Terrestrial Gamma Radiation Dose (TGRD) Environmental Distribution in Alluvial Soil Region, its Monsoonal Variation and Assessment of Lifetime Cancer Risk

Pandey Shwetank Shashi[1,2], Singh Bholey[1,2], Barwa Manjeet Singh[2*], Gautam Y.P.[3] and Pani Balaram[2*]
1. Department of Chemistry, University of Delhi, Delhi-110007, Delhi, INDIA
2. Department of Chemistry, Bhaskaracharya College of Applied Sciences, Sector-2, Phase-1, Dwarka-110075, Delhi, INDIA
3. Environmental Survey Laboratory, Narora Atomic Power Station, Bulandshahr-202389, UP, INDIA
*manjeetbarwa@gmail.com, balarampani63@gmail.com

Abstract

Present study aimed to measure GIS based annual effective dose (AED) and to assess the associated health risk from outdoor terrestrial gamma radiation dose (TGRD) in alluvial soil region of Etah and Hathras districts of Uttar Pradesh in India. Total 252 sample doses were measured using the Geiger Muller tube based survey meter. 126 sample doses were measured in pre-monsoon season at different grids of study region and 126 sample doses were measured in post-monsoon season at the same grids.

From the TGRD values, AED and excess lifetime cancer risks (ELCR) were calculated by standard methods. Results showed that TGRDs varied from 64 to 195 nSv/h and 70 to 219 nSv/h in pre-monsoon and post-monsoon season respectively for the 7 tehsils of the study region. Calculated mean AED ranged between 0.148 to 0.169 mSv/y in pre-monsoon season and 0.122 to 0.163 mSv/y in post-monsoon season. Calculated mean ELCR of tehsils was found in the range of 0.556 × 10^{-3} to 0.634 × 10^{-3} and 0.459 × 10^{-3} to 0.613 × 10^{-3} in pre and post-monsoon season respectively. The TGRDs, calculated AED and ELCR were found higher than the world average value and show high variations with monsoon.

Keywords: Gamma Radiation, GIS, Etah, Hathras.

Introduction

Radiation is an inescapable thing for the living beings. Humans are exposed to it throughout the life. However, doses and dose rates are variable depending on the several factors such as place of residence, sex[2], age, lifestyle etc. It may be internal, external or combination of it which produces a joint dose distribution for different body parts.

Based on sources, radiation is classified as anthropogenic and natural radiation. Anthropogenic radiation includes radiation from nuclear weapons, nuclear power plants[12], uranium mining and milling[32], fertilizers[3], cigarettes[18], medical facilities[11] and natural radiation includes radiations from soil, vegetation etc.

Based on sources, natural radiation is further classified as internal, cosmic and terrestrial. Internal radiation includes radioactive potassium-40[28], carbon-14[33], lead-210[21] present in human bodies. Cosmic radiation was caused by interaction of charged particles from the sun and stars with the earth's atmosphere and magnetic field. Terrestrial radiation exposure is known to be the significant source of public exposure to ionizing radiation. Geological formations, soil types, rainfall, drainage patterns and man-made activities are the important factors affecting terrestrial radioactivity. Terrestrial radiation exposures arise mainly from the primordial radionuclide such as ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. These radionuclides are found on the earth which came into existence with the creation of the planet and they may lead to toxicity[16].

These are present in almost all geological materials in our environment. These radionuclide are carried to the soils, streams and rivers by rain because of rock weathering. Presence of radionuclide in earth crust may be estimated by recording natural gamma radiation in that particular area. The levels of radioactive nuclides in rock, soil and groundwater vary with the geological locations; therefore, it is important to measure the dose rates at different geological areas.

The aim of the present study was to measure the environmental distribution of TGRD, its monsoonal variation and calculation of annual effective dose and lifetime cancer risk for the residents in the alluvial soil region of the Etah and Hathras districts lying in the central region of Yamuna-Ganga doab.

Material and Methods

Study Area: Etah and Hathras districts are adjacent to each other and the region is located in the western part of the Uttar Pradesh state as shown in figure 1. The study district Etah is located between latitudes 27.27 to 27.77 N and longitudes 78.17 to 79.28 E and district Hathras is located between latitudes 27.30 to 27.83 N and longitudes 77.88 to 78.53 E. The total geographical area of the study region is approx 4,250 sq. km and total population was 25,03,061 in 2011[5]**.** The studied region is agriculture dominated area with intensive use of fertilizers. This alluvial soil region lies in central Ganga-Yamuna doab.

