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A study of seasonal variation and impact of geology on gamma radiation levels of district Faridabad of State Haryana, India

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Abstract

In the present study, 366 locations were selected from the Faridabad district of Haryana, India, for seasonal gamma radiation measurements in indoor/outdoor environments. It was measured by a radiation monitor PM 1405 (Polimaster instrument/ Republic of Belarus). The measured gamma was statistically analysed using the Wilcoxon signed-ranks test, Shapiro–Wilk test, Mann–Whitney test, and ANOVA test. The significance value of the outdoor gamma dose rate in winter ($OGDR_W$) is found to be less than the significance level (0.05), indicating that the geology has a significant impact on $OGDR_W$. The estimated annual effective dose was related to the values stated by UNSCEAR and ICRP.

Keywords Gamma radiation · Seasonal variation · Geology · Statistical analysis · Annual effective dose rate

Introduction

Natural radioactivity originates from the disintegration of primordial radionuclides and cosmic radiation interaction, which is responsible for continuous exposure to the human body. The total annual effective dose due to natural radiation to the public is 2.2 mSv [1]. The greatest contributor to natural radiation exposure to humans is radon along its progenies, about 55% of total annual exposure (responsible for 1.2 mSv radiation dose) [2, 3]. The gamma radiation from cosmogenic and terrestrial sources accounts for 37.5% of the total annual exposure, which is 2nd greatest contributor (responsible for 0.9 mSv radiation dose) [1]. Cosmic rays from outer space, whereas the ^{235}U, ^{238}U, and ^{232}Th series of terrestrial radioactive nuclides and non-series ^{40}K cause the terrestrial component. However, the measurements of radon along its decay products in the environment are primarily concerned, but monitoring gamma radiation level is also essential. Continuous exposure to gamma radiation over a long duration can have serious health hazards. High gamma radiation exposure to living beings can damage the cells in the body and can be responsible for stochastic health effects and the likelihood of producing genetic damage and cancer. Radiation can either injure or pass through cells without causing harm because the human body has the ability to mend cells through a self-repair mechanism. However, there is also a possibility of cell damage in the case of high doses or exposure for a long period [4, 5].

Environmental parameters such as moisture contents, temperature, pressure, diurnal and seasonal variation of weather, the geology of the regions, altitude of monitoring locations, building materials of dwellings, ventilation conditions, the lifestyle of peoples, etc., affect the levels of natural radiations (increased or decreased) in the environment [6–21]. Elevated thorium in India perfectly aligns with the outcomes of enriched thoron in the environment. It was shown in the radiation examined chart of India due to the elevated thorium level in the earth's crust [22, 23]. Thoron itself emits alpha radiation, but the progenies of thoron, which are ^{212}Pb, ^{212}Bi, and ^{208}Tl, emit gamma radiation. Radon emits alpha radiation, but its progenies ^{214}Pb, ^{214}Bi, and ^{210}Pb emit gamma radiation. Tanwar et al. [24] reported that the regions of northern India have the Gangetic sediment of quaternary age that possesses more natural radioactivity and may be responsible for the increased level of

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outdoor gamma. Literature evidence indicates that gamma levels vary seasonally. Patel et al. [5] reported that the outdoor gamma exposure rate was marginally lower in summer than in winter. Patni et al. [19] reported that the local geology of the regions affects the gamma levels. Thus, the literature review reveals that local geology, influences of seasonal variations, enhanced building materials used for construction, etc., affect particularly the gamma level. However, a few investigations of gamma levels were performed in the nearby and other regions of India to understand the variation of gamma radiation [25–33]. No such data on gamma radiation levels is available in the literature for the present study region. Also, in the published literature, attempts were made to estimate the outdoor gamma radiation levels, but there is scanty data on direct indoor gamma radiation measurements. In those studies, the indoor gamma levels (gamma radiation dose) were calculated using indoor occupancy factors considering outdoor gamma radiation values. Since building materials affect the indoor radiation levels and further decay products (^{214}Pb, ^{214}Bi, and ^{210}Pb/^{212}Pb, ^{212}Bi, and ^{208}Tl) also emit gamma radiation may be influencing factors for indoor gamma. Thus, there is a research gap in this field.

The main objectives of this paper were to measure the gamma radiation level in indoor and outdoor air, to estimate the seasonal variation of gamma level, to study the impact of geology (lithology) on gamma level, and to analyse the results statistically. The outcomes of the paper will contribute to the national radiation mapping program. This study is also important in considering both climate change and human health, which are addressed in the action plan for the Sustainable Development Goals (SDGs) of the United Nations (SDGs 3 and 13).

