Study of distribution of ^{226}Ra, ^{232}Th and ^{40}K in different rock formations and their dose estimation in and around Chickmagalur, India

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► ***Original article***

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Received: July 2012
Accepted: Dec. 2012

Int. J. Radiat. Res., July 2013; 11(3): 183-187

ABSTRACT

Background: The concentrations of radionuclides like ^{226}Ra, ^{232}Th and ^{40}K and the dose rate are measured in igneous and metamorphic rock formations in and around Chickmagalur. A total of 236 samples from 13 different locations around study area were analyzed. ***Materials and Methods***: The activity concentrations of the three radioactive elements were determined for mean period of 25000 s using HPGe (GMX - 10190) detector and the dose calculations were made using standard formulae. ***Results***: The mean activity concentrations in igneous rocks recorded were 36.6 $Bqkg^{-1}$, 73.2 $Bqkg^{-1}$ and 992.3 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K respectively. The mean activity concentrations in metamorphic rocks were 17.2 $Bqkg^{-1}$, 28.1 $Bqkg^{-1}$ and 617.8 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K respectively. Assuming 20% occupancy factor, the corresponding mean annual effective dose due to igneous and metamorphic rocks were 169.6 µSv and 90 µSv respectively. ***Conclusion***: The concentrations of radionuclides were found to be in similar with global and Indian average [1-3].

Keywords: *Radionuclides, Igneous rock, metamorphic rock and effective dose.*

INTRODUCTION

Background radiation is of terrestrial and extra-terrestrial origin. Terrestrial radiation is emitted by radioactive nuclides present in earth's crust of varying amount in all environmental matrices. Background radiation mainly belongs to radionuclides from uranium and thorium series and ^{40}K, is a major component of human radiation exposure [4]. Estimation of these radio-nuclides in rocks of different formation is important from the point of view of predicting the terrestrial external exposure from gamma radiation.

Uranium and thorium are present in all types of rocks and soils. They have heterogeneous distribution in the earth's crust due to geochemical and geophysical processes, which slowly recycle the crystal material to and from the mantle. In the present study, rock types of igneous and metamorphic groups, which are endemic to the region, were taken up for detail study. ^{226}Ra is found to be occurring in equilibrium with ^{238}U unless the environmental factors alter this ratio [5, 6].

MATERIALS AND METHODS

The study area belongs to Chickmagalur district, is a part of Sahyadri region lays in the Western ghat of Karnataka, India. It has a plateau region with elevation mapping from 600 to 1100 m above the sea level at latitude

between 13^0 10^1N and 13^0 45^1N and longitude between 75^0 40^1E and 76^0 5^1E [7, 8].

Igneous rock samples includes acidic rock and granite from 6 prominent regions of Chickmagalur and metamorphic rock includes Chlorite Gneiss, Actinolite Schist, Chlorite Schist, Amphibolites, Quartzite with pyrite of 7 regions located around Chickmagalur were selected based on their occurrence (figure 1).

In each location 8-10 spots (0.5 m^2) were selected and surface rock was broken with hammer into gravel size. At each spot about 1 kg sample was collected and composited sample of about 2 kg filled in a polythene bag and labeled. The sample crushed into fine powder (150µm) and about 200g filled in a plastic container and sealed using molten paraffin wax against air leakage and subjected to radiometric measurements [9].

Detector configuration

In the present study HPGe gamma ray spectrometer (GMX - 10190 – P, Resolution of 1.75 keV [FWHM] at 1.33 MeV and 17 % relative efficiency at 1.33 MeV) was used for the identification and measurement of the radionuclides. The calibration of the counting system was made with a standard source of the same geometry and composition as the sample of IAEA standard from Environmental Survey Laboratory, Kalpakkam. In order to standardize the measurements some of the samples were analised using similar system in the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam. Comparison of concentration of radionuclides in both detectors revealed that the activity of radionuclides was well within the standard deviation. Gamma spectra of the samples were obtained over an average period 25,000 seconds. Gamma rays of peaks of energy 609.51 keV with intensity of 46.1 %, 583.19 keV with intensity 85.97 % and 1460.8 keV with intensity 10.7% were used for the determination of ^{226}Ra, ^{232}Th and ^{40}K respectively [10].