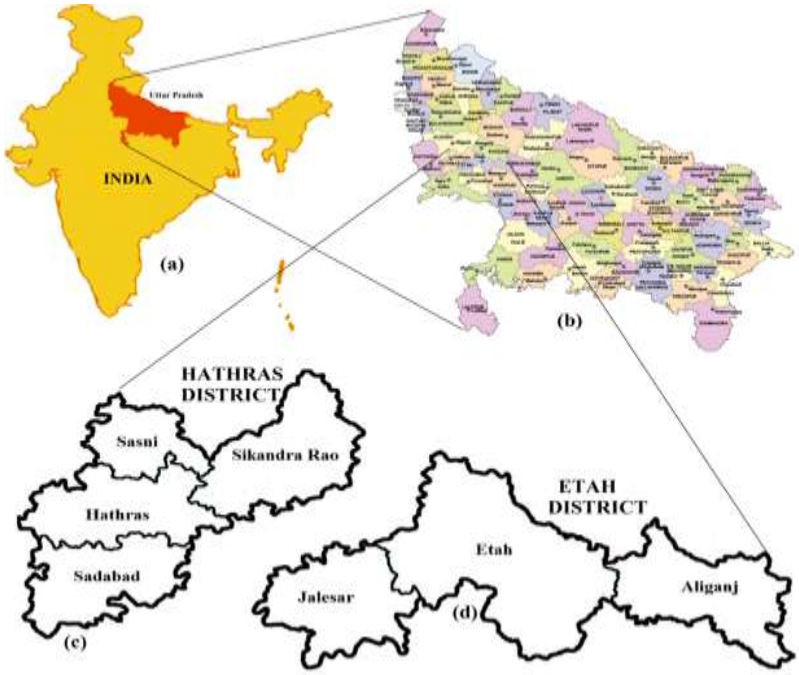

Figure 1: Location of Etah and Hathras districts

Sampling: In view of covering the entire study region, the districts were divided into grid pattern of size 6×6 km^2 to have a systematic sampling. Readings were taken at one sampling point from each grid as the representation of that grid. It was done in both pre-monsoon season as well as in post-monsoon season to study the seasonal variation. Readings were recorded in the month of May, June and October of 2017 and 2018. Gamma radiation was measured by the Polimaster Model - PM 1405 survey radiation monitoring meter at location sites.

The PM1405 survey meter incorporates a large energy compensated Geiger Muller tube for precise measurement of the ambient equivalent dose rate of the gamma radiation in the range from background level to 100 mSv/h (10 R/h). Equipment was preset with higher values beep system. The sampling areas were unoccupied and open. Reading was taken at one meter above the ground level along with GPS reading by using Garmin model eTrex 30x. Data analysis and contour plot analysis were done by using Minitab 17 software. Akima's polynomial method interpolation was used for two dimensional contour plots.

Exposure Analysis: Health risk in terms of annual effective dose (AED) was calculated by using following formulae[8]:

$$AED\ (mSv/y) = TGRD \times 24\ hours \times 365\ days \times OF \times CC \times 10^{-6} \quad (1)$$

where TGRD is Terrestrial Gamma Radiation dose in nSv/h, Occupancy Factor (OF) is 0.2 for outdoor radiation and Conversion Coefficient (CC) from the absorbed dose in air to the effective dose received by adults is 0.7. Excess lifetime cancer risk was calculated by using the following equation:

$$ELCR = AED \times DL \times RF \quad (2)$$

where DL is duration of life (65.8 years) and RF is fatal cancer risk factor (per sievert) which is taken as 0.057 as suggested by ICRP[13].

Results and Discussion

Distribution of TGRD: The measured terrestrial gamma radiation dose in the study region was found to vary from 64 nSv/h to 195 nSv/h in pre-monsoon season and from 70 nSv/h to 219 nSv/h in post-monsoon season. The tehsil wise descriptive statistics of TGRDs including minimum, mean, median, maximum, standard deviation, skewness, number of samples are given in table 1.

For Anderson-Darling test, null hypothesis H_0 was "TGRDs were normally distributed" and the alternative hypothesis H_1 was "TGRDs were not normally distributed". In all the tehsils except Jalesar (post-monsoon) and Sikandra Rao (post-monsoon), p is more than 0.05, hence, null hypothesis was not rejected. In the case of Jalesar (post-monsoon) and Sikandra Rao (post-monsoon), p is less than 0.05, hence, null hypothesis was rejected and the TGRDs were not normally distributed in these cases. The box plot distribution and cumulative distribution of the tehsils in pre and post-monsoon season are described in figure 2 and 3 respectively. Etah and Sikandra Rao tehsils have outlier values in post-monsoon season. The highest variation in the range over the season change is observed in Sasni tehsil.

Wiebull distribution and histogram analysis are shown in figure 4. All the tehsils except Sasni are showing high shape value in pre-monsoon season comparing to post-monsoon season. In Sasni tehsil, shape value for pre-monsoon is 4.859 whereas for post-monsoon, it is 6.332. All the tehsils, except

Sikandra Rao, are showing high scale value (63.2 percentile of the data) in pre-monsoon season in comparison of post-monsoon season. In Sikandra Rao tehsil, scale value for pre-monsoon is 143.0 nSv/h whereas for post-monsoon, it is 147.4 nSv/h.

