INTAKE DOSE RATE DUE TO VARIOUS GRANITE SAMPLES OF BANGALORE CITY, INDIA

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Abstract. The majority of total radiation dose received by the world population comes from background natural radiation. The distinguishing features of this radiation include relatively persistent exposure of a population at a specific place. The amount of background radiation that is generally present in the environment is greatly influenced by the inhalation of radon (Rn), thoron (Tn), and their offspring. In light of this, measurement of dose rate exposure due to granite flooring has been attempted in Bangalore. Fifteen different granite samples, used as flooring for construction in buildings, were examined for a period of three years. Solid state nuclear track detector-based dosimeters, can technique, and radiation survey meters have been used. All the experimental observations were made according to the standard protocols provided by the Bhabha Atomic Research Centre, Mumbai, India. The arithmetic mean dose rate varied between 1.39 ± 0.06 and 2.09 ± 0.10 mSv y^{-1}. The values of dose rates were found to be higher in granite and lower in coarse-grained dolerite. All 15 types of granite samples have undergone a minimum of 30 measurements. The greater activity concentration of radionuclides found in granite samples leads to higher dose rates.

Key words: Background gamma radiation, granite, Ra, Rn, Tn, dose rate.

INTRODUCTION

Several past research have thoroughly mapped the external gamma radiation rates in India. The average external gamma radiation exposure for India [23] is around 775 Gy y^{-1}, according to a national study of outdoor natural gamma radiation levels using thermo-luminescent dosimeters spanning many places dispersed throughout the country. Mishra and Sadasivan [22] estimated a national average value of 707 Gy y^{-1}, based on natural radioactivity measurements of undisturbed soil samples collected from more than 30 different locations around the country and assuming a uniform cosmic ray component as 287 Gy y^{-1}. It is reported [27] that of the terrestrial component, ^{40}K contributes 48.7 %, followed by the Th series (33.6 %) and the U series (17.7 %). The Rn exhalating properties of porous materials, both naturally occurring like soil, coal, rocks, and man-made like mining wastes, fly ash

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and many building materials etc. have been the object of several investigations [18]. Shiva Prasad *et al*. [31] have reported slightly higher radioactivity concentrations in the soil and building materials of present study area. Therefore, the dose rates received by the public could be at an alarming level. In light of this, an attempt has been made to measure the intake dose rate due to various granite samples used as flooring material in Bangalore city.

MATERIALS AND METHODS

AREA OF PRESENT STUDY

The current study is focused on Bangalore city, which spans a region of around 240 km^2 [4]. The city is located at 12.96° N, 77.56° E, with an average elevation of roughly 920 m above the sea level [6]. Nearby pet granites, groups of younger than peninsular gneiss rocks, that are composed of various potassium granite types with varied color, texture, and different intrusion relationships, surround this region. Pink, grey, and porphyries gneisses with big feldspars and black dolerite are the typical rocks. These rocks are part of a geological belt of 20–35 km wide [4]. It has been reported that the radioactivity of building materials collected from this location is greater than the permissible threshold and greater than that of the soil [31]. The granite samples used for the present gamma radiation survey measurements are igneous rocks with mineral compositions of pyroxene (bronzite), plagioclase feldspar, zircon, leucosome, quartz, feldspar, and k-feldspar. All the samples, found all across the state of Karnataka, are used as building materials and ornamental stones, too. For the current study, granite samples that are available in the districts of Bangalore, Ramanagara (50 km), Mandya (90 km), and Mysore (135 km) were analyzed. These granites have an age range from 1.5 to 3.3 billion years. The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in soil samples from Bangalore are lower than those of Nelamangala and Magadi, the city's outskirts [31]. The activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples used in this investigation were found to be higher than the respective global averages. The absorbed dose rate owing to ^{226}Ra, ^{232}Th, and ^{40}K concentration in soil varied between 0.59 and 1.44 mGy y^{-1}. An intensive effort has been made to evaluate the intake dose rate exposure caused by various granite samples used as flooring in the houses of Bangalore.