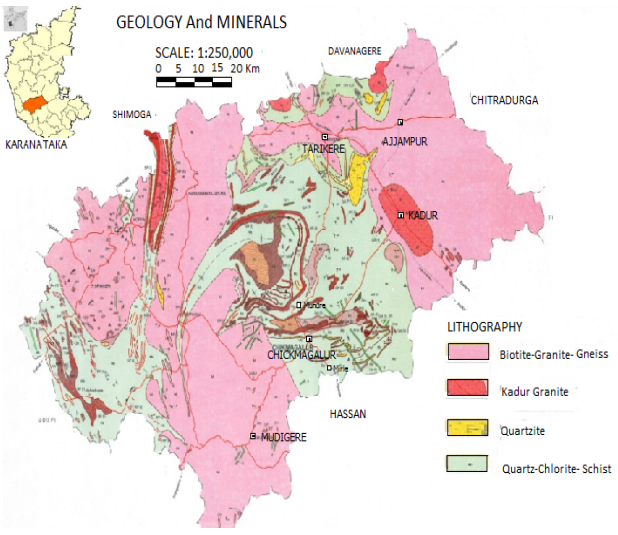

Figure 1. Geological map of study area.

Calculation of Activity concentration in Bqkg^{-1}

The activities of radionuclides were calculated using the following relation.

$$\text{Activity}\,(\text{Bq.kg-1}) = \frac{(S \pm \sigma)10^7}{EWA}$$

where, S is the net counts/sec under the photo peak of interests is the standard deviation of 'S', E is the counting efficiency (%), A is the gamma abundance of the radionuclide and W is the mass of the sample (g) [10, 12].

Calculation of dose rate in nGyh^{-1}

The gamma dose rate (D) calculation was carried out using the formula:

$$D\,(nGyh^{-1}) = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K$$

Where, A_{Ra}, A_{Th} and A_K are the activity concentrations of radium, thorium and potassium respectively in Bqkg^{-1}.

The annual effective dose (d) is calculated using the formula (assuming 20% occupancy) [10].

$$d\ (\mu Sv) = D \times 24 \times 365 \times 0.7 \times 0.2 \times 10^6.$$

RESULTS AND DISCUSSION

Igneous rocks

The results obtained for granite and acidic rock belonging to igneous group are tabulated in table 1. The activity concentration of ^{226}Ra and ^{232}Th ranges from 28 Bqkg^{-1} to 43 Bqkg^{-1} and 48.4 Bqkg^{-1} to 93.4 Bqkg^{-1} with geometric mean

Table 1. Radioactivity in Igneous Rocks (Granites) around Chickmagalur Region:

Regions	Location & Rock type	Activity concentration (Bqkg^{-1})			$\frac{^{232}Th}{^{226}Ra}$	Gamma Dose Rate (nGyh^{-1})			Total Dose* (nGyh^{-1})	Dose (µSvy^{-1})
		^{226}Ra	^{232}Th	^{40}K		^{226}Ra	^{232}Th	^{40}K		
1	Ajjampura-Acidic Rock	31.9±3.3	48.4±4.7	820.2±41	1.52	13.6	32.0	35.3	112.9	138.4
2	Chickmagalur -Granite	40.1±1.2	66.7±6.7	1070.2±38	1.66	17.1	44.2	46.0	139.3	170.8
3	Kadur-Granite	28.0±1.2	63.4±5.4	1078.7±48	2.26	12.0	42.0	46.4	132.4	162.3
4	Kalyadi-Granite	43.0±2.6	91.6±5.0	858.5±42	2.13	18.4	60.6	36.9	147.9	181.4
5	Mirle -Granite	39.5±4.8	87.9±5.4	1119.6±7	2.23	16.3	58.2	48.1	154.6	189.5
6	Mudigere -Granite	39.7±1.2	93.4±7.5	1049.1±40	2.35	8.2	61.8	45.1	147.1	180.3
Range		28.0-43.0	48.4-93.4	820.2-1196.0	1.52-2.35	8.2-18.4	32.0-61.8	35.3-48.1	112.9-154.6	138.4-189.5
G-Mean		**36.6**	**73.2**	**992.3**	**2.0**	**13.8**	**48.46**	**42.66**	**138.3**	**169.6**
Cosmic ray component of 32 nGy.h^{-1} included [3]										

