ISSN 1066-3622, Radiochemistry, 2021, Vol. 63, No. 5, pp. 672–681. © Pleiades Publishing, Inc., 2021.

Gamma Dose Rate and Annual Effective Dose Equivalent in Uttara Kannada District, Karnataka, India

S. Suresh[a], D. R. Rangaswamy[b,c], J. Sannappa[c,*], and E. Srinivasa[d]

[a] *Department of Physics, M.P.E Society's S.D.M. Degree College, Honavar, Karnataka, 581334 India*
[b] *Department of Science and Humanities, PES University, Electronic City Campus, Bangalore, 560100 India*
[c] *Department of Studies in Physics, Kuvempu University, Shankaraghatta, 577451 India*
[d] *Department of Physics, IDSG Government College, Chikkamagaluru, 577102 India*
**e-mail: Sannappaj2012@gmail.com*

Received January 28, 2021; revised April 26, 2021; accepted April 29, 2021

Abstract—This study reports the gamma absorbed dose rate (GADR) in 88 locations within five different geological regions of Uttara Kannada district. The measurements were made using a UR-705 environmental radiation dosimeter. The outdoor gamma absorbed dose rate varies from 44.5 to 220.0 nGy h^{-1} with the mean value of 78.0 nGy h^{-1}, which is 1.3 times higher than the international average value of 59 nGy h^{-1}. The indoor gamma absorbed dose rate varies from 57.3 to 242.5 nGy h^{-1} with an average of 90.0 nGy h^{-1}, which is slightly higher than the world average of 84 nGy h^{-1} as suggested by UNSCEAR-2000. The estimated dose rate varies with the geological background and soil type. The total AEDE ranges from 0.3 to 1.38 mSv $year^{-1}$ with an average of 0.53 mSv $year^{-1}$. The average total AEDE is lower than the dose limit of 1 mSv $year^{-1}$ for public, suggested by ICRP-1991.

Keywords: ambient gamma radiation, absorbed dose, Uttara Kannada, health hazards, primordial radionuclides

DOI: 10.1134/S1066362221050179

INTRODUCTION

Including human beings, all living organisms on the globe are regularly irradiated by external and internal radiation sources. Cosmic rays of extraterrestrial origin are the sources of external exposure. Primordial radionuclides such as ^{40}K, ^{226}Ra, ^{232}Th, and ^{238}U exist in rocks, soil, and building materials in varying amount and are the prime sources of terrestrial exposure [1]. Radionuclides are distributed in soil and other environmental matrices nonuniformly; hence, knowledge of their distribution is of utmost importance to assess the radiological health hazards. The activity of radionuclides in the environmental matrix varies with geological places; hence, the gamma exposure rate depends on the geology and geography of the area [2]. Igneous rocks like granites show elevated radiation level, whereas sedimentary rocks show lower level. Shales and phosphate rocks with comparatively higher radionuclide content are exceptions [3]. The radiation exposure from natural sources is roughly 97%, and the remaining 3% is from artificial sources. The exposure to ionizing radiation is continuous, natural, and inescapable [4, 5]. From the viewpoint of health physics, knowledge about these radiations is essential. Hence, in environmental radioactivity estimation, the measurement of ambient gamma radiation level from terrestrial and extraterrestrial sources has prime importance. Some researchers from Mangaluru University have estimated GADR, radionuclide distribution, and radioactivity in soil and vegetation along coastal Karnataka, Kaiga, and Goa [6–8]. Narayana and Rajashekara [9] measured the transport of ^{210}Po and ^{210}Pb in river water samples. These studies were primarily focused on the assessment of radioactivity levels in and around the Kaiga nuclear power plant. Sannappa et al. [10] measured the ambient gamma radiation level in few coastal taluks of Uttara Kannada district. The ongoing investigation is an effort to understand the baseline radiation data of the entire Uttara Kannada district. The geology of Uttara Kannada district is quite distinct because of long coastal belt, Western Ghats with thick forest, Malnad, and plane land. Also, efforts were made to evaluate the influence of different geology on the terrestrial gamma dose rate in this region.