Spatial and Monsoonal Variation: District wise spatial and monsoonal comparison is shown in figure 5. The world outdoor gamma radiation average is 59 nGy/h[15]. In pre-monsoon season of Etah district, it is observed that the high TGRD values lie in south and south-west part with small distance in the contours which means steep slope of TGRD value. In post-monsoon season, high TGRD values shifted from the previous coordinates. 6.94 % and 12.5 % of Etah district samples are more than the thrice of the world average TGRD in pre-monsoon and post-monsoon season respectively. In case of pre-monsoon season of Hathras district samples, high TGRD was observed in the north part of the district with steep slopes whereas in post-monsoon, it shifted to the north-east part with comparatively gentle slopes. 1.8 % of samples in pre-monsoon and 11.11% in post-monsoon exceeds the thrice of the world average.

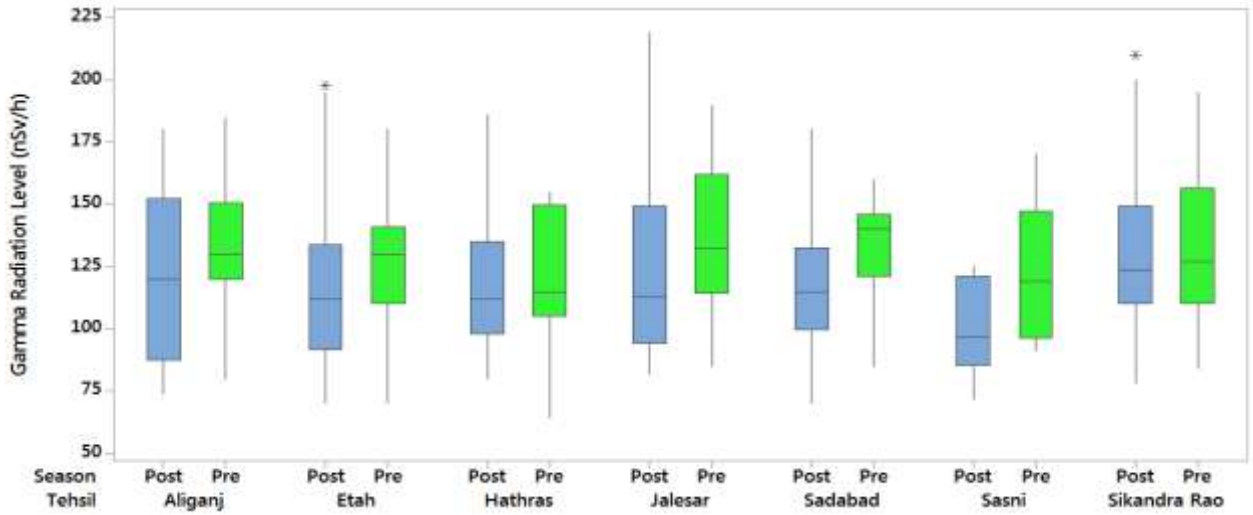

Figure 2: Box Plot distribution of TGRD (Alphabetical Order)

Table 1
Descriptive Statistics of TGRD

	AD Normality		Descriptive Statistics						
Tehsil	**A^2**	**P-value**	**Min**	**Mean**	**Median**	**Max**	**SD**	**Skewness**	**N**
District Etah: Pre-Monsoon									
Aliganj	0.31	0.517	80	132.12	130	185	28.55	0.156	17
Etah	0.48	0.221	70	127.32	130	180	26.63	-0.24	37
Jalesar	0.40	0.330	85	137.89	132.5	190	29.72	0.12	18
Total	0.47	0.234	70	131.10	130	190	27.82	0.004	72
District Hathras: Pre-Monsoon									
Hathras	0.52	0.152	64	121	115	155	28.04	-0.36	15
Sadabad	0.36	0.398	85	132.69	140	160	19.76	-0.99	13
Sasni	0.21	0.75	91	122.83	119	170	29.46	0.708	06
Sikandara Rao	0.65	0.076	84	131.95	127	195	27.44	0.53	20
Total	0.54	0.159	64	128.07	126.5	195	26.00	-0.002	54
District Etah: Post-Monsoon									
Aliganj	0.35	0.429	74	119.71	120	180	35.82	0.344	17
Etah	0.64	0.087	70	119.05	112	198	34.59	0.655	37
Jalesar	0.80	0.030	82	125.83	112.5	219	41.04	1.061	18
Total	1.21	<0.005	70	120.90	113.5	219	36.16	0.72	72
District Hathras: Post Monsoon									
Hathras	0.38	0.351	80	118.2	112	186	26.16	1.064	15
Sadabad	0.29	0.557	70	116.31	115	180	27.27	0.654	13
Sasni	0.26	0.571	72	100	96.50	125	19.69	0.021	6
Sikandara Rao	0.98	0.011	78.0	133.30	123.5	210	37.86	0.872	20
Total	1.69	<0.005	70	121.31	120	210	31.85	1.081	54