GEOMORPHOLOGY AND GEOLOGY

Bangalore city is situated on top of an archean-era hard and somewhat dense gneissic basement (2,500–3,500 million years ago). From the Golf Course in the north central section of the city to Vasantpur in the south (a distance of over 13 km), a significant granitic intrusion extends, averaging 4 km from east to west [4]. Further, from the Puttanna Chetty road of Chamrajpet to Bikaspura road of Bangalore South, a roughly 7.3 km long magmatic intrusion is formed within the granitic runs, and this is a parallel road to Krishna Rajendra Road [4]. Hard massive rocks including gabbro, dolerite, norite, and pyroxenes make up the majority of these fundamental intrusions, which mark the end of the Archean epoch (Lower Proterozoic; 1,600–2,500 million years ago). The Bangalore city contains south Pennar basin. A tiny tributary of the Arkavati, the Vrishabhavathi, exits the city roughly diagonally from the southwest [4]. At the junction of the Mysore Road and the Bangalore University Road, it divides off upon entry, giving rise to the Nagarabhavi Thorai. Due to structural control likely imposed by currently active faults and other north-south trending lineaments in its path, the river Arkavati diverges north from the Cauvery [4]. The central denudation plateau is nearly devoid of topography, and the drainage network's erosion and transfer of sediments create the lateritic clayey alluvium that can be found throughout the city center. Low relief terrain that abruptly joins the plateau is known as the pediment or pediplain. The river Arkavati and its minor tributaries may have eroded the land and caused elevation along active lineaments. The ensuing alluvial fan sediments have been spread out along the waterways or transported by them [4].

MEASUREMENT PROCEDURE

Exhalation measurements for Rn and Ra concentrations were made using can technique method [1, 2]. Fifteen samples of soil and granite used in building construction were taken in known quantities (0.01 kg) and placed in plastic cans after being oven dried and filtered using a 150 µm sieve. Each can's bottom lid was fastened with solid state nuclear track detector-based films (LR-115 Type II) so that the detector's sensitive side faced the samples. The cans were sealed and tightly closed from the top. The films were collected and chemically etched in 2.5 NaOH solutions at 60 °C for the duration of the entire season after being exposed for a period of 90 days. The detectors were cleaned, dried, and their alpha levels were measured using a spark counter. According to other researchers [6, 11, 29], the calibration factor for the provided LR-115 type II detector is 0.021 tr cm^{-2} d^{-1} = 1 Bq m^{-3}, which was used to translate the recorded track density (tracks cm^{-2} day^{-1}) into Rn concentration in Bq m^{-3}. The following equation [3, 12, 19] has been used to compute the effective Ra content (C_{Ra} in Bq kg^{-1}):

$$C_{\mathrm{Ra}} = \frac{\rho h A}{K T_{\mathrm{e}} M} \qquad (1)$$

where, ρ is background corrected track density due to Rn (track cm^{-2}), h is the distance between the detector and top of the sample (m), A is surface area of sample (m^2), K is sensitivity factor (track cm^{-2} d^{-1} per Bq m^{-3}), M is mass of sample (kg) and T_e is effective time of exposure (days) given by [30]:

$$T_e = \left[T_{1/2}\lambda^{-1}\left(1 - e^{-\lambda T_{1/2}}\right)\right] \quad (2)$$

where λ is the decay constant for Rn, given by $\lambda = \frac{0.693}{T_{1/2}}$. Here, $T_{1/2}$ is the half-life of Rn which is 3.82 d.

Mass exhalation rates, M_{Ex} and surface exhalation rates, S_{Ex} were calculated using the following equations [25, 28]:

$$M_{Ex} = \frac{C\,V\,\lambda/M}{T + 1/\lambda\left(e^{-\lambda t} - 1\right)} \ (\mathrm{Bq\ kg^{-1}h^{-1}}) \quad (3)$$

$$S_{Ex} = \frac{C\,V\,\lambda/A}{T + 1/\lambda\left(e^{-\lambda t} - 1\right)} \ (\mathrm{Bq\ m^{-2}h^{-1}}) \quad (4)$$

where, C is the integrated Rn exposure ($\mathrm{Bq\ m^{-3}h^{-1}}$), V is the volume of air in the can (m^3), T is the time of exposure (h), λ is the decay constant for Rn (h^{-1}), M is mass of sample (kg) and A is surface area of the sample (m^2).

DOSE DUE TO RADIONUCLIDES

Hyper pure germanium detector was used to calculate the concentration of gamma active radionuclides such as ^{226}Ra, ^{232}Th, and ^{40}K, in soil samples [33, 36]. The following relation [35] was used to compute the absorbed dose rates in air from the measured concentrations of ^{226}Ra, ^{232}Th, and ^{40}K:

$$D_{act}(\mathrm{nGy\ h^{-1}}) = [(0.427 \times A_{Ra}) + (0.666 \times A_{Th}) + (0.043 \times A_K)] \quad (5)$$

where, D_{act} is the absorbed dose, A_{Ra}, A_{Th}, and A_K are activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K respectively, in Bq kg^{-1}.

DOSE DUE TO INDOOR RADON AND PROGENY

Formula of Mayya *et al.* [21] was used to calculate the concentrations of Rn and Tn. The dose conversion parameters published by UNSCEAR [35] were used to determine the indoor inhalation dose rates D (mSv y^{-1}) caused by Rn, Tn and their progeny, as shown below:

$$D(\mathrm{mSv\ y^{-1}}) = 10^{-3}[(0.17 + F_R)C_R + (0.11 + 40F_T)C_T] \quad (6)$$

where, F_R and F_T are equilibrium factors for Rn and Tn, C_R and C_T are Rn and Tn concentrations. Numerical values given in the above relations are the dose conversion factors for gas and progeny concentrations.