GEOLOGY OF THE STUDY AREA

The Uttara Kannada district is located between 13°55' and 15°31' N, 74°0' and 75°10' E. The total area of Uttara Kannada district is 10291 km^2, and the total population in the district is around 1.6 millions; about 75% of the population resides in rural area. The dense forest of Western Ghats is the ideal condition for soil formation. The rich humus mixed with the local soil gives way to forest soil, whereas the foothills of Western Ghats are covered by iron-rich lateritic soil, which is reddish brown in color, and alluvial soil along the banks of River Sharavati. The Mundagod taluk is covered with black cotton soil. Lateritic soil, sandy soil, red loamy soil, and alluvial soil are the soil types. The rock system consists of granites, Dharwad rocks, granitic gneiss, laterite, alluvium, chlorite schist, basalt, metamorphic gneiss, limestone, and banded magnetic quartzite. The minerals include iron ore, bauxite ore, magnetite, silicate, etc. Figure 1 shows the geological map of the study area.

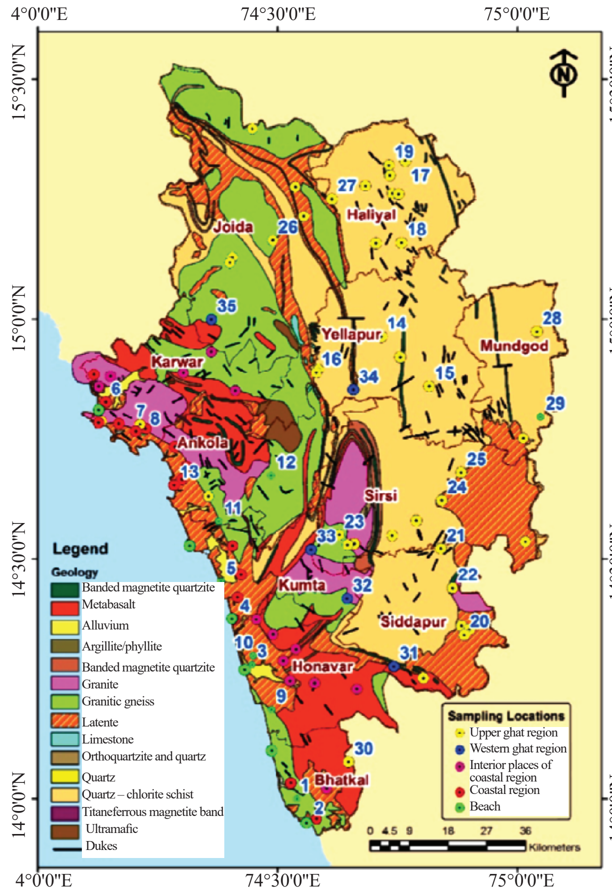

Fig. 1. Geological map of Uttara Kannada district.

MATERIALS AND METHODS

Gamma Absorbed Dose Rates (GADR) in Air

The ambient gamma absorbed dose rate was measured with a low-level environmental radiation micro-R survey dosimeter (Model UR705, Nucleonics Systems Pvt Ltd., Hyderabad). This portable survey meter was integrally coupled with a 1" × 1" NaI(Tl) scintillator to a 1.5" PMT. The instrument was calibrated with a ^{137}Cs standard source (Nucleonics Systems). It was calibrated to read the exposure rate in two ranges with the estimation sensitivity of 0 and 10 μR h^{-1} and exposure with the measuring sensitivity of 1 μR h^{-1} and accuracy of ±10% with ^{137}Cs. The energy response was within ±10% in the range from 60 keV to 1.33 MeV.

Estimation of Gamma Absorbed Dose Rate

Estimation of the gamma absorbed dose rate is an important part of environmental radiation dosimetry. The gamma absorbed dose rate was estimated in 88 different sites of the study area. In every location, three to four sites were randomly selected, and at each site eight to ten readings were recorded with a period of 5 min. The arithmetic means of all the measurements represent the activity of the given location. To prevent the impact of buildings and ground on the outdoor gamma absorbed dose, the measurements were made 1 m above the ground and 6 m away from the walls of any nearby buildings. In order to satisfy criteria for indoor gamma absorbed dose measurements, the measurements were made inside the buildings 1 m above the ground level at the center of the particular volume. The exposure rate was converted to absorbed dose rate using the relation 1 μR h^{-1} = 8.7 nGy h^{-1} [1, 11].