About the study area

District Faridabad extends longitude and latitude from 28° 13′ 16″ E to 28° 28′ 08″ E and from 77° 26′ 51.4″ N to 77° 19′ 36.6″ N, as shown in Fig. 1. The study area is surrounded in the east, west, and north by Uttar Pradesh, Gurugram and Mewat regions, and Delhi. Faridabad has total area of 741 sq/km and has 149 villages and 3 towns. The population of this region is about 2,515,529, estimated up to 2023 [34]. Handpumps, tubewells, borewells, etc., are the groundwater and Agra Canal and river Yamuna are the surface water sources in this area. Groundwater occurs in alluvium and the underlying weathered/fractured quartzites [35, 36]. The geology (lithology) information of the study area is depicted in Fig. 2. It included the rocks of the age Holocene and the group of rocks is newer alluvium with lithology of grey micaceous sand, silt, and clay, rocks of the age Holocene and the group of the rock is newer alluvium with lithology of yellowish-brown loose sand with or without kankar, rocks of the age Meghalayan and the group of rock is newer alluvium with lithology of grey micaceous sand with or without kankar, rocks of the age Middle-Late Pleistocene and the group of rock is older alluvium with lithology of oxidised silt clay with and micaceous sand and kankar, rocks of the age Palaeoproterozoic and the group of