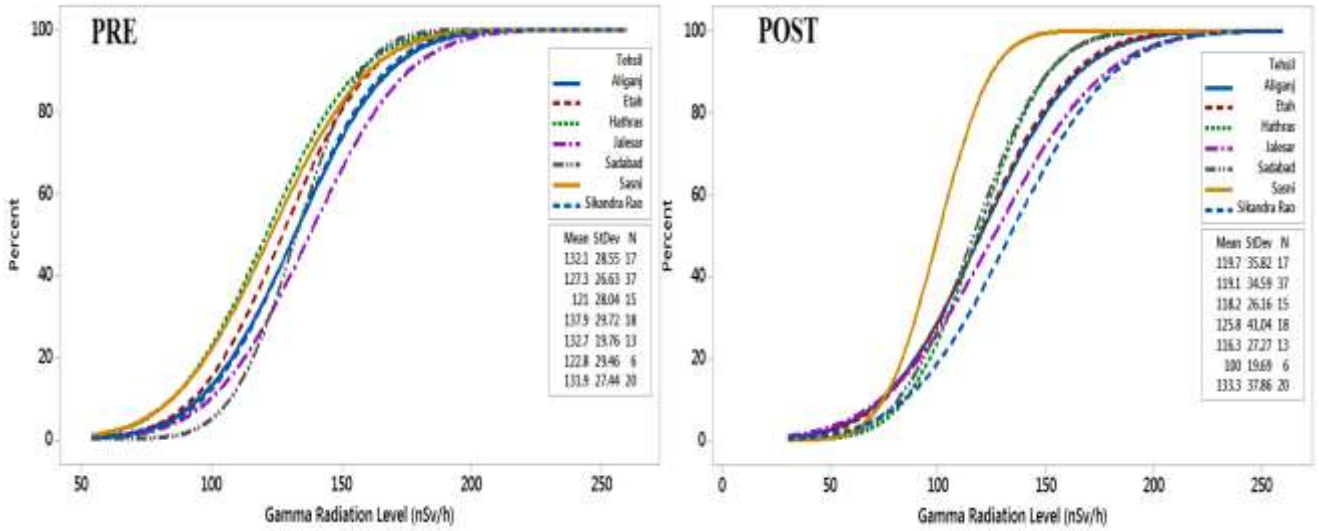

Figure 3: Cumulative distribution function of TGRD of different tehsils

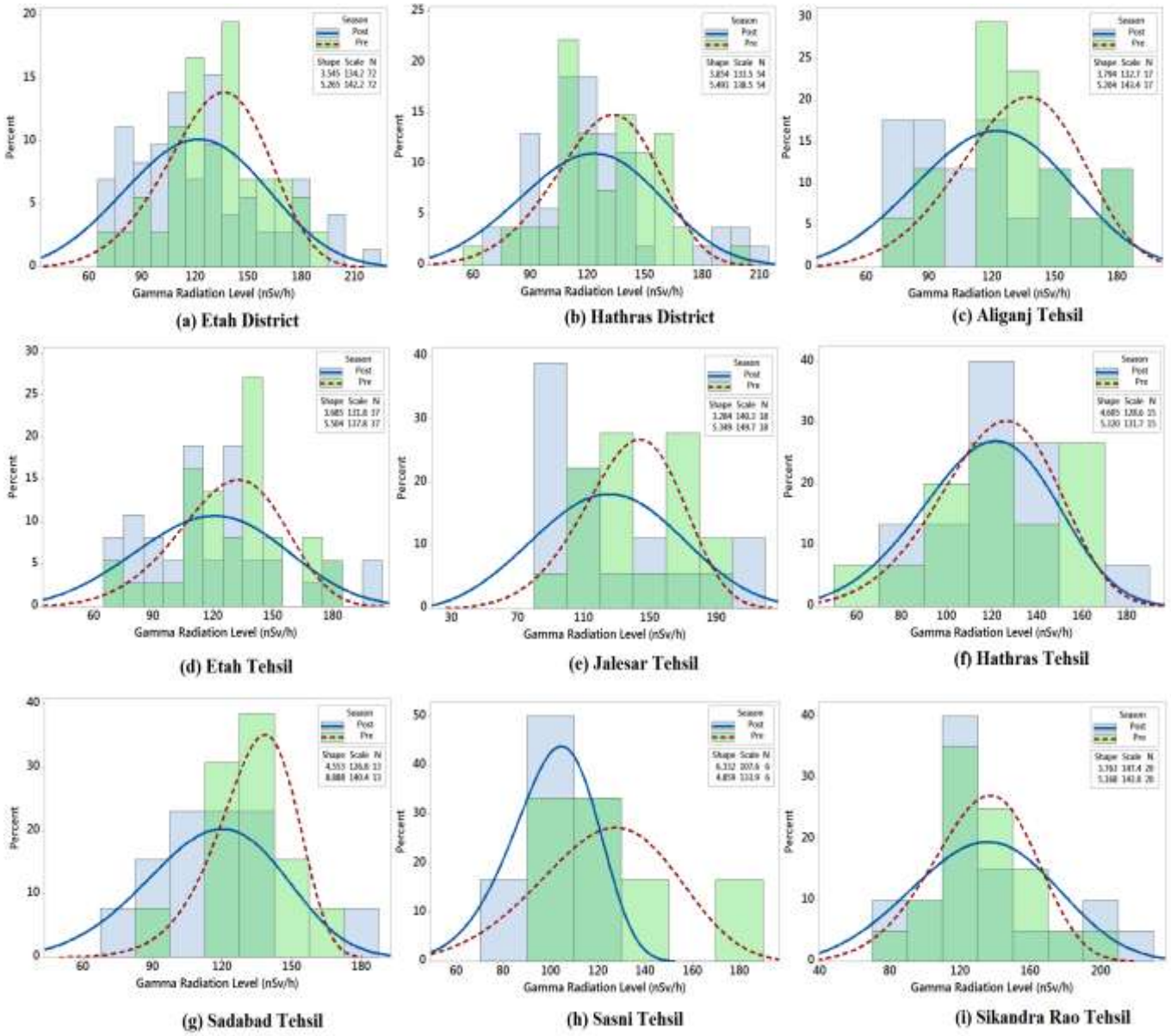