The indoor and outdoor annual effective dose equivalents (AEDE) were estimated using following equations:

$$\text{AEDE(Indoor) (mSv year}^{-1}) = D_{\text{in}} \times 8760 \times 0.8 \times 0.7 \times 10^{-6},$$

$$\text{AEDE(Outdoor) (mSv year}^{-1}) = D_{\text{out}} \times 8760 \times 0.2 \times 0.7 \times 10^{-6},$$

where D_{in} (nGy h^{-1}) and D_{out} (nGy h^{-1}) are the gamma absorbed dose rates, 8760 is the number of hours in a year (365 days), and 0.8 and 0.2 are the indoor and outdoor occupancy factors. The indoor and outdoor occupancy factors were determined based on interviews with residents. People in the study area spent 5 to 6 h in outdoor and 18 to 19 h in indoor environment. Compared to men, this occupancy factor (OF) shifts for women toward indoor environment (OF = 5/24 for outdoor, 19/24 for indoor environment). 0.7 Sv Gy^{-1} is the dose conversion coefficient [3].

RESULTS AND DISCUSSION

Terrestrial Gamma Absorbed Dose Rate

Table 1 shows the average GADR and AEDE in 88 locations across five different geological regions of the study area. As can be seen, in the entire study area outdoor GADR ranges from 44.6 to 220.1 nGy h^{-1} with an average value of 78 nGy h^{-1}, which is 1.3 times higher than the global average value of 59 nGy h^{-1}. The indoor GADR varies from 57.4 to 242.5 nGy h^{-1} with an average value of 90 nGy h^{-1}, which is slightly higher than the world average value of 84 nGy h^{-1} [1].

Along the coastal region, the outdoor GADR ranges from 62.0 to 220.1 nGy h^{-1} with an average value of 97.7 nGy h^{-1}, which is 1.65 times higher than the global average. In this region, the highest outdoor dose rate was observed at Binaga. The underlying rock system of the location consists of Dharwad rocks, which are granitic with higher activity concentration of radionuclides [12]. The indoor GADR ranges from 70.7 to 154.8 nGy h^{-1} with an average value of 98.8 nGy h^{-1}, which is 1.7 times higher than the world average value. The highest indoor dose rate is observed in the dwelling of Bangaramakki, which is situated near granitic quarry. Higher GADR was observed at Murdeshwara, Shirali, Kaikini, Maavalli, Ankola, Belse, Aversa, Todur, and Chandia. This is due to the presence of granite and granitic gneiss bed rock with elevated concentration of radionuclides. The pink granite and grey granites were used for the construction of buildings as flooring materials; they contain higher activity of primordial radionuclides.

In the interior region of the coastal taluks, the outdoor and indoor GADR varies from 60.4 to 148.1 nGy h^{-1} and 71.8 to 222.7 nGy h^{-1} with an average value of 76.1 and 95.9 nGy h^{-1}, respectively; these values are higher than the world average value. In this region, both outdoor and indoor GADR is higher in Jainabasadi at Nagarbastikeri. It may be due to the fact that the entire Basadi was built of granitic stones with elevated activity of radionuclides [12]. This is a historical monument with inadequate ventilation; hence, it shows higher GADR [13]. The lower outdoor GADR was observed at Jankadkal, Naajgar, Kenchgar, Chandavar, Kadtoka, Areyngdi, Allanki, Upponi, Sadashivgad, Asnoti, and Baleguli, because the rock and soil system in these areas is lateritic and alluvium with lower activity of radionuclides.

