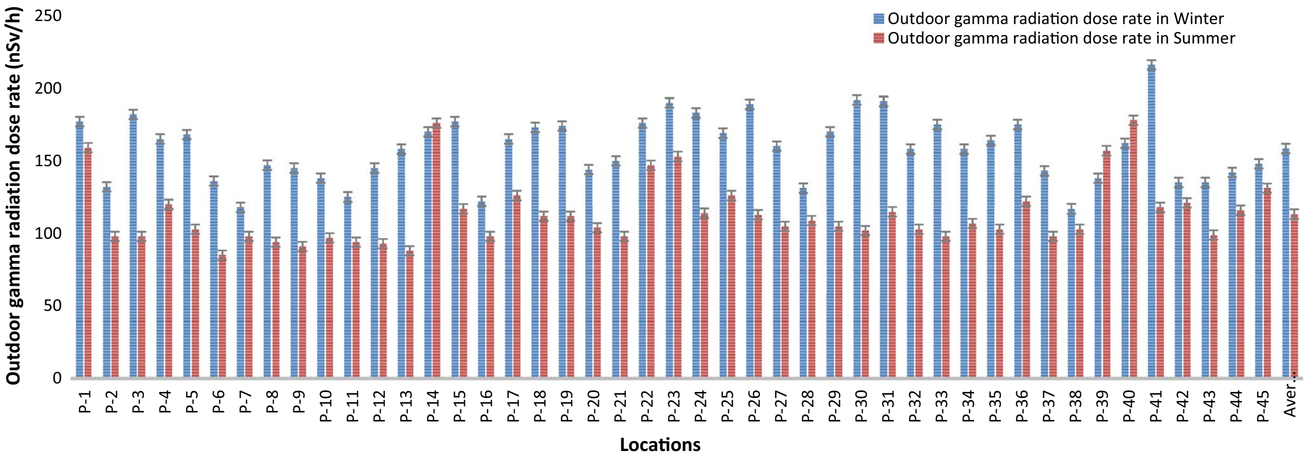

Fig. 2 Outdoor gamma radiation dose rate in winter and summer seasons

Results and discussion

The results of measurement of outdoor gamma radiation dose rate at 45 locations of Panipat district for both seasons i.e. winter and summer are given in Table 1. It was found to range between 117 ± 5.850 nSv/h and 216 ± 10.800 nSv/h with an average of 158.400 ± 7.920 nSv/h in winter season (Fig. 2) and from 85 ± 4.250 nSv/h to 178 ± 8.960 nSv/h, with an average of 113.420 ± 5.670 nSv/h in summer season (Fig. 2). Only at one location in winter season i.e. P-41, the gamma radiation dose rate was higher than 200 nSv/h, while for all locations, in both seasons, the gamma radiation dose was observed within the typical range of 20 to 200 nSv/h as reported by UNSCEAR. Somewhat similar results for outdoor gamma radiation dose rate were observed in different regions of India [16, 17].

Seasonal variation

At 51% locations in winter season and 38% locations in summer season, the gamma dose rate level was higher than its mean value in winter and summer season respectively. The average gamma dose rate in winter season was higher than the summer season as shown in Fig. 2. Possibly, this may be due the precipitation of radionuclides such as ^{214}Pb and ^{214}Bi which are brought down to ground surface with the scavenging effect of raining in winter season (post-monsoon period) [18]. Precipitation elevates gamma dose rate intensity at ground surface significantly [19–21]. Various radionuclides consisting ^{7}Be, ^{212}Pb, ^{210}Pb were observed in precipitation [19].

Annual effective dose and excess lifetime cancer risk

The annual effective dose (AED) due to outdoor gamma radiation was found to be 0.143 ± 0.007 mSv/year to 0.265 ± 0.013 mSv/year and 0.104 ± 0.005 mSv/year to 0.218 ± 0.011 mSv/year with an average of 0.194 mSv/year

