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Measurement of environmental gamma dose levels around Udupi district of coastal Karnataka, India

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Abstract The outdoor and indoor environmental gamma dose rates in air have been measured in several parts of Udupi district, Karnataka, India using thermoluminescent dosimeters (TLDs). The outdoor annual gamma dose values varies in the range 0.49–1.17 mGy/year with mean 0.75 ± 0.18 mGy/year. Similarly indoor annual gamma dose varies in the range 0.51–1.10 mGy/year with mean 0.74 ± 0.13 mGy/year. The mean values of indoor and outdoor gamma dose rates were 84 and 86 nGy/h respectively with indoor to outdoor dose ratio of 1.02.

Keywords Environmental TLD · Thermoluminescence · Dosimetry · Udupi · Environmental radioactivity

Introduction

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the ecological and geographical conditions [1]. The levels of radioactive nuclides in rock and soil vary with geological locations and natural radiation is the largest source of population dose. In this context, it is important to measure the dose rates at different geological areas. The two prominent sources of external radiations are cosmic rays and terrestrial gamma rays. Terrestrial external gamma dose are essentially from ^{40}K and radionuclides in the ^{238}U and ^{232}Th series present in the earth crust. These radionuclides impart not only external dose to the population, but also enter the human body through food chain and inhalation thus resulting in the internal radiation dose to population. The main contributors to the air dose are ^{208}Tl and ^{238}Ac from the ^{232}Th series and ^{214}Pb and ^{214}Bi from the ^{238}U series, which are short-lived decay products of ^{220}Rn and ^{222}Rn respectively. A number of gamma rays with maximum energy up to 2.62 MeV are emitted from these radionuclides. The estimated average global concentration level of ^{238}U and ^{232}Th in soil is 33 and 45 Bq/kg respectively [1], In the Indian context, these values are 31 and 63 Bq/kg respectively [6]. The dose levels in India, due to terrestrial gammas from ^{40}K, ^{238}U and ^{232}Th series radionuclides are estimated as total of 69 nGy/h [2], as compared to the global average value of 59 nGy/h [1]. The major part of exposure from terrestrial radiation is caused by radon (^{222}Rn) and, to a lesser extent, thoron (^{220}Rn). Radon and thoron are gases which form part of the uranium and thorium decay chains. Because they are gases they can seep out from where they are produced in rocks of the building materials of our homes, and then be inhaled along with their short-lived progeny. The inhalation of radon and its progeny is the single biggest source of radiation exposure in the world. In most areas, the building materials enhance indoor exposure rate by 40–50% above outdoor levels. The indoor to outdoor ratios in countries varies from 0.8 to 2. For wooden and lightweight houses, a ratio near one would be expected. For houses of brick, stone, or concrete, the concentrations in the building materials and surrounding source geometry would give the indoor-outdoor absorbed dose rate ratio above 1 and up to 2. The radioactivity of soil which

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contributes to the external exposure is formed by the weathering of the rocks from which the soil is derived. The radioactivity in soil is reduced with respect to parent rock due to weathering and leaching. The aim of the present study is to measure the levels of outdoor and indoor ambient gamma radiation levels and determine the annual effective dose to which people are exposed in the region of Udupi district.

Experimental

Study area

Udupi is surrounded by Dakshin Kannad district to the South, Uttar Kannad district to the North. It is bound by Arabian Sea in west and Western Ghats in the east. Land nearer to sea is plain with small hills and paddy fields, coconut gardens etc. Land bordering the Western Ghats in the east is covered with forests and hilly terrain; the forests are very thick in some parts. The district is characterized by sandy soil along the coastal belt and lateritic soil in other parts with high iron and aluminum contents. Laterite stones are available more in the high plain of interior districts which are useful for construction purpose. Udupi district is one among 30 districts of Karnataka state, India. The district lies between 13°04′ and 13°59′ North latitude and 74°35′ and 75°12′ East longitude covering an area of 3575 sq km. The location of Udupi district is shown in Fig. 1. A total of twenty-five locations were selected for this study in which Indoor and outdoor gamma dose measurements for each locations were carried out using TLDs.