In the upper Ghats region, the outdoor and indoor GADR ranges from 53.4 to 155.0 nGy h^{-1} and 67.6 to 242.5 nGy h^{-1} with an average value of 74.4 and 88.3 nGy h^{-1}, respectively. The outdoor GADR is 1.2 times greater than the global average, but the indoor GADR is slightly higher than the world average. In this region, the highest GADR was observed in Madhukeshwara temple at Banavasi, an ancient monument of the Kadamba dynasty. The entire temple was built of granite stone with inadequate ventilation condition, and the surrounding area is covered by granite rocks with elevated activity of radionuclides [12]. Excluding this temple, the average indoor GADR in all other locations is lower than the global average value, which can be attributed to the presence of chlorite schist containing lower radionuclide concentrations. Higher GADR is observed in the dwellings of Haliyal College, Kesarolli, Siddapur, Tarali, Petesara, and Mundgod. The geology of these locations is granitic in nature with higher activity of radionuclides [12]. In addition, Pink granite has been used for flooring materials in Haliyala college enhances the gamma absorbed dose rate.

In the Western Ghats region, the outdoor and indoor GADR ranges from 49.6 to 66.0 nGy h^{-1} and 57.4 to 69.6 nGy h^{-1} with an average value of 58.7 and 64.0 nGy h^{-1}, respectively. The outdoor GADR is closer to the world average, but the indoor GADR is much lower than the world average. This may be due to the presence of rocks like basalt and metamorphic gneiss and of hilly type soil which is humus in nature; they show lower activity of radionuclides. Furthermore, the dwellings were built using local bricks, soil, and sand with mosaic tiles as flooring materials; they show lower activity of radionuclides.

In beaches, the outdoor GADR ranges from 44.6 to 70.0 nGy h^{-1} with an average value of 57.9 nGy h^{-1}, and it is well below the world average. The lowest value was observed at Tagore beach in Karwar, which may be due to the presence of more silica in the sand.

Table 1. Average ambient gamma absorbed dose rate (GADR) and annual effective dose equivalent (AEDE) in Uttara Kannada district

Site no.	Location	Area code	Absorbed dose rate, (nGy h^{-1})		Indoor/Outdoor	Annual Effective dose equivalent, (mSv $year^{-1}$)		
			outdoor	indoor		outdoor	indoor	total
Along coastal region								
1	Dhareshwara	A-1	63	79	1.26	0.08	0.39	0.47
2	Baggon cross	A-2	65	83	1.28	0.08	0.41	0.49
3	Baleguli cross	A-3	63	90	1.43	0.08	0.44	0.52
4	Belke	A-4	68	76	1.13	0.08	0.37	0.46
5	Aversa	A-5	82	107	1.31	0.10	0.52	0.62
6	Belse	A-6	116	119	1.03	0.14	0.58	0.73
7	Ammadalli	A-7	89	100	1.12	0.11	0.49	0.60
8	Todur	A-8	125	130	1.04	0.15	0.64	0.79
9	Binaga	A-9	220	–	–	0.27	–	0.27
10	Chandia	A-10	94	105	1.11	0.12	0.51	0.63
11	Ankola	A-11	113	119	1.05	0.14	0.58	0.72
12	Neval Base Ghat	A-12	141	–	–	0.17	–	0.17
13	Binga Gate	A-13	108	–	–	0.13	–	0.13
14	Binga	A-14	98	–	–	0.12	–	0.12
15	Hegde	A-15	65	77	1.20	0.08	0.38	0.46
16	Bergi	A-16	63	71	1.12	0.08	0.35	0.43
17	Maajali	A-17	62	74	1.20	0.08	0.36	0.44
18	Bellmbara	A-18	68	75	1.11	0.08	0.37	0.45
19	Karwar	A-19	83	98	1.18	0.10	0.48	0.58
20	Shirali	A-20	117	120	1.03	0.14	0.59	0.73
21	Bangaramakki	A-21	149	155	1.04	0.18	0.76	0.94
Interior regions of coastal taluks								
22	Sadashivgad	A-22	68	–	–	0.08	–	0.08
23	Sadashivegad	A-23	63	108	1.71	0.08	0.53	0.61
24	Asnoti	A-24	67	82	1.22	0.08	0.40	0.48
25	Mallapur	A-25	74	86	1.16	0.09	0.42	0.51
26	Ansi	A-26	72	86	1.20	0.09	0.42	0.51
27	Kaiga cross	A-27	65	–	–	0.08	–	0.08
28	Kadtoka	A-28	67	77	1.14	0.08	0.38	0.46
29	Hadinbal	A-29	70	73	1.05	0.09	0.36	0.45
30	Gundbal	A-30	71	78	1.09	0.09	0.38	0.47
31	Upponi	A-31	60	75	1.25	0.07	0.37	0.44

Table 1. (Contd.)

