Natural Radionuclide in soil samples and radiation dose to the population of Chamarajanagar district, Karnataka State, India

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ABSTRACT

This study is intended to assess activity of the natural radionuclide in natural soil and rock in study area and to estimate the radiological parameters such as radium equivalent activity, external hazard index and absorbed dose rate, which are related to the external γ-dose rate to assess the radiological hazards to human health and for checking its quality in general and knowing its effect on the environment. The measured activity concentrations for these natural radionuclides were compared with the reported data for other countries. The data obtained are essential for development of standards and guidelines concerning the use and management of soil and rock materials for construction of building and other purposes. In the present study, measurement of activity concentration of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in natural soil samples by using the method gamma ray spectrometry method, in some locations of Chamarajanagar district, in Karnataka state India, were made. The activity concentrations of radionuclides in the soil samples of the study area varied in the range from 4.85-14.15Bqkg^{-1}, 21.59-47.27Bqkg^{-1}, 19.87-47.79Bqkg^{-1}, respectively for ^{226}Ra, ^{232}Th and ^{40}K. Annual effective dose due to gamma radiation emitted by ^{226}Ra, ^{232}Th and ^{40}K present in soil varies from 2.44-5.86μSvy^{-1}.

Key words: Soil, Chamarjanagar, Gamma ray spectrometry.

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INTRODUCTION

Since the origin of the earth, the naturally occurring radionuclides are present in the earth's crust. Soil being a natural body, its formation begins with the breakdown of rock into regolith [1]. Soil is the important environmental sample, which may comprises of various amounts of natural radionuclide, mainly of uranium and thorium series, and the radioactive isotope of potassium. For radiation exposure in nature, members of the radioactive decay chain of ^{232}Th,^{235}U and ^{238}U with ^{40}K are mainly responsible. The contribution of ^{235}U to the

environmental dose is very small [2,3]. Therefore primordial radionuclides ^{238}U, ^{232}Th,^{40}K have sufficiently longer half-lives and decay to attain the stable state emitting ionizing radiations.

In the ^{238}U series, the decay chain segment begins from ^{226}Ra, which is radiologically the most important and, therefore, reference is often made to ^{226}Ra instead of ^{238}U. These radionuclides are the main sources of the external and the internal radiation exposures. The external exposure may caused by direct gamma radiation and inhalation of radioactive inert gases ^{222}Rn and ^{220}Rn, and their short-lived progenies may leads to internal exposure [2,4].

Activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the soil mainly depends on geological and geographical conditions. On the earth, the natural radioactivity in certain locations varies within narrow margins, but in some other locations there are wide deviations from normal levels due to abundance of minerals with high radioactivity [2-5]. From the natural health hazard point of view, it is necessary to study the dose limits of public exposure and the measurement of natural environmental radiation level in air, water, foodstuffs, soil, rock etc., to estimate human exposure to natural radiation sources.

Gamma ray spectrometry is a technique for determining qualitative and quantitative artificial and natural radioactivity in the environmental and geological samples by measuring their gamma ray emission. This study is important to assess activity of the natural radionuclide in natural soil and rock in study area and to estimate the radiological parameters such as radium equivalent activity, external hazard index and absorbed dose rate, which are related to the external γ-dose rate to assess the radiological hazards to human health and for checking its quality in general and knowing its effect on the environment. The measured activity concentrations for the natural radionuclide were compared with the reported data for other countries. The data obtained are essential for development of standards and guidelines concerning the use and management of soil and rock materials for construction of building and other purposes. In the present study estimation of primordial radionuclide ^{226}Ra, ^{232}Th,^{40}K in soil samples of Chamarajanagar district was made by using the gamma ray spectrometry method.