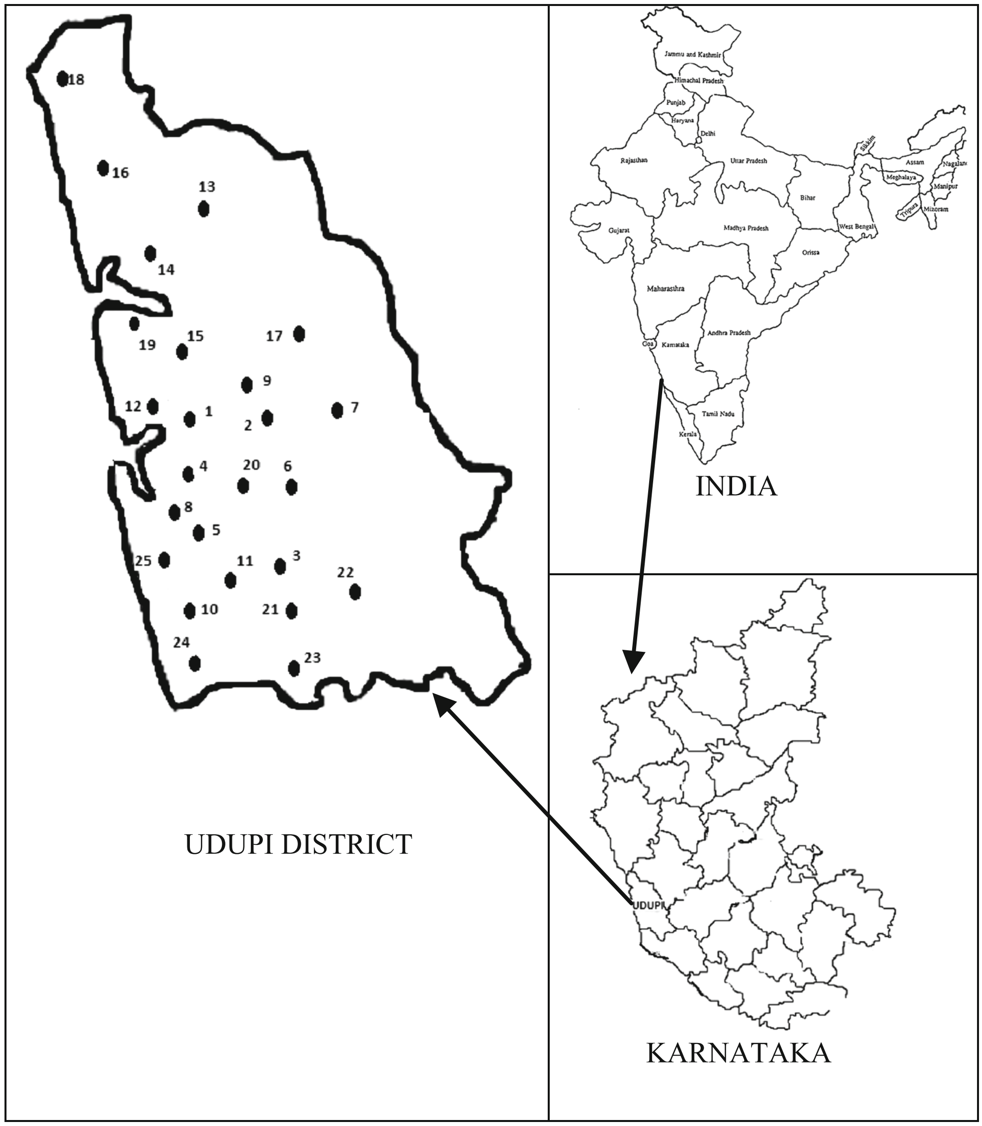
Thermoluminescence Dosimeter description

In present study, outdoor and indoor external gamma dose rates in air have been measured in the environment of Udupi district. These measurements were carried out using thermoluminescent dosimeter (TLD). TLDs are one of the best dosimeters used in fields of personal, medical, industrial and environmental applications [3]. TLD is a passive device for the measurement of gamma dose and in this the dose is acquired and stored for a long period of time until the system is stimulated by heat. Since even at the same place the ambient radiation level also varies at different times due to weather conditions, the advantage of this system is that as it acquires the dose continuously the variation of dose during different periods of time is averaged out. The measured dose rates include both terrestrial and cosmic ray components. Measurements were carried out using dosimeters based on $CaSO_4$:Dy Teflon discs which were found to be best for environmental dosimetry [4]. $CaSO_4$:Dy Teflon TLD discs with optimized Dy concentration of 0.2 mol%, specifically designed for environmental thermoluminescent dosimetric purposes are being used [5]. These TLDs are annealed at 250 °C for the period of 3 h in an oven with air circulation. Background readings are recorded using automatic TLD badge reader indigenously developed by BARC.