Site no.	Location	Area code	Absorbed dose rate (nGy h^{-1})		Indoor/Outdoor	Annual effective dose equivalent (mSv $year^{-1}$)		
			outdoor	indoor		outdoor	indoor	total
33	Jalavalli	A-33	69	81	1.17	0.09	0.40	0.48
34	Jaina Basadi	A-34	148	223	1.50	0.18	1.09	1.28
35	Marukeri	A-35	105	110	1.05	0.13	0.54	0.67
	Upper Ghat regions							
36	Katoor	A-36	63	78	1.24	0.08	0.38	0.46
37	Kumbarwad	A-37	79	82	1.04	0.10	0.40	0.50
38	Joida	A-38	61	84	1.38	0.07	0.41	0.48
39	Ganeshpura	A-39	67	74	1.10	0.08	0.36	0.44
40	Chapali	A-40	92	97	1.05	0.11	0.47	0.59
41	Ulavi cross	A-41	67	98	1.47	0.08	0.48	0.57
42	Pradhani	A-42	67	86	1.29	0.08	0.42	0.51
43	Dandeli	A-43	63	77	1.22	0.08	0.38	0.46
44	Kerwada	A-44	53	69	1.29	0.07	0.34	0.40
45	Aaluru	A-45	59	68	1.15	0.07	0.33	0.41
46	Supa Dam cross	A-46	64	–	–	0.08	–	0.08
47	Kesarolli cross	A-47	66	–	–	0.08	–	0.08
48	Halyal	A-48	69	86	1.25	0.09	0.42	0.51
49	Halyal College	A-49	66	124	1.88	0.07	0.61	0.68
50	Kesaroli	A-50	80	110	1.38	0.10	0.54	0.64
51	Karlkatta	A-51	60	68	1.12	0.07	0.33	0.41
52	Sambrani	A-52	69	72	1.05	0.08	0.35	0.44
53	Bhagavathi	A-53	78	84	1.07	0.10	0.41	0.51
54	Manchikeri	A-54	68	73	1.08	0.08	0.36	0.44
55	Satodifalls cross	A-55	57	–	–	0.07	–	0.07
56	Yellapura	A-56	80	80	1.00	0.10	0.39	0.49
57	Mogod falls	A-57	65	–	–	0.08	–	0.08
58	Bhommanahalli	A-58	77	85	1.11	0.09	0.42	0.51
59	Vajralli	A-59	69	76	1.11	0.08	0.37	0.46
60	Basal	A-60	57	69	1.21	0.07	0.34	0.41
61	Malagi	A-61	61	74	1.21	0.08	0.36	0.44
62	Sirsi	A-62	67	85	1.26	0.08	0.42	0.50
63	Isloor	A-63	68	81	1.19	0.08	0.40	0.48
64	Ragihosalli	A-64	75	89	1.19	0.09	0.44	0.53
65	Mundgod	A-65	92	102	1.11	0.11	0.50	0.61

Table 1. (Contd.)