STUDY AREA

Chamarajanagar district is considered as the study area. This is the southernmost district of Karnataka state, situated between North latitude 11º 40' 58" and 12º 6' 32" and East longitude 76º 24¹ 14" and 77º 64' 55". Topography of the study area is undulating and mountainous with north south trending hill ranges of Eastern Ghats. Salem and Coimbatore districts of Tamilnadu in the East, Mandya and Bangalore districts in the North parts of Mysore district in the west and Nilgiris district of Tamilnadu in the south, bound the Chamaraja Nagara District. The study area comprises granite, gneisses, charnockites, pegmatite and dolerite intrusions overlaid by different soils. The Major type of soil in district, are reddish brown forest soil, yellowish grey soil, grayish sandy loamy soils, mixed soils.

MATERIALS AND METHODS

Sampling:

Soil samples were collected from different locations of study area to determine the distribution of radionuclide in the soil samples and correlate the same with radiation exposure level. The soil sampling places were carefully selected such that the places were free from surface run-off during heavy rain. An area of about 0.5 m^2 was marked and was cleared of vegetation and roots. The marked spot was dug up to a depth of 50 cm and about 2 kg of soil was collected at each Location. Finally, the samples were mixed thoroughly and extraneous materials such as plants, debris, big pieces of stones, and pebbles were removed [5-8]. Composite samples of about 2 kg were taken and sealed in a polythene bag.

Processing of Samples:

The samples were transferred to a porcelain dish and were then crushed in to fine powder and the sample is obtained by using scientific sieve of 150 micron mesh size. The samples were then over dried at 110℃ for 24 hours. Then about 425 g of sample was sealed in an airtight PVC container, to prevent the escape of radiogenic gases radon and thoron, which is used for measurements. Before measurements, the containers were kept sealed about four weeks in order to reach equilibrium of ^{238}U, and ^{238}Th and their respective progenies. After the attainment of secular equilibrium between uranium and thorium and their decay products, the samples were subjected to high-resolution gamma spectroscopic analysis. The activity of radionuclide was calculated using equation 1[7].

$$A\left(\mathrm{Bqkg^{-1}}\right)=\frac{(S\pm\sigma)\times 100\times 1000\times 100}{\mathrm{E}\times\mathrm{W}\times A}\rightarrow 1$$

Where, A=Activity concentration of the radionuclide in $Bqkg^{-1}$, S is the net counts/sec under photo peak of interest, σ is the standard deviation of S, E is the counting efficiency (%), A is the gamma abundance(%) of radionuclide and W is the mass of the sample(kg).

RESULTS AND DISCUSSIONS

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, in soil samples collected from Chandakavadi, Hebbasuru, Heggavadi Villages and Kanakagiri Hill, MM hill, Kuderu and Santhe Marahalli Villages of Chamaraja Nagar district were estimated by the method of gamma ray spectrometry. The experiments were carried out at USIC, Mangalore University.

The spectral data plot of soil sample (Chandakavadi village) is shown in fig 1. The photo peak of energy 609.31 keV (which is emitted by ^{214}Bi, a decay product of ^{226}Ra) with intensity of 43.30% was used for the quantitative determination of ^{226}Ra, the photo peaks of 583.19 keV with intensity 85.97% and 911.05 keV with intensity 27.7% were used for the quantitative determination of 232Th, and the characteristic photo peak of 40K is at 1460.8 keV with intensity 10.7% [9].