Dose analysis methodology

An appropriate number of TLDs are kept as control TLDs at both laboratory and field location to determine the control dose at both these locations and transit TLDs were used to determine the transit dose. Dose received during the periods between fabrication-deployment and retrieval-analysis periods are carefully evaluated using these control TLDs and subtracted from the gross dose to obtain dose for 90 days at the deployment location. Each TLD, bearing an identification number is deployed at a pre-designated location for a period of three months at height of 1.5 m from ground. After three months these exposed TLDs are replaced by new set of TLDs. The exposed TLDs are retrieved back to BARC for further analysis. Annual values for all the locations are evaluated based on the average quarterly values during a particular year by normalizing to 365 days. These TLDs have been thoroughly characterized based on ANSI 545 [6] criteria for the environmental radiation monitoring using TLDs. The absorbed dose was calculated using standardized methodology. Normally, in any given quarter, about 5–10% TLDs are lost at the location of deployment. As such, for evaluation of annual values for a particular year, minimum of three quarterly values should be available to get representative dose level at the location. To estimate the annual effective doses (AED), one has to take into account the conversion coefficient from absorbed dose rate in air to effective dose and the occupancy factor. UNSCEAR recommended the outdoor and indoor occupancy factor of 0.2 and 0.8 respectively [1]. The occupancy factor is the proportion of the total time during which an individual is exposed to a radiation field, implying that 20% of the time is spent outdoors, on average, around world. The AED thus was calculated using the following formula,

Fig. 1 Location map for study



$$AED(mSv/year)_{indoor} = D(nGy/h) \times 8760(h/year) \times 0.8 \times 0.7(Sv/Gy) \times 10^{-6} \quad (1)$$

$$AED(mSv/year)_{outdoor} = D(nGy/h) \times 8760(h\ /year) \times 0.2 \times 0.7(Sv/Gy) \times 10^{-6} \quad (2)$$

Quality assurance of TLDs

Quality assurance in the TLD monitoring starts from assessing the quality of the card. After heat treatment, only those discs are selected that show the background reading within 10% of the average reading. Calibration of the 20 mCi ^{137}Cs source is routinely checked by a standardized protocol. This is done by exposing the TLDs to a standard source for various exposures and calibration procedure is carried out. The calibration of the phosphor for each batch is also confirmed by evaluating the control TLD.

Results and discussion

The results of outdoor and indoor annual gamma dose in air measured using TLD, which includes both terrestrial and cosmic ray components, is shown graphically in Figs. 2 and 3. Figure 2 gives the outdoor annual gamma dose; the values were found in the range 0.49–1.17 mGy/year with mean 0.75 ± 0.18 mGy/year. Similarly Fig. 3 gives indoor annual gamma dose in the range 0.51–1.10 mGy/year with mean 0.74 ± 0.13 mGy/year. The outdoor and indoor radiation level follows almost a uniform pattern with dose rate close to the mean values. The possible gamma dose rate in the indoor environment is attributed to building

