Terrestrial gamma radiation dose measurement along Yagachi river, Karnataka

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Abstract

Humans are constantly exposed to radiations emitted by terrestrial and extraterrestrial sources, as well as radiations produced within their bodies. An attempt was made in this study to detect ambient gamma radiation levels in the Yagachi river basin, Karnataka State. Ambient gamma radiation levels were monitored in 2022 with a portable radiation dosimeter (MICRO-R-SURVEY METRE NUCLEONIX UR705) at various sites both indoor and outdoor of the study region. The study area indoor absorbed dose rate varied from 52.2 to 243.6 nGy h^{-1}, with a mean of 113.1 nGy h^{-1}. The research area outdoor absorbed dose rate varied from 43.5 to 139.2 nGy h^{-1}, with a mean value of 68.771 nGy h^{-1}. Indoor annual effective dose range from 0.256 to 1.195 mSv y^{-1}, with a average value of 0.555 mSv y^{-1}. Outdoor annual effective dose range from 0.061 to 0.195 mSv y^{-1}, with a average value of 0.096 mSv y^{-1}. In this study area, the absorbed dose rate and annual effective dosage were lower than the global average limit 2.4 mSv y^{-1}
Key Words: Radiation monitoring, radionuclides, dose rate, Population

1. Introduction

All species on this planet are exposed to tremendous levels of ionizing radiation, which is all around us. Natural radiation contributes the most to the annual average dosage received by humans (UNSCEAR 2000).The first source of natural radiation exposure is extremely energetic cosmic ray particles that collide with the earth's atmosphere. The second contributors are terrestrial radioactive materials that were formed during the formation of the earth and are found everywhere on the earth's crust as well as in the human body. Knowledge of terrestrial radiation such as gamma and radioactivity will be useful in health physics. Terrestrial radiation is caused by radionuclides found in variable concentrations in soil, rocks, construction materials, water, and the atmosphere (Sannappa et al, 2003). The outer layer of the earth's crust, which extends about half a meter, contributes effectively the greatest extent for this component of background radiation at any point; the radioisotopes contributing are daughter products of natural ^{238}U, ^{235}Th, and ^{40}K (ICRP 1990, UNSCEAR 1998, Sannappa et al, 2003). Rain transports radionuclides to soil, streams, and rivers as a consequence of rock weathering. Natural ambient radioactivity and the related outdoor gamma radiation exposure are essentially determined by biological and geographical factors. The concentrations of nuclides with radioactivity in soils and rocks vary according to geological conditions. Internal radioactivity is spread throughout the body in tissues, with ^{40}K contributing the most. Because of inadequate ventilation, lung irradiation from radon and thoron breathed from air and their daughter products is often higher within the building. Knowledge regarding the population exposed to natural radiation and the overall distribution of such exposed people is significant not only for its own sake, but also for epidemiological studies pertaining to radiation exposure (Choubey et al, 1997, Ningappa et al, 1997). Natural sources account for approximately 80% of the world's cumulative radiation exposure of the population (Tchorz-Trzeciakiewicz et al., 2023). Environmental radioactivity measurements are required in this context to assess the background radiation level given by natural radioactive sources of geological and cosmic origin. The detailed thorough dose assessments are accessible in UNSCEAR (2000) and ICRP reports (1991). Both of these committees assessed the current state of scientific understanding and arrived at their best estimates of the mean yearly dosage applicable to individuals in the population as a whole. Several studies conducted around the world have demonstrated ambient radiation such as gamma exposures in various geological locations (Usikalu et al, 2023, Bhuyan et al., 2023, Rangaswamy et al, 2015, Negi 2009, Sreenth Reddy et al, 2010, Tchorz-Trzeciakiewicz, 2021).Thus, assessing gamma radiation from natural sources is not only necessary but also beneficial. The current study's goal is to assess indoor and outdoor ambient gamma radiation exposure in the Yagachi river basin in Karnataka, India.

2. Study area

The Yagachi River is located in Karnataka, India, with latitudes ranging from 12° 52' 58" to 13° 25' 1" N and longitudes ranging from 75° 59' 54" to 75° 59' 54" E. It is a significant tributary of the Hemavathi River. It begins in the Baba Budan hill range in Chikmagalur and runs through Belur taluk and Hassan District. It merges with the Hemavathi river at Gorur. It has a tributary named Votehole. A Votehole dam is being constructed on a stream near Rajanahalli. Its catchment area stretches from Mullayyanagiri (Baba Budan Range) south to Gorur Dam. Yagachi, like Votehole, provides irrigation and drinking water to the towns of Belur, Chikmagalur, Arsikere, and Hassan (Ground water information booklet Hassan district 2007, Ground water information booklet Chikmagalur district 2007). The study area spans about 116 kilometres in length, Charnokite, gneisses, unidentified crystallines, slates, the phyllites & schists, granite, and peninsular gneiss are the most prevalent rock types in the research region, but peninsular gneiss is the most important (Ground water information booklet Hassan district 2007, Ground water information booklet Chikmagalur district 2007). The study area is represented as shown in Figure 1.