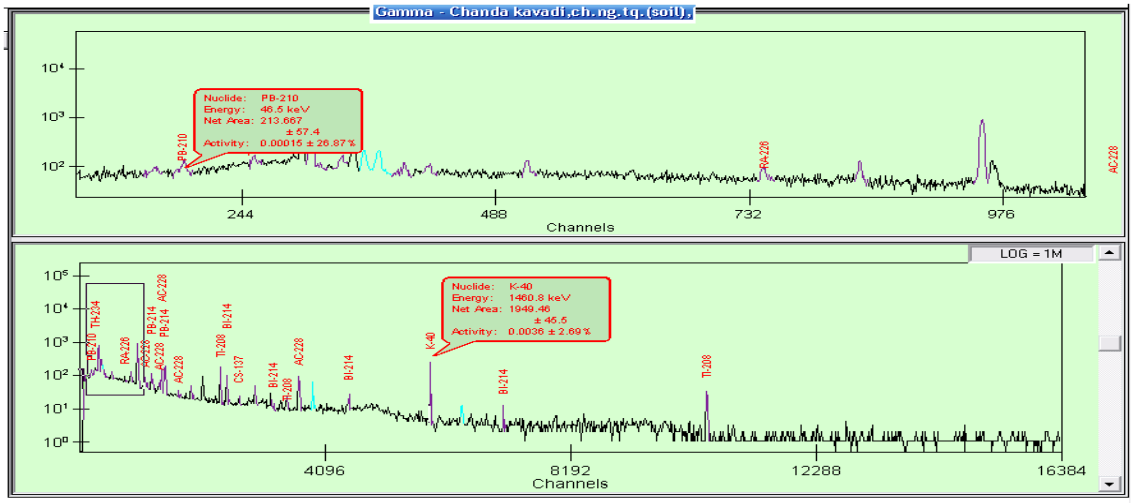

Fig 1: Spectral Data Sheet of Soil from Chandakavadi

The results of measurements of natural radionuclide (^{226}Ra, ^{232}Th and ^{40}K) concentrations in soil samples is summarized in Table 1. and Table 2. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, in the soil samples from the studied areas varies from 4.85-14.15 Bqkg^{-1}, 21.59-47.27 Bqkg^{-1}, 19.87-47.79Bqkg^{-1}, respectively. Higher value of ^{226}Ra is observed at Heggavadi, higher value of ^{232}Th is observed at Kanakagiri hill, and the ^{40}K activity concentration is found higher at MM Hills, in other locations the values are not significantly high.

Table1. Activity concentration and Hazard Indices of natural radionuclides

Location	*Activity concentration (Bqkg^{-1})*			A_{Ra}/A_{Th}	H_{ex}	I_α	$I_\gamma \times 10^{-3}$
	A_{Ra}	A_{Th}	A_K				
Chandakavadi	10.33	28.76	313.78	0.36	0.20	0.05	0.28
Hebbasuru	8.91	38.30	310.41	0.23	0.24	0.04	0.32
Heggavadi	14.15	32.98	183.92	0.43	0.20	0.07	0.27
Kanakagiri Hill	13.52	47.27	311.66	0.28	0.28	0.07	0. 38
Kuderu	8.90	22.69	49.34	0.39	0.12	0.04	0. 16
MM Hills	4.85	21.59	322.19	0.22	0.16	0.02	0. 23
Santhe Marahalli	11.47	25.44	115.85	0.45	0.15	0.06	0. 20
Minimum	4.85	21.59	49.34	0.22	0.12	0.02	0.27
Maximum	4.15	47.27	322.19	0.45	0.28	0.07	0.32
Average	9.62	29.82	207.06	0.34	0.19	0.05	0.29
Median	10.33	28.76	310.41	0.36	0.2	0.05	0.28

Average values of the activity concentrations of natural radionuclides in soil samples, in the study area were 9.62 $Bqkg^{-1}$, 29.82 $Bqkg^{-1}$, and 207.06 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th, and ^{40}K respectively. The average values for normal background areas of Indian soil are 15, 18.36 and 369.6 $Bqkg^{-1}$. The world wide average concentrations of natural radionuclides in soil are 35, 30, and 400$Bqkg^{-1}$ respectively for ^{226}Ra, ^{232}Th, and ^{40}K [2]. The global average of radium (^{226}Ra) thorium (^{232}Th) and potassium (^{40}K), in soil samples are 30, 45, and 420 respectively [7,10,11].

Compared to Indian average values the measured value of radium and potassium are low and that of thorium is high in the study area. But the average values of radium, thorium and potassium were low compared to world average.