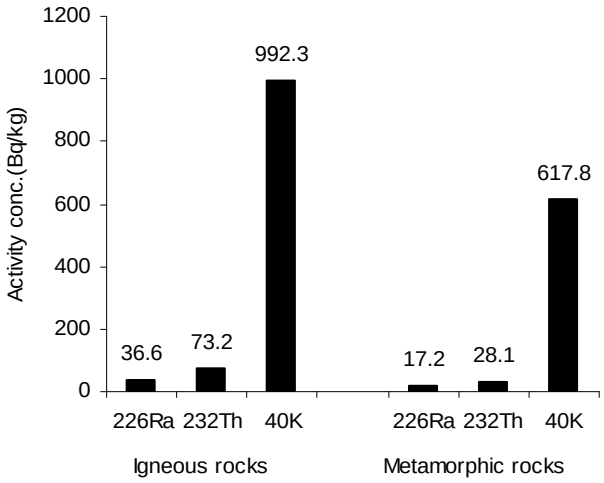

Figure 2. Activity concentrations of individual radionuclides in Igneous and Metamorphic rocks.

of 36.6 Bqkg^{-1} and 73.2 Bqkg^{-1} (figure 2) respectively. The ratio of concentrations of thorium and radium ranges from 1.5 to 2.4 with a geometric mean of 2.0. In most of igneous rocks, thorium is usually present in accessory minerals such as monazite, thorite, zirconite etc. derived from granite and gneiss and shows higher value of thorium which are comparable with reported figures of 1.1 to 2.0 [6, 13].

Granites are associated with higher level of ^{40}K. The concentration of ^{40}K range from 820.2 Bqkg^{-1} to 1119.6 Bqkg^{-1} with geometric mean of 992.3 Bqkg^{-1}. The abundance of potassium in granites is due to minerals like feldspar, orthoclase, muscovite etc. [14].

Since silica content in granites is high so also is the concentration of potassium and consequently the associated radioactivity due to ^{40}K.

The total gamma dose rates due to all the three radionuclides in igneous formation of rocks including cosmic ray component range between 138.4nGyh^{-1} and 189.5 nGyh^{-1} with a geometric mean of 169.6 nGyh^{-1}. The lower and higher dose rate recorded at Ajjampura -Acidic rock and Mirle-granite respectfully. The total gamma dose rate for different regions of igneous rock formation is shown in the figure 3. These vlues were comparable granitic region found elsewhere [9, 10, 15].

Metamorphic rocks

The concentration of primordial radionuclides in schist, gneiss, quartzite and pyrite rocks belonging to the metamorphic group are tabulated in table 2. The radium and thorium activities range from 7.5 to 36.7 Bq.kg^{-1}and 14.0 to 79.4 Bqkg^{-1} (figure 2) respectively. The mean thorium/radium ratio is 1.5 while the range is between 0.9 and 2.5. Since the two radionuclides belong to different chemical groups and different radioactive series one

cannot expect a systematic relation between them. This is true also in the context of other types of rocks and environmental matrices. The Kalasapura and Kalyadi quartzite with pyrites show relatively low concentrations of ^{226}Ra and ^{232}Th, being respectively 10.0 & 7.5 Bqkg^{-1} and 14.0 & 16.2 Bqkg^{-1} respectively. This is attributable to the high concentration (80 – 90%) of quartz. It is an established fact that quartz contains little radioactivity. The chlorite-schist from Ajjampura and Mundre show higher concentration of ^{226}Ra and ^{232}Th (31.9 & 36.7 Bqkg^{-1} and 30.0 & 79.4 Bqkg^{-1}).

These values are also comparable to normal granites [9]. ^{40}K concentration is found to vary considerably from trace quantities to 869.7 Bqkg^{-1} with geometric mean 617.8 Bqkg^{-1}.

The quartzite show only traces of potassium while the chlorite schist contain higher values (816.7 Bqkg^{-1}). Figure 4, shows the variation of gamma dose and these values are comparables with normal regions [15, 16].

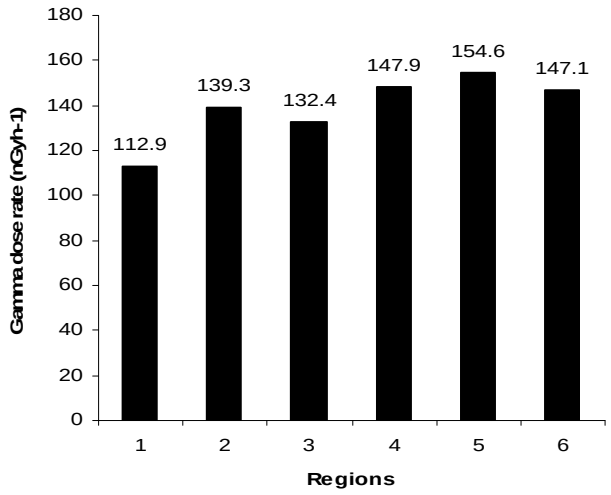

Figure 3. Gamma dose rates due to igneous rocks.