Site no.	Location	Area code	Absorbed dose rate (nGy h^{-1})		Indoor/Outdoor	Annual effective dose equivalent (mSv $year^{-1}$)		
			outdoor	indoor		outdoor	indoor	total
67	Amminalli	A-67	65	88	1.35	0.08	0.43	0.51
68	Hanmanti	A-68	69	85	1.24	0.08	0.42	0.50
69	Banvasi temple	A-69	155	243	1.56	0.19	1.19	1.38
70	Avaraguppa	A-70	69	83	1.21	0.08	0.41	0.49
71	Kansur	A-71	90	92	1.02	0.11	0.45	0.56
72	Tarali	A-72	85	95	1.12	0.11	0.49	0.60
73	Balikoppa	A-73	75	78	1.03	0.09	0.38	0.47
74	Siddapura	A-74	89	96	1.09	0.11	0.47	0.58
75	Vatgar	A-75	76	79	1.04	0.09	0.34	0.43
76	Mavingundi	A-76	67	69	1.03	0.08	0.34	0.42
				In Ghats				
77	Koogar Ghat	A-77	58	61	1.06	0.07	0.29	0.36
78	Gerusoppa Ghat	A-78	54	57	1.07	0.07	0.26	0.33
79	Badaal Ghat	A-79	66	68	1.03	0.08	0.32	0.40
80	Devimane Ghat	A-80	50	61	1.22	0.06	0.24	0.30
81	Arabil Ghat	A-81	65	70	1.08	0.08	0.32	0.40
82	Anshi Ghat	A-82	60	67	1.11	0.07	0.30	0.37
				In beaches				
83	Tagore	A-83	45	–	–	0.06	–	0.06
84	Kasarkod	A-84	53	–	–	0.07	–	0.07
85	Dhareshwara	A-85	70	–	–	0.09	–	0.09
86	Murdeshwara	A-86	61	–	–	0.07	–	0.07
87	Sodigadde	A-87	68	–	–	0.08	–	0.08
88	Kudle Beach	A-88	52	–	–	0.06	–	0.06
	Minimum		45	57	1.00	0.06	0.28	0.06
	Maximum		220	243	1.88	0.27	1.19	1.37
	Average		78	90	1.18	0.10	0.44	0.45
	GM		75	87	1.18	0.08	0.43	0.37
	SD		28	30	0.16	0.03	0.15	0.23

Variation of Indoor and Outdoor GADR with Geological Region

The variation of indoor and outdoor GADR with geological region is shown in Fig 2. As can be seen, the highest average indoor and outdoor GADR is observed along the coastal region. This is due to the fact that these locations have granite and granite gneiss bed rock system with high radionuclide activity [12]. In the interior regions of coastal taluks, the average indoor and outdoor GADR is lower than in the coastal region but higher than in the upper Ghat region. This may

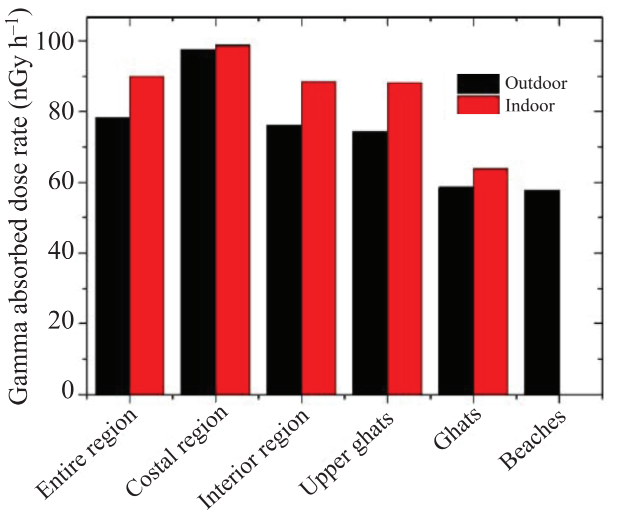

Fig. 2. Variation of gamma absorbed dose rate with the geological region.

be due to the fact that there are several places in this region with latraritic bed rocks and some places with alluvilum and metabasalt that show lower radionuclide activity. In the upper Ghat region, the average indoor and outdoor GADR is lower than the coastal and interior regions, probably because of the presence of chlorite schist in this region. In the Western Ghats region, the outdoor GADR is closer to the world average, but the indoor GADR is much lower than the world average values for indoor atmosphere. This may be due to the presence of the basalt rock system, metamorphic gneiss, and hilly-type soil with lower activity of radionuclides. The average outdoor GADR in beaches is lower than the world average, which may be due to higher silica content in the beach sand.