DOSE DUE TO VARIOUS GRANITE SAMPLES

The RDS-31S/R Multipurpose survey meter, MIRION Technologies, Health Physics Division, Germany, continues the line of RADOS [34] survey meters offering modern design and approach to radiation monitoring. It has been used to conduct extensive study on background gamma radiation levels in Bangalore city. It is a battery-powered device with an energy-compensated Geiger-Müller tube serving as the principal detector. This device is capable of detecting gamma radiation with an energy range of 48 keV to 3 MeV. This device is used to measure the dose rate in granite samples.

RESULTS

Fifteen different granite samples, including granite (white), granite porphyry pink feldspar, syenite porphyry, granite porphyry, granite pink polished, diorite porphyry, felsite porphyry, granite coarse grained, granite (green), felsite green compact, gneiss, felsite, granite (pink), bronzite peridotite, and dolerite coarse grained, were used for flooring of the house. Rn exhalation rates were done at several locations of Bangalore city, and wide differences in concentrations were seen. Samples of granites used in the present study are shown in Table 1.

It is possible that the dose variation is due to the presence of radioactive elements in the building construction materials. Although Rn exhalation rates were recorded in a typical study room (the office room of Government Science College) from February to April, they ranged from 49.6 to 4,694.3 mBq m^{-2} h^{-1} with an arithmetic mean of 1,605.5 mBq m^{-2} h^{-1}, while they were found to range from 1,99.7 to 3,034.4 mBq m^{-2} h^{-1} with an arithmetic mean of 1,260.4 mBq m^{-2} h^{-1}. The Rn exhalation rates, measured in the office room, ranged from 227.1 to 1,717.2 mBq m^{-2} h^{-1} with an arithmetic mean of 1,229.6 mBq m^{-2} h^{-1} from May to July, and from 303.3 to 1,836.0 mBq m^{-2} h^{-1} from August to October with an arithmetic mean of 1,229.6 mBq m^{-2} h^{-1}. While the summer was dry, a much deeper table water depth during this campaign manifests itself a higher Rn exhalation rate from the soil [16, 17]. The exhalations were minimum during August to October, this being likely due to the overestimation of soil water saturation [13, 15], which may in turn lead to lower Rn concentration levels. The exhalation rates were higher during February to April; this may be because the soil and rock species were highly porous during this season [35].

The mean concentrations of ^{226}Ra, ^{232}Th, and ^{40}K were 26.2, 53.1, and 635.1 Bq kg^{-1}, respectively, comparable with the data from around the world [4]. Due to the presence of granites in the area, known to have higher amounts of ^{226}Ra and ^{232}Th, several of the locations displayed higher concentrations of these radionuclides. Feldspars, a component of granites, are responsible for the greater ^{40}K content.

Table 1

Granite samples analyzed in the present measurement

Dolerite coarse grained 	Bronzite peridotite 	Granite 
Felsite 	Gneiss 	Felsite green compact 
Granite(dark gray) 	Granite coarse grained 	Felsite porphyry 
Diorite porphyry 	Granite pink polished 	Granite porphyry 
Syenite porphyry 	Granite porphyry 	Granite(gray) 

Dabayneh [9] reported that the Rn exhalation rates for building materials such as granites were slightly higher than those from marbles. So, this could be the reason for higher Rn exhalation in granite samples. The ^{226}Ra activity in building construction material is higher than in soil, although the Rn exhalation rate is lower due to the lower porosity (by up to 30 %) of these materials [33]. Despite the lower concentration of ^{226}Ra in the soil, higher soil porosity may be the reason for higher Rn exhalation rate [33]. The amount of ^{226}Ra in a substance determines the Rn exhalation rate when materials have identical porosities. Similar observations have also been made elsewhere [8]. These rocks are firmly planted between 8 and 15 km below the crustal level. Annual average dose rate in various granite samples used for building construction are shown in Fig. 1. The arithmetic mean and geometric mean were in the range of 1.34 to 2.08 mSv y^{-1} and 1.33 to 2.02 mSv y^{-1}, respectively, while the maximum dose rates for the examined granite samples ranged from 1.72 to 2.71 mSv y^{-1} and the minimum values varied from 1.05 to 1.66 mSv y^{-1}.