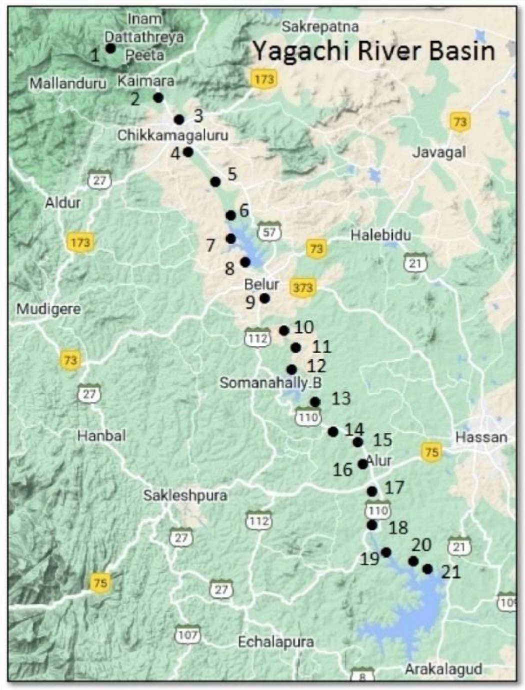

Figure1: Location map of the study area (Yagachi river basin).

3. Methodology :

The external gamma dose rates in the air were determined at various locations throughout the study area using a portable GM tube-based Environmental radiation dosimeter (MICRO-R-SURVEY METRE NUCLEONIX UR 705, Hyderabad, India), which is specifically designed to serve as a low level survey metre for use in indoor environments. It is an excellent tool for monitoring environmental radiation as well as geological exploration for radioactive materials. This portable survey metre is built around a 1" X 1" NaI (Tl) Scintillator that is integrally attached to a 1" photomultimeter, and it provides an accurate result in measuring the minimal gamma radiation dose rate. The 5V regulator output, high voltage circuit, gamma detector probe, pulse amplifier, discriminator circuit, a real-time clock, micro microcontroller and associated circuit blocks comprise the portable survey metre. The equipment was calibrated at Nucleonix Systems (P) Ltd's Radiation Standard as well as Calibration Lab with ^{137}Cs as the standard source. The detailed approach can be found elsewhere. After a few minutes of operation, the dosimeter displays the radiation dosage rate value. The indoor and outdoor measurements were collected at one metre above the ground (Ajayi, 2009). At each location, the average of the readings was determined. The exposure rate (R h^{-1}) was translated to the dosage rate (nGy h^{-1}) using a conversion factor of 1R h^{-1} = 8.7 nGy h^{-1}, and the annual effective dose (AED) in mSv y^{-1} was determined using

$$AED = DxTxOFxCC \qquad (1)$$

where, D is the absorbed dose rate, T is the time in hours for one year (8760 hours), OF is the occupation factor of 0.8 and 0.2 for indoor and outdoor, and CC is the conversion coefficient of 0.7 Gy^{-1} (Ajayi. 2009).

4. Results and Discussion

Table 1 summarises the measurement results and mean indoor and outdoor absorbed dose rate (ADR) and AED in several places around the Yagachi river basin. In the studied area, the indoor ADR ranged from 52.2 to 243.6 nGy h^{-1}, with a average value of 113.1 nGy h^{-1}. The variance in ADR is attributed to the kind of flooring and ventilation. Dattathreya peeta and Kimara have a high absorbed dose rate. The cause for this is due to poor ventilation in the home, the type of building materials used, and the local geology, as the rocks around this area are granites with a greater concentration of radionuclides. Lower absorbed dose rates have been recorded at Yerhalli and Muttanahalli due to good ventilation and local geology, as the surrounding soil and rocks in this location are gneiss with lower radioactive concentrations. The AED for those living in the research area ranged between 0.256 and 1.195 mSv $y^{-1,}$ with an average value of 0.555 mSv y^{-1}.

Table 1 Average Indoor ambient gamma exposure rates and AED along Yagachi river basin.