Table 2. Comparison of the range and mean outdoor gamma absorbed dose rate with the recorded gamma absorbed dose rate in India and other parts of the world

Country	Gamma dose rate (nGy h^{-1})		References
	range	mean	
Kenya	–	420	[15]
Upper Egypt	–	51	[16]
Kuala Lumpur and Putrajaya, Malaysia	17.4–500	183	[17]
Nigeria	40–1265	250	[18]
Vietnam	–	64	[19]
Iran	–	62.57	[20]
Leyte Island, Philippens	21–124	–	[21]
Chamaraja Nagar, India	98.3–708.2	298.1	[22]
Coastal Karnataka, India	26–174	74	[23]
Shimoga, India	87–323.6	177.8	[24]
Chikkamagalure, India	78.3–252.3	174	[25]
Chhattisgarh, India	103–201	143.6	[26]
World (outdoor)	–	59	[1]

The average indoor absorbed dose rates were higher than the outdoor absorbed dose rate in all the studied areas. The gamma radiation in the indoor atmosphere mainly depends upon the concentration of primordial radionuclides in the soil, rocks, and building materials. The fraction of exhaled gamma radiation is attenuated when it passes into the residence through the building materials. The soil is the primary cause of indoor and outdoor gamma radiation. Use of granite, granitic gneiss, and other decorative materials to build walls and floor and lower aeration conditions inside the residence raise the indoor gamma radiation dose. Another prime factor for higher indoor gamma dose is the geological conditions in the underneath rocks and soil [14]. Lower GADR is observed at certain sites; since these sites are associated with laterite and metabasalt, these rocks contain lower primordial radionuclide activity.

The gamma absorbed doses were measured by holding the detector 1 m above the ground. The neutron component of the cosmic rays does not penetrate deeply into the atmosphere at low altitude regions to hit the earth. Also, the directly ionizing component of the cosmic rays is more strongly attenuated at lower altitudes because of attenuation effects of atmosphere layers. Thus, as the region's altitude declines, the background radiation declines.

The variation of outdoor GADR and indoor GADR with the area (locations) is shown in Figs. 3a, 3b. The correlation between the indoor and outdoor GADR is shown in Fig. 4. The correlation is positive with the correlation coefficient R^2 = 0.77. The mean outdoor GADR was compared in Table 2 with the recorded mean GADR values in India and different parts of the globe.

Annual Effective Dose Equivalent (AEDE)

The estimated outdoor AEDE varies from 0.06 to 0.19 mSv year^{-1} with an average value of 0.10 mSv year^{-1},