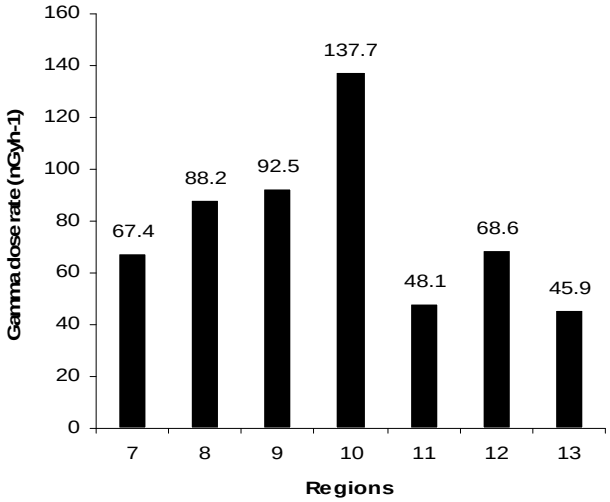

Figure 4. Gamma dose rates due to metamorphic rocks.

Table 2. Radioactivity in Metamorphic Rocks around Chickmagalur Region.

Regions	Location & Rock type	Activity concentration (Bq.kg^{-1})			$\frac{^{232}Th}{^{226}Ra}$	Gamma Dose Rate (nGyh^{-1})			Total Dose* (nGyh^{-1})	Dose (μSvy^{-1})
		^{226}Ra	^{232}Th	^{40}K		^{226}Ra	^{232}Th	^{40}K		
7	Ajjampura –1 -Chlorite Gneiss	17.0 ± 2.0	42.5 ± 2.0	BDL	2.5	7.3	28.1	BDL	67.4	82.6
8	Ajjampura-2 -Actinolite Schist	27.6 ± 3.7	34.7 ± 5.1	498.4 ± 45.9	1.3	11.8	23.0	21.4	88.2	108.1
9	Ajjampura-3- Chlorite Schist	31.9 ± 4.6	30.0 ± 3.5	628.6 ± 75.5	0.9	13.6	19.9	27.0	92.5	113.4
10	Mundre-Chlorite Schist	36.7 ± 2.3	79.4 ± 5.3	869 ± 40.8	2.2	15.7	52.6	37.4	137.7	168.8
11	Karthekere -Amphibolite	10.7 ± 2.8	17.4 ± 4.2	BDL	1.6	4.6	11.5	BDL	48.1	58.9
12	Kalasapura- uartz-ite with pyrite	10.0 ± 2.9	14.0 ± 2.3	534.7 ± 62.1	1.4	4.3	9.3	23.0	68.6	84.1
13	Kalyadi--Quartzite with pyrite	7.5 ± 1.0	16.2 ± 2.6	BDL	2.2	3.2	10.7	BDL	45.9	56.2
Range		7.5-36.7	14.0-79.4	BDL-869.7	0.94-2.16	3.2-15.7	9.3-52.6	BDL-37.4	45.9-137.7	56.2-168.8
G-Mean		**17.2**	**28.1**	**617.8**	**1.5**	**7.35**	**18.61**	**26.55**	**73.39**	**90.0**

BDL: Below Detection Limit -Cosmic ray component of 32 nGy.h^{-1} included [3]

CONCLUSION

The annual effective dose rates due to all the three radionuclides including cosmic ray component in igneous and metamorphic rocks were recorded 169.6 and 90.0 μSv respectively. In igneous rocks, concentration of thorium is relatively high in comparison with other formation. The activity concentration and hence the gamma dose rates in the present study has also established the baseline data for ^{226}Ra, ^{232}Th and ^{40}K in the rock samples of Chickmagalur region. The concentrations of the radionuclides and the gamma radiation level were found to be similar trends in comparison with global and Indian average [1,2,15,16].

ACKOWLEGEMENTS

The authors would like to express their sincere thanks to the Principals and Management authorities of PES Institute of Technology & Management, Shimoga and GFGC Sira, India, for their cooperation and support during this work.

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