Figure 4: Weibull distribution and histogram of TGRD of districts and tehsils

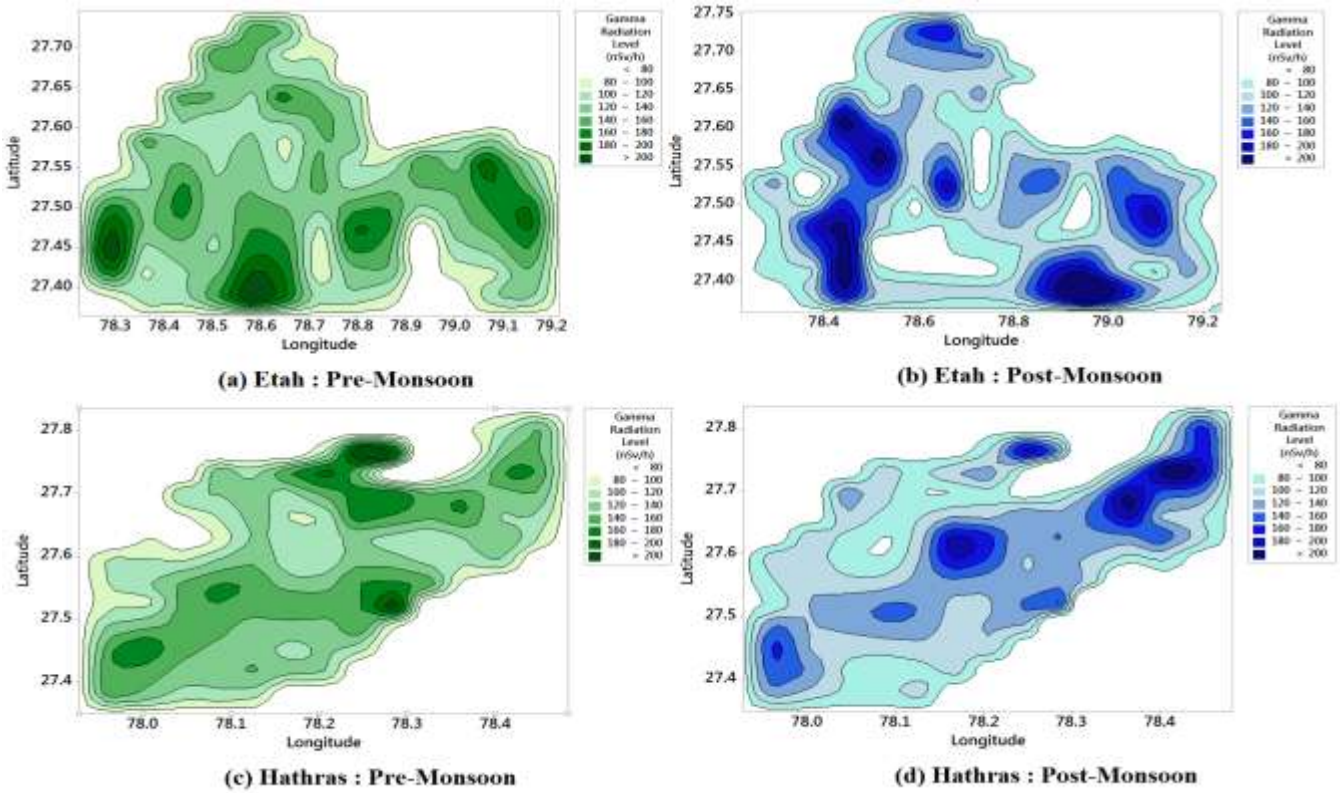

Figure 5: Spatial and seasonal variation of gamma radiation level of different districts