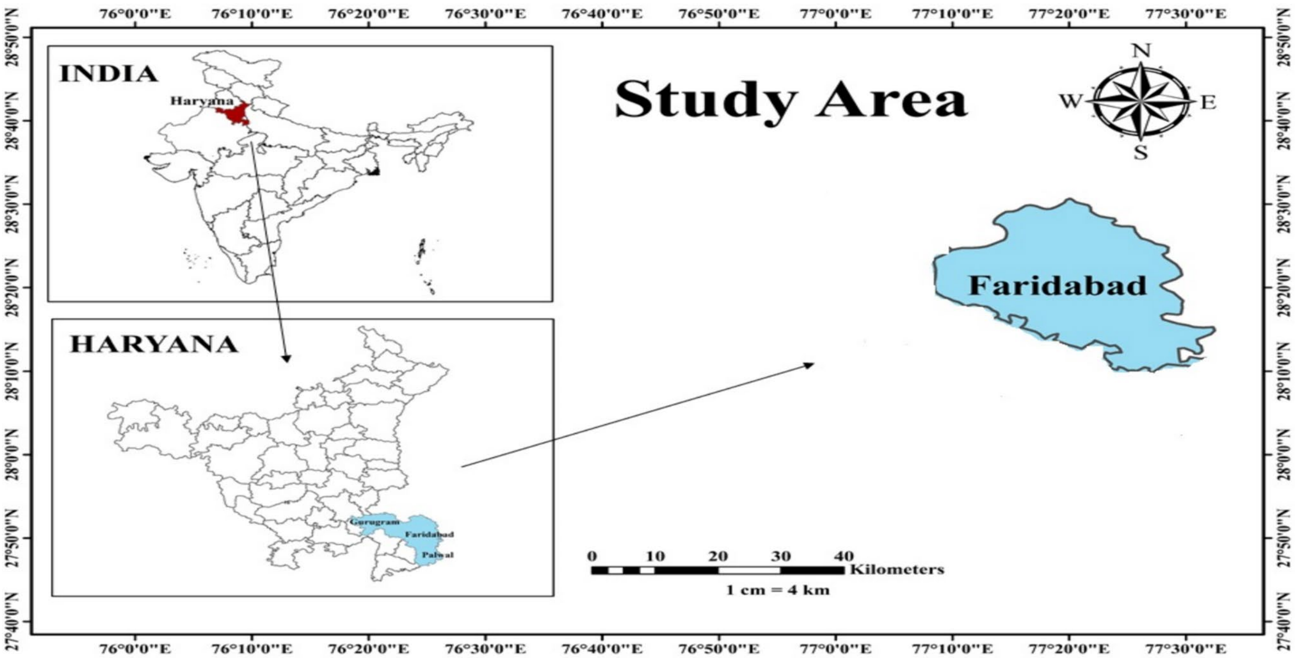


Fig. 1 The map of study region of Faridabad

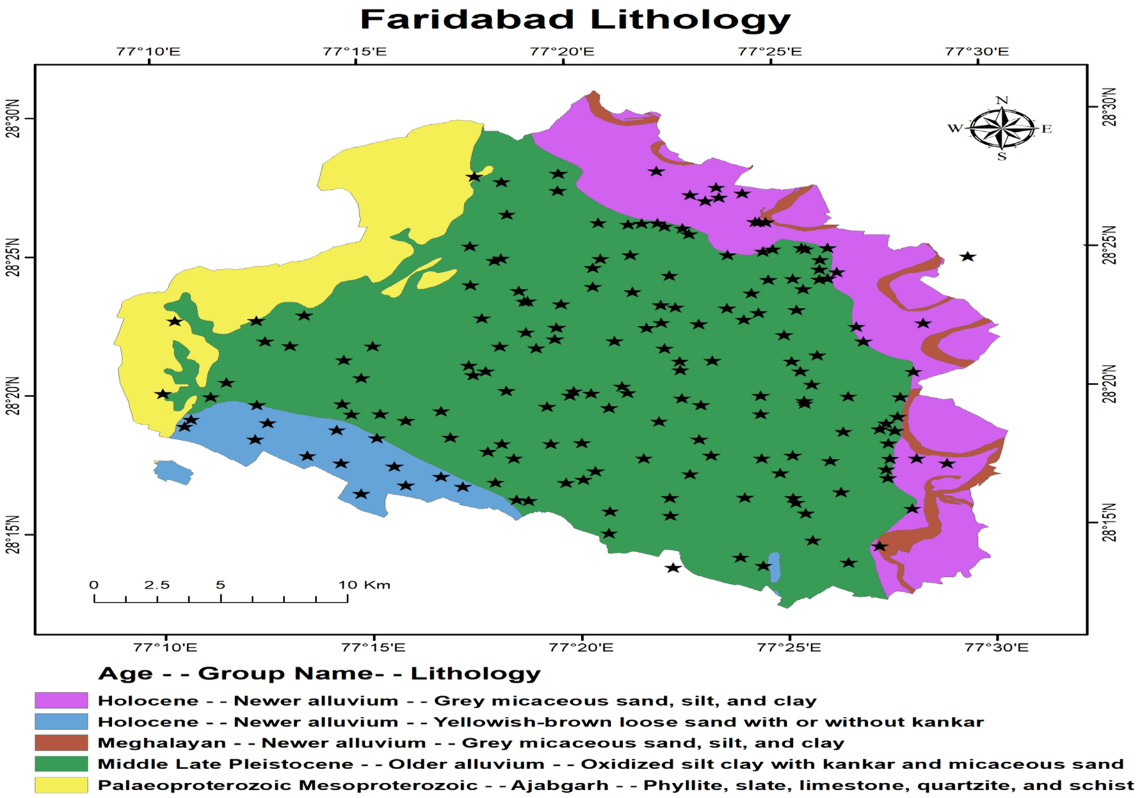


Fig. 2 Geology (lithology) map of the study area

rock is Mesoproterozoic Ajabgarh with lithology of Phyllite, slate, limestone, quartzite, and schist. Out of these five different categories of geology (lithology), the measurements were carried out in the four geological regions, as mentioned in Table 1.

Methodology

Gamma radiation monitoring

A total of 366 sampling locations for gamma radiation measurements were selected to ensure the entire study region was covered. 183 locations were selected for indoor monitoring (inside the dwellings) and 183 for outdoor monitoring (just outside the dwellings in open space). The outdoor locations were chosen just outside the dwellings so that an intercomparison could be made with the indoor gamma radiation levels. Location coordinates were noted with the help of GPS MAP (GARMIN 78), which were further used to prepare gamma radiation interpolation maps of the region. For every location, measurements were carried out 5 times with the error value within 5%, and an average was drawn from it. The gamma radiation level was measured using a radiation monitor PM 1405 (Polimaster instrument, Republic of Belarus). The gamma exposure rate was measured at one meter from the ground. Gamma radiation of 0.05–3 MeV can be detected from the PM 1405 monitor. It is capable

Table 1 Description of Geology (lithology) of district Faridabad, State Haryana, India

Geology group	Age-group name with lithology description	Monitoring locations (indoor/outdoor)
Group 1	Holocene (newer alluvium) with grey micaceous sand, silt, and clay	17
Group 2	Holocene (newer alluvium) with yellowish brown loose sand with or without kankar	13
Group 3	Middle Late Pleistocene (older alluvium) with micaceous sand and oxidised silt clay with kankar	03
Group 4	Palaeoproterozoic Mesoproterozoic (Ajabgarh) with phyllite, slate, limestone, quartzite, and schist	150

of measuring doses between 0.01 µSv/h and 100 mSv/h. It was calibrated by a cesium-137 source with an accuracy of (20 + 1/H)%. As per the published reports, the results of this instrument are comparable with the thermoluminescence dosimeter, a nearly ten percent variation in results, which might be the error in measurements [19, 37].

The AED due to gamma radiation was calculated for both outdoor ($AED_{outdoor}$) and indoor (AED_{indoor}) environments using Eqs. 1 and 2 [1, 5]

$$AED_{outdoor}\left(\frac{mSv}{y}\right) = \left\{ OGDR\left(\frac{nSv}{h}\right) \times T_{out}\left(\frac{h}{y}\right) \times C_c\left(\frac{Sv}{Gy}\right)\right\} \tag{1}$$

and

$$AED_{indoor}\left(\frac{mSv}{y}\right) = \left\{ IGDR\left(\frac{nSv}{h}\right) \times T_{in}\left(\frac{h}{y}\right) \times C_c\left(\frac{Sv}{Gy}\right)\right\} \tag{2}$$

where, OGDR and IGDR are outdoor and indoor gamma dose rates (nSv/h), respectively, T_{out} and T_{in} are annual outdoor and annual indoor occupancy times of 1752 h and 7008 h, respectively, and C_c is the conversion coefficient (0.70 Sv/Gy).

Statistical analysis

Descriptive analysis was employed using Microsoft excel 2019. ORIGIN was used for statistical analysis of data on gamma radiation levels using the Wilcoxon signed-ranks test, Shapiro–Wilk test, and Mann–Whitney test. ANOVA was employed on the data using SPSS. Shapiro–Wilk test was applied to test the normality of data, weighing the alternate hypothesis—that the data is not normally scattered—against the null hypothesis, which holds that the data is normally distributed. Wilcoxon signed-ranks test was applied to see the impact of season on gamma radiation level, considering the null hypothesis that gamma radiation level is the same in different seasons while the alternate is that the gamma dose rate is different in different seasons. Mann–Whitney test was applied to see the difference between indoor and outdoor gamma radiation levels. ANOVA was utilised to see the impacts of geology on gamma radiation levels. ArcMap 10.7 was employed to interpolate the radiation level in both seasons to comprehend the gamma dose rate distribution pattern.