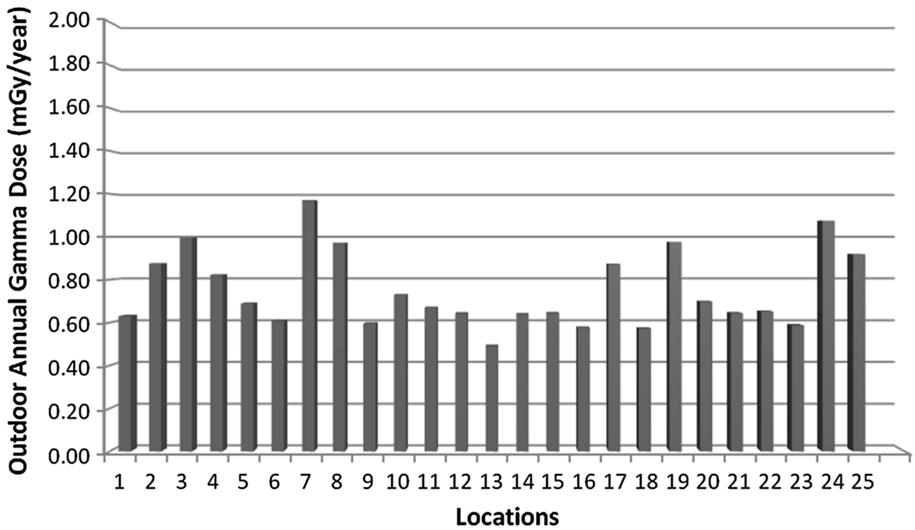


Fig. 2 Outdoor absorded annual gamma dose measured using TLD

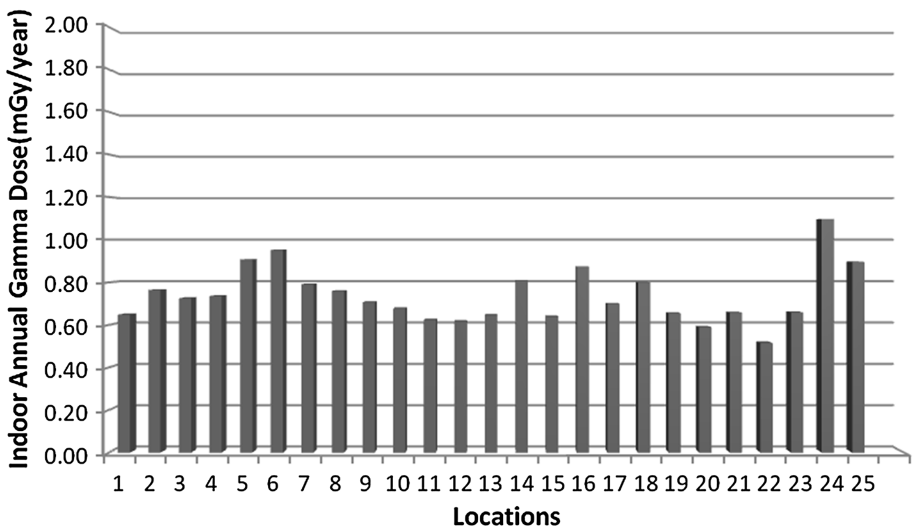


Fig. 3 Indoor absorded annual gamma dose measured using TLD

material used for construction. The use of gneissic granites, soil and other decorative stones for the construction of wall and floor and due to poor ventilation condition inside the building enhances the concentration of Radon, Thoron and their progenies. This contributes to the elevated indoor gamma absorbed dose. The ratio of indoor to outdoor gamma doses, in normal radiation background areas in India, is found to be approximately 1.2, particularly in houses which have tiled/cemented floors and concrete walls and ceilings. In Udupi district indoor to outdoor ratio is found to be 1.02, were most of houses surveyed were having tiled floors and concrete/cement walls and ceilings.

Measured absorbed gamma dose rates were used to calculate the AED received by the people of surveyed area. For calculating AED, we have used the dose conversion factor of 0.7 Sv/Gy and occupancy factor of 0.8 and 0.2 for indoor and outdoor respectively. Estimated values of AED for indoor exposure range from 0.29 to 0.61 mSv with mean 0.41 mSv. For outdoor exposure, AED ranges from 0.07 to 0.16 mSv with mean value of 0.1 mSv. The resulting worldwide average of the AED is 0.48 mSv, with the results for individual countries being within the 0.3–0.6 mSv range [1]. The resulting average AED for Udupi district is 0.51 mSv.

The comparison of external outdoor gamma dose rate in Udupi district with other environs is presented in Table 1. It can be seen that absorbed dose rate vary from 56 to 134 nGy/h with a mean value of 86 nGy/h. The mean value of dose rates prevailing in Udupi district is comparable with the mean values of 97 nGy/h reported for Udupi and Karkala Taluks measured using GM survey meter, mean value 58 nGy/h for Kaiga region and 71 nGy/h for Karnataka state. The measured outdoor gamma dose rate in the present study is also comparable with the all India average and world average as shown in Table 1. There was no data available for comparing the external indoor gamma dose rate in Udupi district.

Table 1 Comparison of gamma dose rates in Udupi district with other environ

	Range (nGy/h) Outdoor	Mean (nGy/h)	Reference
Udupi district	56–134	86	Present work
Udupi and Karkala taluks	70–123	97	[7]
Kaiga	43–77	58	[8]
Karnataka	43–99	71	[9]
All India	46–131	88.5	[9]
World	18–93	59	[1]

Conclusions

The outdoor and indoor radiation level follows almost a uniform pattern with dose rate close to the mean values. Indoor to outdoor ratio in the present study is found to be 1.02. The measured outdoor gamma dose rate in the present study is comparable with the all India average and world average for normal background. There is no known prior outdoor and indoor data in the area of study using TLDs. Such investigations are important not only for assessing population exposure and performing epidemiological studies but also for serving as a reference to possible environmental contamination due to human activity.

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