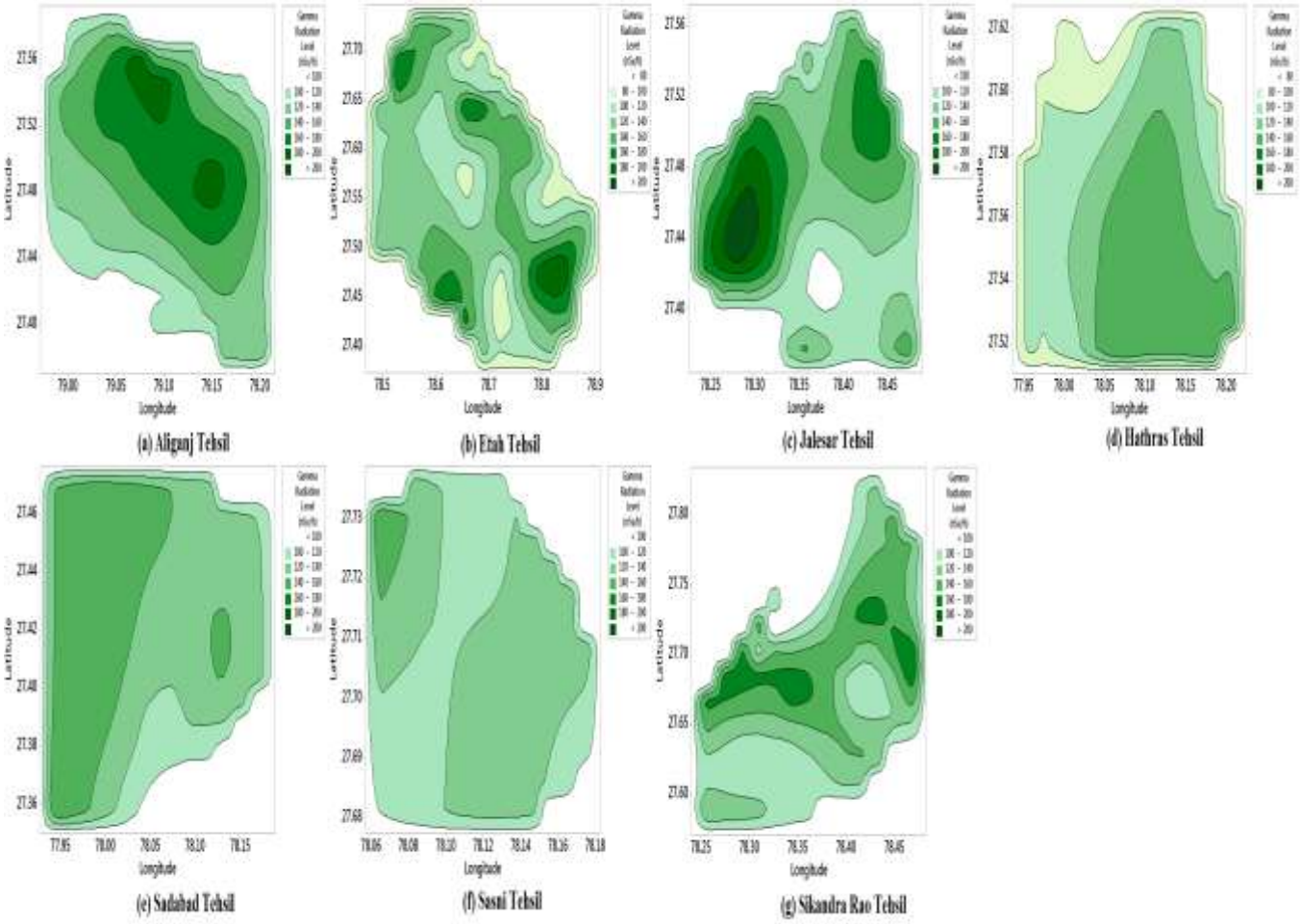

Figure 6: Spatial variation of gamma radiation level of different tehsils in pre-monsoon season

Tehsil wise spatial and monsoonal comparison is shown in figures 6 and 7. Aliganj, Hathras, Sadabad and Sasni tehsils have large distance between the contours means, they have gentle slopes in TGRD values. In Etah Tehsil, high TGRD value was observed in south-east part in pre-monsoon season whereas in post-monsoon season, high TGRD value shifted to west part. In Jalesar tehsil, high TGRD region shifts from west to eastern part over the monsoon. In Sikandra Rao tehsil, small distance contours are present in both seasons which indicated that the TGRD values are having steep slope. It is observed that 70% of the samples have TGRD more than twice of world average in this tehsil in post-monsoon season.