Results and discussion

A wide variation of gamma was observed in the present study. It was due to the difference in topography, geology, and altitude of locations in the present study region. Statistical parameters of measured GDR in indoor and outdoor regions for both seasons are shown in Table 2. The observed mean values of GDR for indoor (i.e. 113 nSv/h for winter and 108 nSv/h for summer) and outdoor regions (i.e. 110 nSv/h for winter and 105 nSv/h) for both seasons were higher than the reported average values of outdoor gamma, which are 88 nGy/h and 91 nGy/h, for India and the world, respectively [1, 38]. There are no values reported for IGDR. The results of the present investigation indicate that the gamma radiation dose at 6 locations in the outdoor region and 4 locations in the indoor region for the winter season, and 12 locations in the outdoor region and 7 locations in the indoor region for the summer season were found less than the average gamma radiation dose (i.e., 88 nGy/h) reported for India. Also, the GDR at 11 locations in the outdoor region and 6 locations in the indoor region for the winter season, and 25 locations in the outdoor region and 12 locations in the indoor region for the summer season were found less than the mean GDR (i.e., 91 nGy/h) reported for the world. All locations have a GDR within 20–190 nSv/h, as

Table 2 Statistical parameters of measured gamma dose rate

	Outdoor gamma dose rate in winter ($OGDR_W$) (nSv/h)	Indoor gamma dose rate in winter ($IGDR_W$) (nSv/h)	Outdoor gamma dose rate in summer ($OGDR_S$) (nSv/h)	Indoor gamma dose rate in summer ($IGDR_S$) (nSv/h)
Mean	110	113	105	108
Standard error	1.2	1.2	1.1	1.1
Median	108	110	101	104
Mode	112	110	98	98
Std deviation	16.2	15.8	15.5	15.2
Sample variance	261.5	250.2	241.4	230
Kurtosis	2.6	2.8	1.6	2.4
Skewness	1.2	1.4	1.2	1.4
Minimum	75	82	75	79
Maximum	179	180	165	172

suggested by UNSCEAR 2000 (United Nations Scientific Committee on the Effects of Atomic Radiation) [1].

The normality of measured gamma levels was examined using the Shapiro–Wilk test, as shown in Table 3. The estimated *p*-values were 3.20×10^{-8} for the outdoor gamma dose rate in the winter season, 1.98×10^{-9} for the indoor gamma dose rate in the winter season, 1.45×10^{-8} for the outdoor gamma dose rate in the summer season, and 1.05×10^{-9} for indoor gamma dose rate in the summer season. Thus, at a significance level (0.05), the null hypothesis was rejected, indicating that the data of $OGDR_W$, $IGDR_W$, $OGDR_S$, $IGDR_S$ was not from the normal distribution.

Seasonal variation of measured gamma levels

The $OGDR_S$ and $IGDR_S$ in pre-monsoon{range (mean)} were found as {75–165 (105)} nSv/h and {79–172 (108)} nSv/h and $OGDR_w$ and $IGDR_W$ in post-monsoon{range (mean)} were found as {75–179 (110)} nSv/h and {82–180 (113) nSv/h respectively, as shown in Table 2. Mean values of $OGDR_w$ and $IGDR_W$ were found higher than $OGDR_S$ and $IGDR_S$. This could be due to radionuclides such as ^{214}Pb and ^{214}Bi that are scavenged by rain during the winter season (post-monsoon period) and brought to the surface. The intensity of the ground surface gamma dose rate is significantly enhanced by precipitation. Radionuclides, including ^{210}Pb, ^{212}Pb, and ^{7}Be were present in the precipitation. Evidence from the published literature suggests that precipitation has the greatest effect on increasing the ambient gamma dose [39–42]. This research supports the trends observed in the afore-mentioned study. The seasonal distributions were statistically analysed. Since the measured gamma level is not normally distributed. Therefore, Wilcoxon signed-rank test was performed to check whether seasonal monitoring is statistically significant or not. It was applied between the outdoor gamma levels of both seasons and between indoor gamma levels of both seasons, as shown in Tables 4 and 5.

Table 3 Shapiro–Wilk test to check the distribution of measured gamma dose rate

	DF	Statistic	*p* value	Decision at level (5%)
$OGDR_W$	183	0.92326	3.20E−08	Reject normality
$IGDR_W$	183	0.90543	1.98E−09	Reject normality
$OGDR_S$	183	0.91843	1.45E−08	Reject normality
$IGDR_S$	183	0.90105	1.05E−09	Reject normality

As depicted from the test statistic of Table 4, the *p*-value is lesser than level of significance. Thus, it is concluded that the two distributions are significantly different at the significance level (0.05).

As depicted from test statistic of Table 5, similarly, the *p*-value is lesser than the level of significance. Thus, it is concluded that the two distributions are significantly different at the significance level (0.05). Therefore, it can be stated that the seasons have a significant impact on the indoor/outdoor gamma radiation level. A similar variation and trend were observed by Tanwer et al. [24] and Jindal et al. [10].