Table 2. Ra_{eq} and Gamma dose rate ($nGyh^{-1}$) and Effective dose rate *(μSvy^{-1})*

Location	*Ra_{eq}*	*Gamma Dose rate($nGy.h^{-1}$)*			*Annual effective dose rate due to Natural radionuclides (μSvy^{-1})*
		Due to Radionuclides	*Measured by Survey Meter*		
			Indoor	*Outdoor*	
Chandakavadi	75.62	35.23	120.93	96.34	4.32
Hebbasuru	87.58	40.19	108.75	105.27	4.93
Heggavadi	75.47	34.12	120.49	101.99	4.18
Kanakagiri Hill	105.11	47.79	133.98	110.42	5.86
Kuderu	45.14	19.87	97.88	92.22	2.44
MM Hills	60.53	28.71	----	----	3.52
Santhe Marahalli	56.77	25.49	----	----	3.12
Minimum	45.14	19.87			2.44
Maximum	105.11	47.79			5.86
Average	72.94	33.23			4.07
Median	75.47	34.12			4.18

Distribution of activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in soils from different locations of the district, are shown in fig 2**.** The Sample codes SCD1, SHB2, SHG3, SKU5, are the soil samples from the locations, Chandakavadi, Hebbasuru, Heggavadi and Kuderu villages in Chamarajanagar taluk, SKH4 is Kanakagiri Hill, and SMM6, is soil samples from Malai Mahadeshwara Hill, in Kollegala taluk, SSM7, is the soil sample from Santhemarahalli village.
From the fig.2 it is clear that, Potassium (^{40}K) activity is found to be higher than that of Radium(^{226}Ra) and Thorium(^{232}Th) in all soils of these regions. The highest activity of Potassium is found in soils from the locations Chandakavadi, Hebbasuru, Kanakagiri Hill, and Malai Mahadeshwara Hill, compared to other locations such as Heggavadi, Kuderu and Santhemarahalli. Presence of high content of Potassium (^{40}K), contributes more gamma radiation dose rates to general public in these regions.

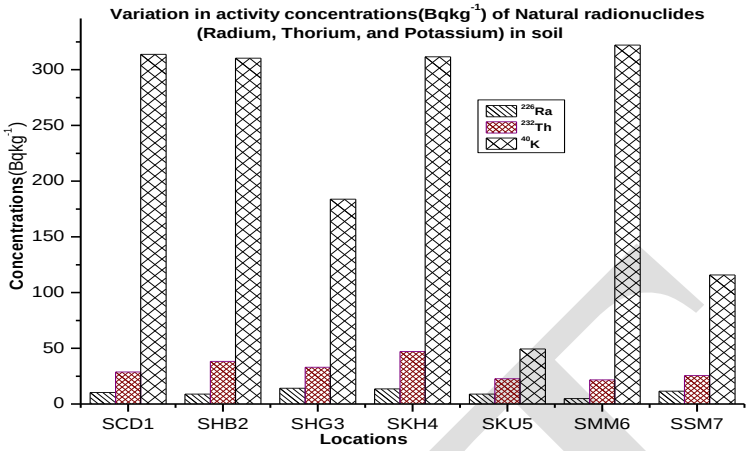

Fig 2: Variation in Activity Concentration of Natural Radionuclides in Soil

The Highest values of the activity concentrations of radium in soil samples are observed at Heggavadi village and Kanakagiri Hill. The higher amount of radium and thorium in soil depends to a large extent on the mineral composition of the host rock. The higher concentration of potassium may be due to excess use of chemical fertilizers in the agricultural lands in these regions.

Compared to ^{226}Ra and ^{232}Th radionuclides the average value of activity concentration of ^{40}K is higher and which contributes higher gamma radiation exposure to public. Correlation between calculated (due to natural radionuclides) and measured (using environmental survey meter) values of gamma absorbed dose rates(nGyh^{-1}) were studied and is shown in fig 3. There is a strong correlation between calculated value and measured value of gamma absorbed dose rate.