In overall observation, it was found that TGRD was higher in pre-monsoon season (overall mean value 129.8 nSv/hr) in comparison of post-monsoon season (overall mean value 121.1 nSv/hr). It was observed that in totality, including both pre and post-monsoon, the study region has 100% values more than world average, 58.33% values more than double of world average, 8.33% values more than triple of world average. A study also reported high natural radioactivity in the alluvial region of Uttar Pradesh state[26].

Excess Lifetime Cancer Risk Assessment: The annual effective dose and excess lifetime cancer risk are mentioned in table 2. The mean AED are 0.162 mSv/y, 0.156 mSv/y, 0.169 mSv/y, 0.148 mSv/y, 0.162 mSv/y, 0.150 mSv/y and 0.161 mSv/y in the pre-monsoon season and 0.146 mSv/y, 0.146 mSv/y, 0.154 mSv/y, 0.144 mSv/y, 0.142 mSv/y, 0.122 mSv/y and 0.163 mSv/y in the post-monsoon season for the tehsils Aliganj, Etah, Jalesar, Hathras, Sadabad, Sasni and Sikandra Rao respectively. For assessing the radiological risk, excess lifetime cancer risks (10^{-3}) were calculated and it was found that mean ELCR values are 0.607, 0.585, 0.634, 0.556, 0.610, 0.565, 0.606 in the pre-monsoon season and 0.550, 0.547, 0.578, 0.543, 0.534, 0.459, 0.613 in the post-monsoon season for the tehsils Aliganj, Etah, Jalesar, Hathras, Sadabad, Sasni and Sikandra Rao respectively.

All the mean values of AED are above the world population weighted average 0.07 mSv/y[15] but still it lies in category of low dose exposures (<100 mSv). Many researchers have reported the low dose exposures as health beneficial such as tumor growth prevention[19], quick heal of wound and relief in arthritis, remedy for various infections[4], act as a stimulant in damaged DNA repair and enhance immune responses[7].

Rivers play very important role in sedimentation of alluvial soils. Radionuclides leach out from the parent rocks due to river flow and precipitation contributes more radioactivity to river water and its alluvial sediments.