GDR in indoor/outdoor regions

The outside locations for gamma radiation monitoring were selected outside the dwellings so that the results could be intercompared with the indoor gamma levels and separate dose values could be determined using indoor and outdoor occupancy factors. The results indicate that the mean IGDR is found to be higher than the OGDR. It might be due to the effect of building materials used for construction. The walls of the investigated dwellings were made up of bricks and other construction materials such as cement, concrete, soil, etc., being used to construct floors and roofs, which continuously emit radiation. Singh et al. [43] reported an increased level of thoron and radon in the dwellings of the district

Table 4 Wilcoxon signed-ranks test to analyse the difference between outdoor gamma levels in both seasons

	N	Min	Q1	Median	Q3	Max
Descriptive statistics						
$OGDR_W$	183	75.5	99.5	108	117.5	178.5
$OGDR_S$	183	75	95	101	112	165
			N		Mean rank	Sum rank
Ranks						
$OGDR_S$–$OGDR_W$		Positive rank	17		50.2	858.5
$OGDR_S$–$OGDR_W$		Negative rank	165		95.7	15799.5
W			Z			Asymp. prob > W
Test statistics						
15799.5			10.50			0

Table 5 Wilcoxon signed-ranks test to analyse the difference between indoor gamma levels in both seasons

	N	Min	Q1	Median	Q3	Max
Descriptive statistics						
$IGDR_W$	183	82	102	110	120	180
$IGDR_S$	183	79	98	104	116	172

		N	Mean rank	Sum rank
Ranks				
$IGDR_S$–$IGDR_W$	Positive rank	7	31.8	223
$IGDR_S$–$IGDR_W$	Negative rank	170	91.3	15,530

W	Z	Asymp. prob > W
Test statistics		
15,530	11.23	0

Faridabad. Although indoor thoron and radon do not affect themselves as they are alpha emitters, the daughter products of thoron (^{212}Pb, ^{212}Bi, and ^{208}Tl) and radon (^{214}Pb, ^{214}Bi, and ^{210}Pb) emit gamma radiations. Thus, indoor gamma radiations may be more inside the dwellings than outside regions. Also, direct gamma radiation emitted from building materials is more contributed to indoor gamma radiation levels. These facts support the increased level of indoor gamma radiation compared to outdoor regions. Measured indoor and outdoor gamma distributions were statistically analysed. Since the measured gamma level is not normally distributed. Therefore, a non-parametric Mann–Whitney test was used to determine whether there was a significant difference between the indoor and outdoor measurements for the same season, as shown in Tables 6 and 7.

As observed from test statistic of Table 6, the *p*-value (0.04077) is lesser than level of significance (0.05). Thus, it is concluded that the two distributions are significantly different at the significance level (0.05).

From the test statistic of Table 7, it was found that the *p*-value (0.01897) is lesser than the level of significance (0.05). Thus, it is concluded that the two distributions are significantly different at the significance level (0.05). Therefore, it can be inferred that indoor and outdoor gamma radiation levels in both seasons are different, and this was statistically supported by the sufficient no. of events through the Mann–Whitney test. It was also revealed that some factors of the indoor environment are contributing to gamma radiation level, leading to its higher level than the outdoor environment. This may be due to the geological composition of indoor construction material that enhances the radiation level in the indoor environment.

The ArcMap 10.7 program's inverse distance weightage (IDW) approach was used to generate interpolation maps of the gamma level. Using values from neighbouring weighted locations, this method calculates an average value for unsampled placesThe gamma dose rate helps to comprehend the distribution pattern as shown in Fig. 3 and Fig. 4.

Table 6 Mann–Whitney test to analyse the difference between outdoor and indoor gamma levels in the winter season

	N	Min	Q1	Median	Q3	Max
Descriptive statistics						
$OGDR_W$	183	75.5	99.5	108	117.5	178.5
$IGDR_W$	183	82	102	110	120	180

	N	Mean rank	Sum rank
Ranks			
$OGDR_W$	183	172.2	31,510
$IGDR_W$	183	194.8	35,651

U	Z	Asymp. prob > U
Test statistics		
14,674	−2.04	0.04077

Table 7 Mann–Whitney test to analyse the difference between outdoor and indoor gamma levels in winter season

	N	Min	Q1	Median	Q3	Max
Descriptive statistics						
$OGDR_S$	183	75	95	101	112	165
$IGDR_S$	183	79	98	104	116	172

	N	Mean rank	Sum rank
Rank			
$OGDR_S$	183	170.5	31,207
$IGDR_S$	183	196.5	35,954

U	Z	Asymp. prob > U
Test statistics		
14,371	− 2.3462	0.01897

Impact of geology (lithology) on GDR

The descriptives of GDR for all geological (lithological) regions for indoor and outdoor regions for both seasons are shown in Table 8. The mean GDR for outdoor and indoor regions were found 110 nSv/h for Group 1, 97 nSv/h for Group 2, 109 nSv/h for Group 3, 111 nSv/h for Group 4 and 113 nSv/h for Group 1, 102 nSv/h for Group 2, 112 nSv/h for Group 3, 114 nSv/h for Group 4, respectively for winter season. The mean GDR for outdoor and indoor regions were found 104 nSv/h for Group 1, 95 nSv/h for Group 2, 102 nSv/h for Group 3, 106 nSv/h for Group 4 and 107 nSv/h for Group 1, 98 nSv/h for Group 2, 106 nSv/h for Group 3, 109 nSv/h for Group 4, respectively for summer season.