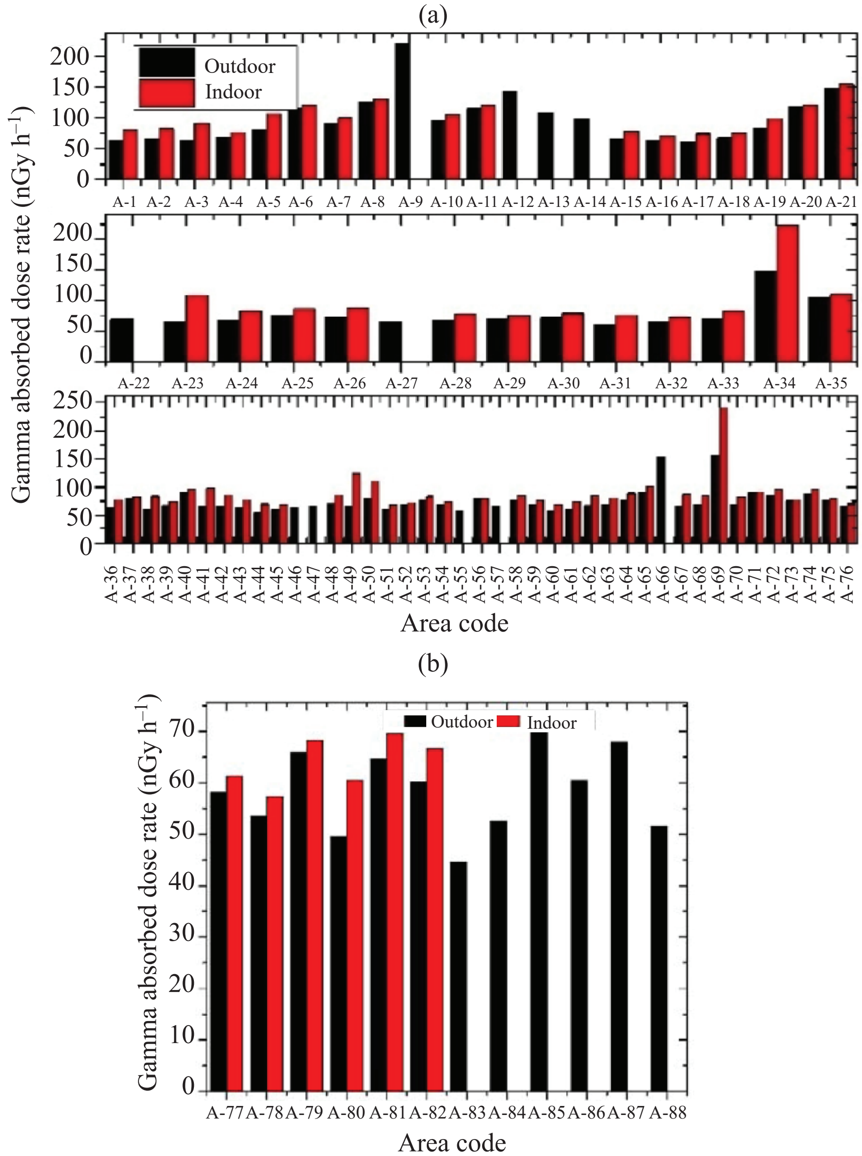

Fig. 3. Variation of the outdoor and indoor gamma absorbed dose rate with the area (location): (a) A-1 to A-76 and (b) A-77 to A-88.

marginally above the global average value of 0.07 mSv year^{-1} [24, 27]. The estimated indoor AEDE ranges from 0.24 to 1.19 mSv year^{-1} with the mean value of 0.44 mSv year^{-1}, which is lower than the global accepted value of 0.48 mSv year^{-1} [1]. The total AEDE ranges from 0.3 to 1.38 mSv year^{-1} with an average value of 0.53 mSv year^{-1}. In the current study, the indoor AEDE values are higher than the outdoor AEDE values. The average AEDE is also much below the dose limit of 1 mSv year^{-1} suggested for public by ICRP (1991) [11, 28]. The indoor to outdoor gamma dose rate ratio ranged from 1.00 to 1.9, with the geometric mean value of 1.2, which is below the global weighted value of 1.4 [1].

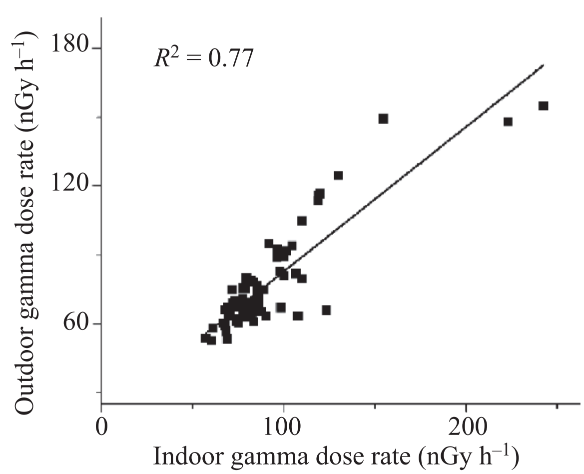

Fig. 4. Correlation between the indoor and outdoor gamma absorbed dose rates.

CONCLUSIONS

In the study area, the measured indoor GADR ranges from 57.4 to 242.5 nGy h^{-1} with the mean value of 90 nGy h^{-1}, which is slightly higher than the international average. The outdoor GADR varies from 44.6 to 220.1 nGy h^{-1} with the mean value of 78 nGy h^{-1}, which is 1.3 times higher than the world average value. The total AEDE is much below the dose limit of 1 mSv $year^{-1}$ suggested for public by ICRP (1991). Thus, the study area is a region with low background radiation, and it cannot pose any health risks. Detailed epidemiological study is needed to assess the potential health effect on residents of this area.

ACKNOWLEDGMENTS

The authors are sincerely grateful to M.P.E Society's, Dr. M.P. Karki, Institute of Excellence and Research, Honnavar, for providing an instrumentation facility to carry out the research work.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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