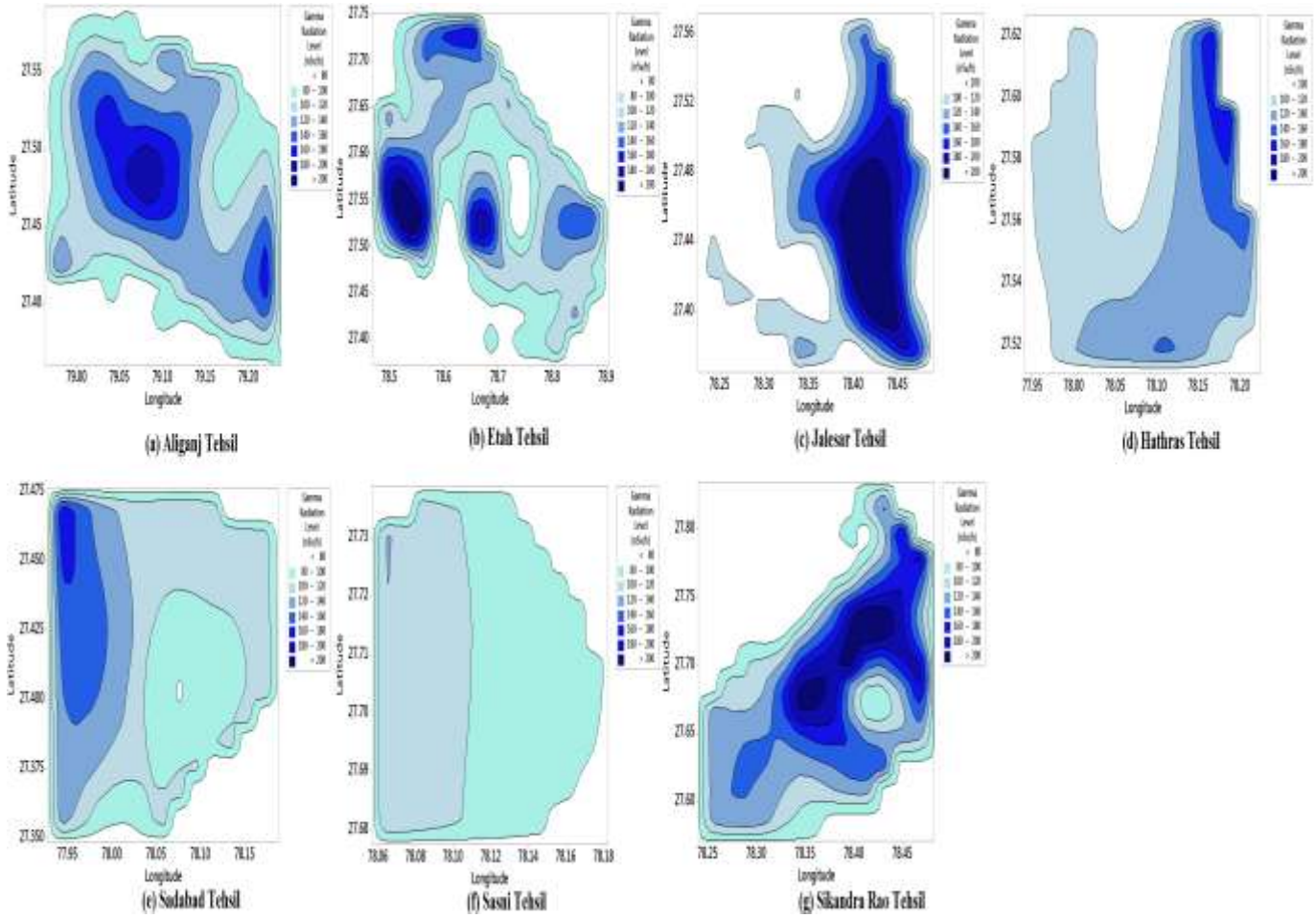

Figure 7: Spatial variation of gamma radiation level of different tehsils in post-monsoon season

Table 2
AED (mSv/y) and Excess Lifetime Cancer Risk in pre and post-monsoon season

	Season	Annual Effective Dose (mSv/y)			Excess Lifetime Cancer Risk (10^{-3})		
Tehsil		**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Aliganj	Pre	0.098	0.162	0.226	0.367	0.607	0.850
	Post	0.090	0.146	0.220	0.340	0.550	0.827
Etah	Pre	0.085	0.156	0.220	0.321	0.585	0.827
	Post	0.085	0.146	0.242	0.321	0.547	0.910
Jalesar	Pre	0.104	0.169	0.233	0.390	0.634	0.873
	Post	0.100	0.154	0.268	0.377	0.578	1.007
Hathras	Pre	0.078	0.148	0.190	0.294	0.556	0.712
	Post	0.098	0.144	0.228	0.367	0.543	0.855
Sadabad	Pre	0.104	0.162	0.196	0.390	0.610	0.735
	Post	0.085	0.142	0.220	0.321	0.534	0.827
Sasni	Pre	0.111	0.150	0.208	0.418	0.565	0.781
	Post	0.088	0.122	0.153	0.331	0.459	0.574
Sikandra Rao	Pre	0.103	0.161	0.239	0.386	0.606	0.896
	Post	0.095	0.163	0.257	0.358	0.613	0.965

In the past years, several radiation studies were carried out on Indian rivers such as Cauvery[20], Sharavathi, Kali, Netravathi[22], Godavari[25], Palar[23], Alaknanda[29] and other countries rivers such as Chao Phraya (Thailand)[27], Pearl (China)[30], Ogun (Nigeria)[14], Nile (Egypt)[1], Arvand (Iran)[6] etc. Apart from the rivers, various studies were conducted at different geological locations. Some already reported similar studied places of India are Odisha (230 nGy/h)[9], Tamil Nadu (115 nGy/h)[10], Shimoga district (177nGy/h)[24] and Balod district (143.6 nSv/h)[15] and some already reported worldwide places are Malaysia (92 nGy/h), Spain (76 nGy/h), Japan (53 nGy/h)[31], Portugal (84 nGy/h)[31] and Kenya (440 nGy/h)[17].

Conclusion

The present study has measured the terrestrial gamma radiation dose (TGRD) rates in the alluvial soil region of Etah and Hathras districts of India. From the TGRD values, spatial distribution, monsoonal variation, annual effective dose (AED) and excess lifetime cancer risk (ELCR) were calculated for the adults. TGRDs were found to be 64 to 195 nSv/h with mean value of 129.8 nSv/h in pre-monsoon season and 70 to 219 nSv/h with mean value of 121.1 nSv/h in post-monsoon season. 58.33 % of the measured data were more than double of world average.

Highest TGRD was observed in Jalesar tehsil. It is found that there is impact of monsoon on variation of TGRD spatial distribution. ELCR values were found to be 0.294×10^{-3} to 0.896×10^{-3} in pre-monsoon season and 0.321×10^{-3} to 1.007×10^{-3} in post-monsoon season. Thus, the exposures of TGRD to the residents does not possess any health hazard.

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