ANOVA is used to study the impact of geology (lithology) on gamma radiation levels. The study region has four different geological groups, and the number of measurements was 17, 13, 3, and 150 in groups 1–4, respectively, as shown in Table 8. The significance value for $OGDR_W$ is $0.026 <$ level of significance (0.05), but greater than in the case of the $IGDR_W$, $OGDR_S$, and $IGDR_S$ as shown in Table 9. Therefore, it can be concluded that geology (lithology) has a significant impact on $OGDR_W$, while it is statistically insignificant in the case of $IGDR_W$, $OGDR_S$, and $IGDR_S$.

Inter-comparison of the results

The results of the present investigation were compared with the outcomes of other investigations carried out in India. Tanwar et al. [24] reported that the annual average OGDR in districts Karnal, Kaithal, and Kurukshetra, State Haryana, were found 116, 122, and 110 nSv/h, respectively. Tanwar et al. [33] reported that the OGDR {range (mean)} in districts Churu and Jhunjhunu, State Rajasthan, varies as {32–231 (134)} nSv/h and {75–188 (124)} nSv/h, respectively. Jindal et al. [26] reported that the OGDR {range (mean)} varies as {108–172 (137)} nSv/h in Bhilai, Chhattisgarh State. Jindal et al. [27] reported that the OGDR {range (mean)} varies as {103–201 (144)} nSv/h in Balod, Chhattisgarh State. Tanwar et al. [29] reported that the OGDR{range (mean)} in district Panipat, State Haryana, was found as {85–216 (135)} nSv/h. Tanwar et al. [32] reported that the OGDR{range (mean)} in district Panchkula, State Haryana, was found as {70–168 (97)} nSv/h. Patel et al. [5] reported that the OGDR {range (mean)} was found as {40–278 (128)} nSv/h, {19–287 (152)} nSv/h, {40–210 (128)} nSv/h, and {74–287 (152)} nSv/h, in district Bharuch, Vadodara, Narmada, and Anand of State Gujrat, respectively. Jindal and Sar [4] reported that the OGDR {range (mean)} of durg, Chhattisgarh State, varies as {117–185 (154)} nSv/h. Raja et al. [30] reported that the OGDR {range (mean)} was found as {35–335 (89)} nSv/h in the region of Southern region of Tamilnadu State. Raja et al. [28] reported that the OGDR {range (mean)} was found as {58–3880 (276)} nSv/h in Virudhunagar, Tamilnadu State. The OGDR {range (mean)} in the present study is found as {75–180 (107)} nSv/h. It indicates that the results for OGDR of the present study are comparable with the investigation carried out in other regions of State Haryana and Southern regions of State Tamilnadu, while studies carried out in regions of State Chhattisgarh, State Rajasthan, State Gujrat, and some regions of State Tamilnadu have higher gamma levels.

Estimated AED due to GDR

AED due to OGDR and IGDR was calculated using the results of measured gamma radiation to assess the impact of gamma rays on people. The annual AED in outdoor and indoor regions {range (mean)} was found as {0.093–0.219 (0.135)} mSv/y and {0.402–0.833 (0.553)} mSv/y in the winter and as {0.091–0.202 (0.129)} mSv/y and {0.487–0.844 (0.529)} mSv/y in the summer, respectively. Thus, all values of estimated AED for the winter season

Fig. 3 Spatial distribution of measured GDR_W in **a** outdoor regions and **b** indoor regions