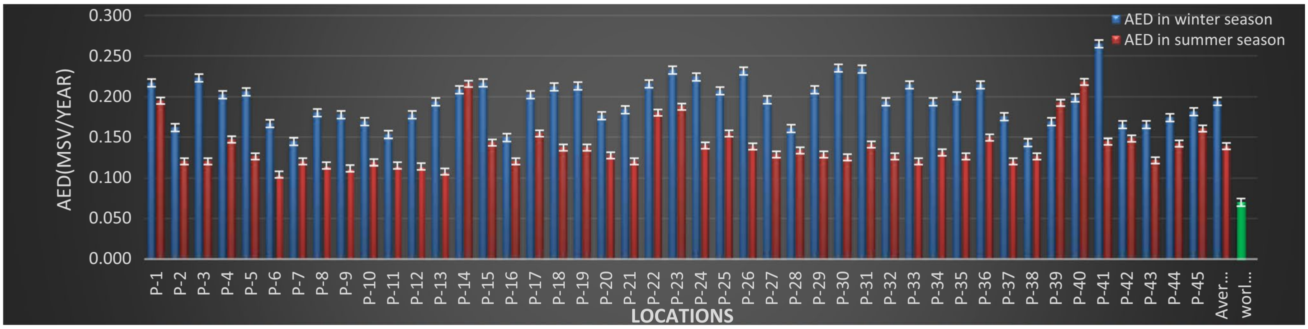

Fig. 3 AED in winter and summer seasons

and 0.139 mSv/year in winter and summer season respectively as detailed in Table 1. As seen from the values, the AED is higher in winter season as compared to summer season was attributed to higher gamma radiation level in winter as compared to summer season [18–21]. The AED at all locations, in both seasons was somewhat higher than the worldwide average value of 0.070 mSv/year [6] as shown in Fig. 3. The higher terrestrial outdoor radiation level is due to the radionuclides present in parental rocks that increases the background radiation level in the area. The district is dominated by gangetic alluvium of quaternary age which has been reported to have higher natural radioactivity [11, 22]. In previous study of groundwater of Panipat district, the groundwater at many locations was found to be contaminated with high uranium [23, 24]. Daulta et al., reported that in 75% of groundwater samples of Panipat district was observed uranium contamination higher than the recommended limit of 30 ppb of WHO [24, 25].

The excess lifetime cancer risk was computed and observed in to be ranged between 0.538×10^{-3} and 0.994×10^{-3} in winter while it was 0.391×10^{-3} to 0.819×10^{-3} in summer. The average value of ELCR in both seasons was higher than the worldwide average value of 0.290×10^{-3} [8]. Although the value of AED and ELCR at studied location of Panipat district was higher than the reported worldwide average values but all values are well below than the background radiation level of 2.400 mSv/year. The AED value due to gamma radiation dose rate at all locations in both seasons are well below the permissible value of AED of 1.000 mSv/year as per ICRP [26]. Therefore, it can be suggested that the radiation level measured in the studied area does not possess any serious health hazard. A group of researchers believe the fact that exposure to low level of radiation might prove good for human health as it aids in accelerating the mechanism of DNA damage repair, reduces genetic instability and enhances overall immune response [27–30]. The low levels of radiation (less than 100 mSv) reported to have some curative effects in different ailments like prevention of tumor growth [31, 32], wound healing, to reduce inflammation of lymph glands, relief from arthritis [33–35] and for treatment of various infections [36]. Therefore, it seems important to explore further and conduct epidemiological surveys of studied area for establishing the fact of possible health effect on sizeable segment of population.

Conclusion

In this study, the outdoor gamma radiation dose rate was observed at 45 locations of Panipat district in winter and summer seasons. The observed radiation dose rate at all locations in both seasons was within the typical range of UNCSEAR reported gamma dose rate of 20 to 200 nSv/h except the one location i.e. P-41 in winter season. The AED values at all the investigated locations in both the seasons are higher than the world average AED value but well below the threshold value of AED i.e. 1.000 mSv/year recommended by ICRP. The values of ELCR in both the seasons are higher than the world average value of ELCR (0.290×10^{-3}). Although, the values of AED and ELCR are higher than the world average value but the value of AED is less than the recommended value of ICRP and moreover, the observed radiation dose rate lies in the recommended range of UNCSEAR, therefore, it is suggested that there is no significant health hazard due to outdoor gamma radiation dose rate in the investigated area. The results obtained from this study may form baseline data, but to evaluate the possible health hazard requires detailed epidemiological study of the area.

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