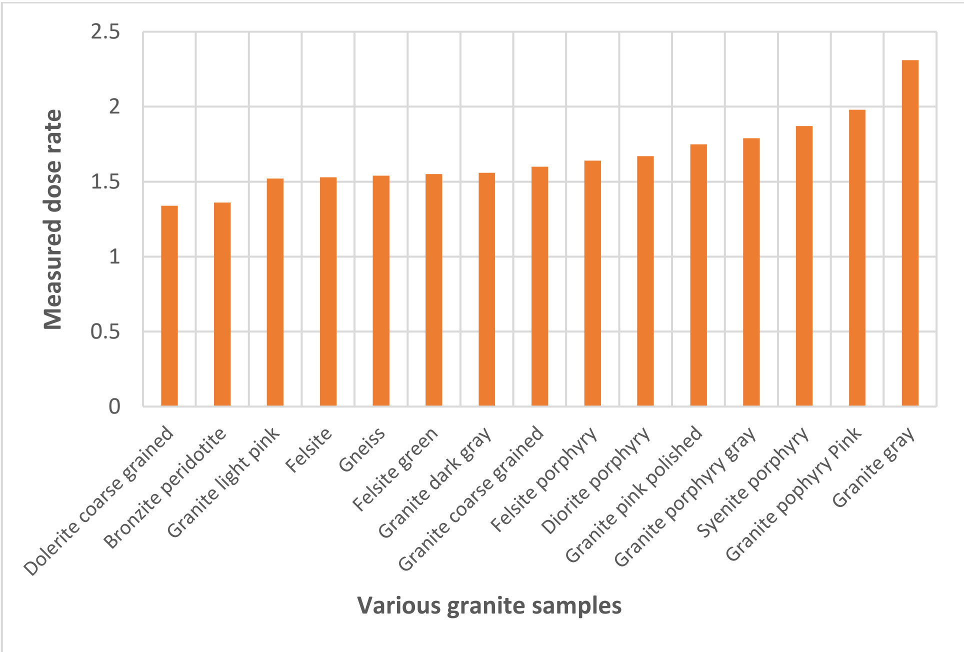

Fig. 1. Measured dose rate (mSv y^{-1}) in various granite samples.

In Bangalore, there are differences in the specific activities of the soil and frequently used building construction materials. The values of specific activity of ^{226}Ra in bricks used in Algeria and Germany are twice as large as those used in Lithuania, while the values of the specific activity of ^{226}Ra in clay used in Germany are less than those used in Lithuania. The specific activity of ^{226}Ra in cement used in India is roughly four times greater than that used in Lithuania. It was discovered that the location of a material's extraction affects the specific activity of a natural radionuclide [8].

The lower dose rate values were found in felsite, which are essentially fine-grained rocks with significantly less porosity than granite, which may be the cause for the lower dose values [14]. The higher dose rate values were found in granite, which may be related to the higher activity concentrations of radionuclide [8]. Because Rn exhalation rate depends on the precise activity of ^{226}Ra and ^{232}Th in the soil and building materials, this information is crucial [10, 24]. A method of preventing Rn exhalation from the earth (such as gap sealing and similar techniques) and enough ventilation are required to reduce the amount of Rn in the closed environment such as houses. Emanation-blocking techniques for building materials (pores filling, surface painting, and similar techniques) must be researched and used. Moreover, carefully selected building construction materials with lower concentrations of ^{226}Ra and ^{232}Th will lower the volumetric activity of Rn in a house. The results given for construction materials [20, 25, 32] are in good accord with the values reported in the present investigations. For the same environment, mean values of Rn and Tn were reported as 24.1 ± 8.3 and 24.5 ± 10.8 Bq m^{-3} respectively [26] and the annual mean value of the gamma absorbed dose rate was 175.8 nGy y^{-1} and the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in rocks as 32.2 to 163.6, 128.3 to 548.6 and 757.4 to 1,418.4 Bq kg^{-1}, respectively, with corresponding arithmetic mean values of 93.2, 306.2 and 1,074.4 Bq kg^{-1} [5].

Earlier reported range of activity, concentration level and the dose rate are in line with our measurements. The measured arithmetic mean value of dose rates in the granite samples of the Bangalore city was found to vary between 1.34 ± ± 0.06 mSv y^{-1} and 2.31 ± 0.10 mSv y^{-1} for granite (white) and dolerite coarse grained, respectively. These findings showed that granite (white) had higher dose rates as compared to dolerite (coarse-grained) dose rates.

CONCLUSION

Bangalore city's soil and building materials were examined for Rn exhalation and background gamma radiation levels.

The findings indicate that Rn concentrations are higher than those of Tn and appropriate control measures need to be taken. The dose rates for the granite samples were also higher.

In order to reduce the impact of radiation on human health, appropriate control mechanism must be put in properly.

A detailed analysis of the materials used in building construction calls for inspection before construction of houses in order to prevent the negative impact on human health.

Large amount of data concerning the radiation emitted by soil and water is required to develop a standard model of Rn concentration for a granite flooring dwelling.

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