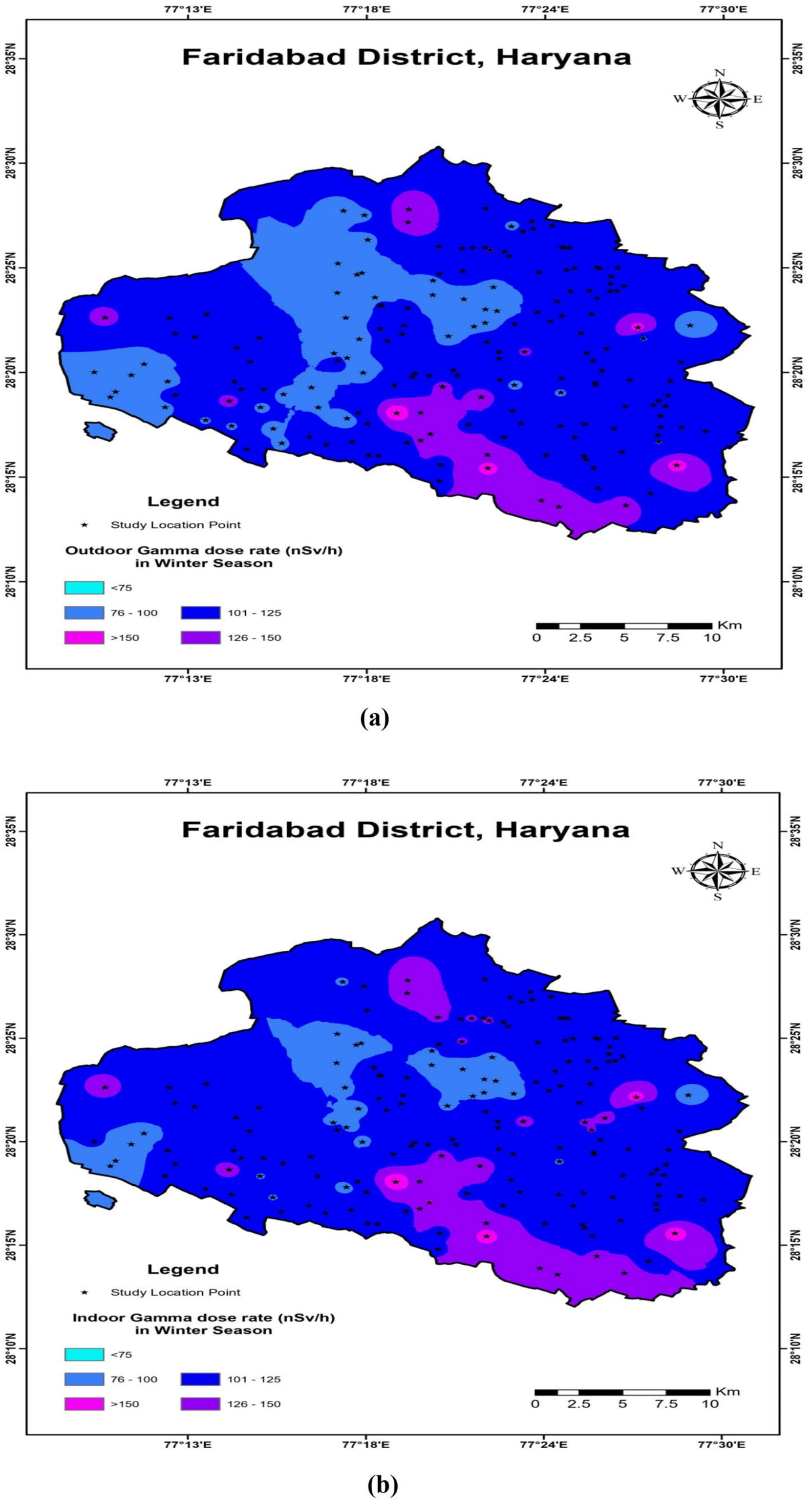
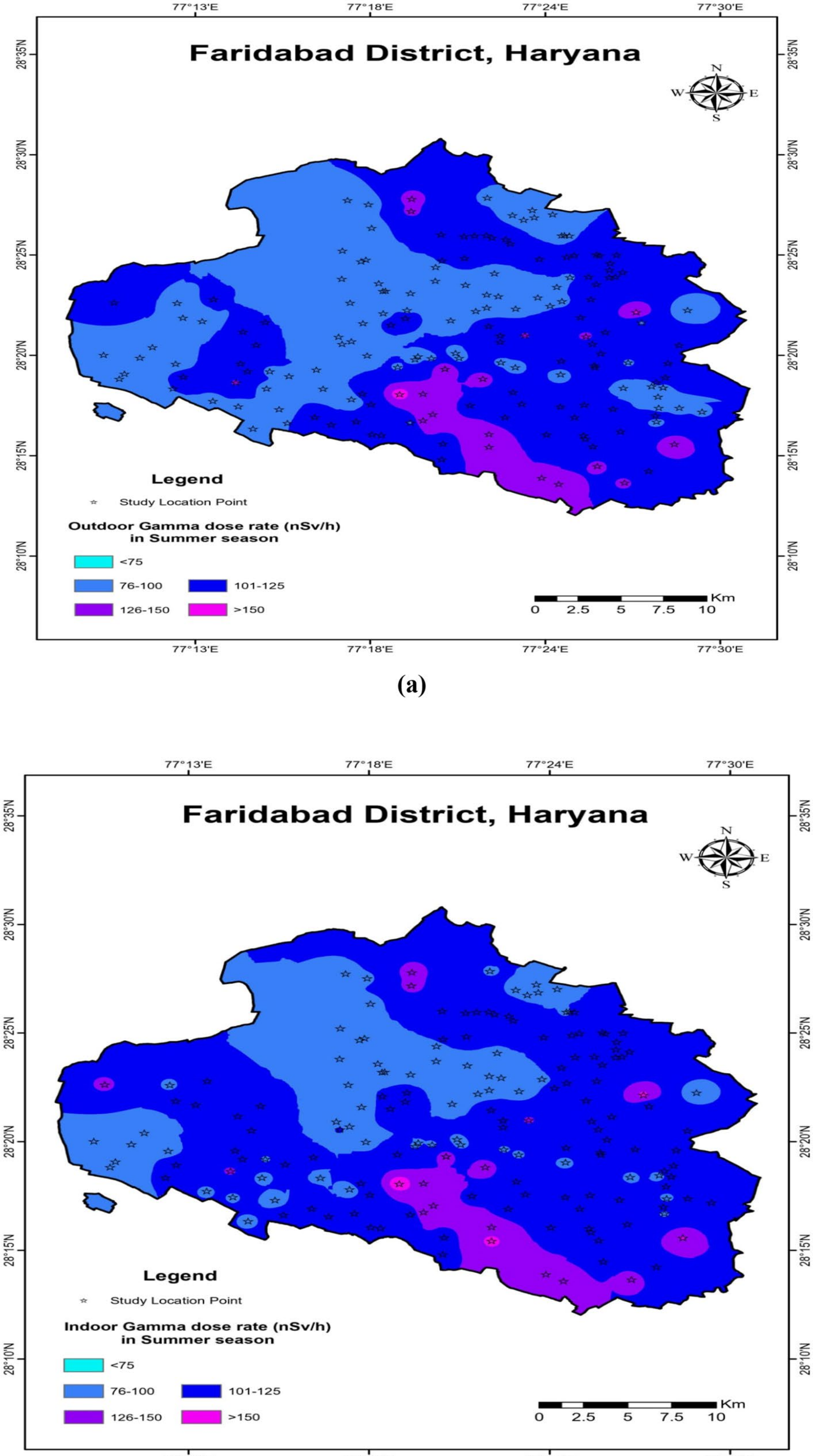