Sl.No.	Location	Latitude	Longitude	E R (μR h^{-1}) Mean±SD	ADR (nGy h^{-1})	AED (mSv y^{-1})	ELRC X10^{-3}
1	Dattathreya peeta	13° 26' 09"	75° 42' 06"	28±04	243.6	1.195	4.482
2	Kimara	13° 22' 17"	75° 74' 36"	26±04	226.2	1.110	4.162
3	Sringeri shri shankara mata	13° 19' 45"	75° 46' 22"	16±03	139.2	0.683	2.561
4	Anjaneya temple Chikkamagalur	13° 18' 35"	75° 46' 34"	16±03	139.2	0.683	2.561
5	Mugulavalli	13° 16' 29"	75° 49' 56"	13±03	113.1	0.555	2.081
6	N.Hosahalli	13° 14' 38"	75° 50' 11"	9±02	78.3	0.384	1.441
7	Kudlur	13° 12' 34"	75° 50' 12"	8±01	69.6	0.341	1.281
8	Shamuboganahalli	13° 11' 03"	75° 50' 55"	14±02	121.8	0.598	2.241
9	Belur	13° 09' 56"	75° 51' 58"	9±01	78.3	0.384	1.441
10	Malegere	13° 07' 27"	75° 51' 58"	14±02	121.8	0.598	2.241
11	Tagare	13° 06' 36"	75° 53' 26"	13±02	113.1	0.555	2.081
12	Simanahally	13° 02' 48"	75° 56' 22"	13±02	113.1	0.555	2.081
13	Hallyyur	13° 11' 26"	75° 56' 00"	8±01	69.6	0.341	1.281
14	Yerehalli	13° 00' 32"	75° 57' 02"	6±01	52.2	0.256	0.960
15	Imatipura	12° 59' 41"	75° 58' 16"	16±02	139.2	0.683	2.561
16	Alur	12° 57' 37"	75° 59' 13"	8±01	69.6	0.341	1.281
17	S Koppalu	12° 57' 09"	75° 58' 56"	16±02	139.2	0.683	2.561
18	Kaggaravally	12° 55' 00"	75° 58' 19"	8±02	69.6	0.341	1.281
19	Chittanahalli	12° 54' 40"	75° 59' 34"	16±03	139.2	0.683	2.561
20	Muttanahalli	12° 53' 15"	76° 00' 38"	6±01	52.2	0.256	0.960
21	Chowdanahalli	12° 51' 24"	76° 02' 08"	10±01	87	0.427	1.601
Minimum				**6±04**	**52.2**	**0.256**	**0.960**
Maximum				**28±04**	**243.6**	**1.195**	**4.482**
Average				**13±04**	**113.1**	**0.555**	**2.081**

Table 2 summarises the average outdoor gamma ADR and AED in several areas across the Yagachi river basin. In the research area, the outdoor ADR ranged from 43.5 to 139.2 nG h^{-1}, with a average value of 68.771 nGh^{-1}. The variance in ADR is attributed to local geology; for example, a high ADR has been recorded in Dattathreya peeta, Kimara due to local geology because this area is bounded by granite type rocks with greater concentrations of radionuclides. Because of the local geology, which is the surrounding soil and rocks have a smaller amount of radionuclides, lower values of ADR were reported at Yarehalli, Muttanahalli and Imatipura. The AED to the research area's public ranged from 0.061 mSv.y $^{-1}$ to 0.195 mSv.y $^{-1}$, with a average value of 0.096 mSv.y $^{-1}$. From the standpoint of radiological health, this is unlikely to provide a considerable additional risk. According to ICRP (1990), the yearly dose threshold for people in the public is 1 mSv.y $^{-1}$, although this dose limit does not apply to those received through natural resources (ICRP 1990). All of the results are substantially below the background radiation limit 2.4 mSv y^{-1} (ICRP 1990). Except in a few cases, indoor absorbed dose rates are often higher than outside dose rates. The increased level of ADRin the indoor atmosphere is mostly due to the usage of rocks and building materials that contain greater amounts of natural radionuclides like ^{226} Ra, ^{232}Th, and ^{40}K (Gabdo et al, 2014). The use of gneissic granites, earth, and other decorative stones in the construction of floors and walls, as well as poor ventilation inside structures, increase radon concentration and radon daughter concentration, both of which contribute to the enhanced gamma absorbed dosage. Outdoor differences in gamma radiation rates from location to location could be attributable to changes in meteorological conditions.

Table 2 Average outdoor ambient gamma exposure rates and AED along Yagachi river basin.