Fig. 4 Spatial distribution of measured GDR_S in **a** outdoor regions and **b** indoor regions



(a)

(b)

Table 8 Descriptives of measured gamma radiation level for different geological regions

Gamma monitoring	Geology (lithology) group	N	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
$OGDR_W$ (nSv/h)	Group 1	17	110	21.5	5.2	98.7	120.7	84	161
	Group 2	13	97	11.8	3.3	89.8	104	76	117
	Group 3	3	109	20.4	11.8	57.9	159.4	94	132
	Group 4	150	111	15.4	1.3	108.6	113.6	84	179
	Total	183	110	16.2	1.2	107.5	112.7	76	179
$IGDR_W$ (nSv/h)	Group 1	17	113	21.6	5.2	101.6	123.7	89	165
	Group 2	13	102	11.5	3.2	94.9	108.8	82	119
	Group 3	3	112	20	11.5	62.4	161.6	99	135
	Group 4	150	114	15.1	1.2	111.2	116	87	180
	Total	183	113	15.8	1.2	110.3	115	82	180
$OGDR_S$ (nSv/h)	Group 1	17	104	19.2	4.7	94.5	114.3	83	152
	Group 2	13	95	11.3	3.1	88.6	102.2	75	110
	Group 3	3	102	19.7	11.3	53.5	151.2	90	125
	Group 4	150	106	15.2	1.2	103.4	108.4	80	165
	Total	183	105	15.5	1.1	102.7	107.2	75	155
$IGDR_S$ (nSv/h)	Group 1	17	107	19.4	4.7	97.3	117.3	87	155
	Group 2	13	98	10.8	3.0	92	105.1	79	114
	Group 3	3	106	19.6	11.3	57.6	155.1	95	129
	Group 4	150	109	14.8	1.2	106.3	111.1	82	172
	Total	183	108	15.2	1.1	105.6	110	79	172

Table 9 ANOVA table for the impacts of geology (lithology) on gamma dose rate

		Sum of groups	df	Mean square	F	Significance
$OGDR_W$ (nSv/h)	Between groups	2400.917	3	800.306	3.156	0.026
	Within groups	45397.312	179	253.616		
	Total	47798.230	182			
$IGDR_W$ (nSv/h)	Between groups	1654.043	3	551.348	2.249	0.084
	Within groups	43887.575	179	245.186		
	Total	45541.617	182			
$OGDR_S$ (nSv/h)	Between groups	1350.289	3	450.096	1.892	0.133
	Within groups	42581.361	179	237.885		
	Total	43931.650	182			
$IGDR_S$ (nSv/h)	Between groups	1247.379	3	415.793	1.832	0.143
	Within groups	40618.927	179	226.921		
	Total	41866.306	182			

were observed greater compared to the world average value of 0.148 reported by UNSCEAR 2000 [1, 24], while 80% and 87% values for outdoor winter and outdoor summer were found below this world average. The estimated AED is found within the permissible limit of 1.0 mSv/y for exposure to the general public as given by ICRP 2007 (International Commission on Radiological Protection) [44]. Also, the average results of the present paper are found within the worldwide range of 0.3–0.6 mSv/y reported by UNSCEAR 2000 [1].

Conclusions

A wide variation in the IGDR and OGDR was observed in the district Faridabad, Haryana, India. The annual average of OGDR and IGDR were found as 107 and 110 nSv/h, which were within the typical range of 20–190 nSv/h as suggested by UNSCEAR. Shapiro–Wilk test confirmed that the gamma levels is not normally distributed. The *p*-values for Wilcoxon signed-ranks test and

Mann–Whitney test imply that there is seasonal variation on gamma radiation and values are significantly different for indoor/outdoor regions. ANOVA stated that geology has a significant impact on $OGDR_W$. The elevated level of average gamma radiation was observed in the winter and indoor environment. The estimated AED is found within the permissible limit of 1.0 mSv/y for exposure to general public as given by ICRP.

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Declarations

Conflict of interest No potential conflict of interest was reported by author(s).

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