Sl.No.	Location	Latitude	Longitude	E R (μR h^{-1}) Mean±SD	ADR (nGy h^{-1})	AED (mSv y^{-1})	ELRC X10^{-3}
1	Dattathreya peeta	13° 26' 09"	75° 42' 06"	16±02	139.2	0.732	0.195
2	Kimara	13° 22' 17"	75° 74' 36"	15±02	130.5	0.686	0.183
3	Sringeri shri shankara mata	13° 19' 45"	75° 46' 22"	12±01	104.4	0.549	0.146
4	Anjaneya temple Chikkamagalur	13° 18' 35"	75° 46' 34"	10±01	87	0.457	0.122
5	Mugulavalli	13° 16' 29"	75° 49' 56"	7±01	60.9	0.320	0.085
6	N.Hosahalli	13° 14' 38"	75° 50' 11"	6±01	52.2	0.274	0.073
7	Kudlur	13° 12' 34"	75° 50' 12"	7±01	60.9	0.320	0.085
8	Shamuboganahalli	13° 11' 03"	75° 50' 55"	10±02	87	0.457	0.122
9	Belur	13° 09' 56"	75° 51' 58"	8±01	69.6	0.366	0.098
10	Malegere	13° 07' 27"	75° 51' 58"	5±01	43.5	0.229	0.061
11	Tagare	13° 06' 36"	75° 53' 26"	7±01	60.9	0.320	0.085
12	Simanahally	13° 02' 48"	75° 56' 22"	9±02	78.3	0.412	0.110
13	Hallyyur	13° 11' 26"	75° 56' 00"	6±01	52.2	0.274	0.073
14	Yerehalli	13° 00' 32"	75° 57' 02"	5±01	43.5	0.229	0.061
15	Imatipura	12° 59' 41"	75° 58' 16"	5±01	43.5	0.229	0.061
16	Alur	12° 57' 37"	75° 59' 13"	7±01	60.9	0.320	0.085
17	S Koppalu	12° 57' 09"	75° 58' 56"	5±01	43.5	0.229	0.061
18	Kaggaravally	12° 55' 00"	75° 58' 19"	7±01	60.9	0.320	0.085
19	Chittanahalli	12° 54' 40"	75° 59' 34"	6±01	52.2	0.274	0.073
20	Muttanahalli	12° 53' 15"	76° 00' 38"	5±01	43.5	0.229	0.061
21	Chowdanahalli	12° 51' 24"	76° 02' 08"	8±02	69.6	0.366	0.098
Minimum				**5±02**	**43.5**	**0.061**	**0.229**
Maximum				**16±02**	**139.2**	**0.195**	**0.732**
Average				**7.905**	**68.771**	**0.096**	**0.362**

Variations of radon progeny concentration in air occur due to changes in weathering factors such as rainfall, soil, and moisture (Megumi, 1998). In general, locations with acid or basic intrusive geological features had a higher average terrestrial gamma absorbed radiation dose rate value depending on geological background. The radionuclides identified in the parent rocks could be the primary cause of the somewhat increased radiation level seen in this geological location. To estimate the radiological danger, Excess Lifetime Cancer Risks (ELCR) were determined from AED values (Table 1 and 2), and outside ranges from 0.229 $x10^{-3}$ to 0.732 $x10^{-3}$ with an average of 0.362 $x10^{-3}$, while interior ranges from 0.960 $x10^{-3}$ to 4.482 $x10^{-3}$ with an average of 2.081 $x10^{-3}$. Notably, these results are greater than the global average ELCR of 0.29 $x10^{-3}$ (Taskin et al, 2009), which necessitates additional research. Despite the fact that the current recorded values of terrestrial gamma radiation and predicted ELCR at the defined areas are higher than the global average.

As a result, the amount of radiation observed at these places may not constitute a health risk. In this context, it is worth noting that a number of researchers have proposed that low-dose radiation exposure may be beneficial to the well-being of humans (Cuttler, 2013) and act as a stimulation to accelerate DNA damage repair, reduce genetic instability, and enhance immune responses, resulting in cytoprotection from low-level radiation (Pandey et al, 2006).

5. Conclusion

Indoor and outdoor terrestrial gamma radiation exposure rates have been measured in and around the Yagachi river basin. Average indoor and outdoor terrestrial gamma radiation exposure rates were 113.1 nGy h^{-1} and 68.771 nGy h^{-1}, respectively, with the former being greater than the world average value and the latter being equal to it. Higher levels of terrestrial gamma radiation dose rates were recorded in sites with granite type of rock, while lower values were observed in locations with gneiss type of rock. AED estimates for indoor exposures varied from 0.256 to 1.195 mSv y^{-1}, with an average value of 0.555 mSv y^{-1}. The annual effective dosage for outdoor exposure varied between 0.061 to 0.195 mSv y^{-1}, having a mean value of 0.096 mSv y^{-1}. The Dattathreya peeta and kimara regions had somewhat higher natural terrestrial radioactivity, this region is attributed to granite rocks with more radionuclides, lower values of AED were reported at Yarehalli, Muttanahalli and Imatipura, but it was still considerably below the background radiation of 2.4 mSv y^{-1}. It is thought that the small amount of radiation in the gneiss region may have health benefits. These findings may serve as a baseline for future epidemiological studies to assess potential community health implications.

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