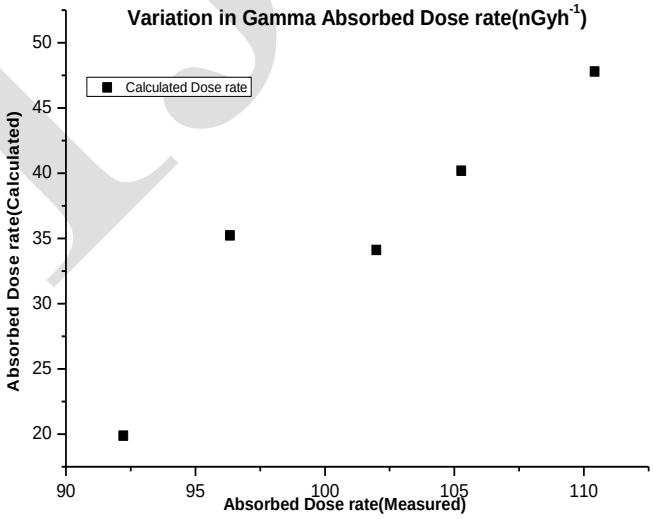

Fig 3: Variation in Gamma Absorbed Dose rate(Measured and Calculated)

Radium equivalent activity is the weighted sum of the activities of Ra, Th, and K based on the assumption, that 10 Bqkg^{-1} of ^{226}Ra,, 7 Bqkg^{-1} of ^{232}Th, and 130 Bqkg^{-1} of ^{40}K deliver equal gamma dose rates. Thus, the radium equivalent, activities (Ra_{eq}) are estimated using the following equation 2 [12,13].

$$Ra_{eq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \rightarrow 2$$

The estimated radium equivalent, activities (Ra_{eq}) varied from 45.14 to 105.11Bq.kg^{-1} with a median of 75.47 Bq.kg^{-1}. Ra_{eq} in soil samples of Chandakavadi, Hebbasuru, Heggavadi and Kanakagiri hill, is found to be higher than the other locations. But in all soil samples studied from the different locations of the study area the Ra_{eq} values are less than the maximum admissible value of 370Bqkg^{-1}. Therefore the external dose rate will be below, 1.5mGy.y^{-1}.
External hazard index can be calculated by the equation 3 [14]. This index value must be less than unity in order to keep the radiation hazard to be insignificant.

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \rightarrow 3$$

Where, $C_{Ra,}$ C_{Th} and C_K are the concentrations of radium, thorium and potassium, respectively. The calculated values of H_{ex} range from 0.12 to 0.28 with a median of 0.2. In all the Soil samples studied, the external hazard index is $H_{ex} \leq 1$. Therefore, the area under study is safe and soil samples of the district can be used for construction purposes, which does not pose any health risk.
Gamma activity concentration index I_γ has been defined by the European Commission, and is given by the equation 4 using which I_γ is calculated [15].

$$I_\gamma = 3.33C_{Ra} + 5.0C_{Th} + 0.33C_K) \times 10^{-3} \rightarrow 4$$

$I_\gamma \leq 2$ correspond to a dose rate criterion of 0.3 mSv.y^{-1}, whereas $2 < I_\gamma \leq 6$ corresponds to a criterion of 1 mSv.y^{-1}. The calculated gamma index I_γ for soil samples ranges from 0.27 to 0.32 Bq.kg^{-1}. But average value being 0.22 which is less than 0. 3mSv.y^{-1}.
The absorbed gamma dose (external) rate (G_d), in air 1m above the ground surface for uniform distribution of radionuclides was computed considering conversion factors for radium thorium and potassium as 0.462, 0.604, and 0.0417 respectively [2] using equation 5.

$$G_d\left(\text{nGyh}^{-1}\right) = 0.462C_{Ra} + 0.604C_{Th} + 0.0417C_K \rightarrow 5$$

Where C_{Ra} ,C_{Th}, C_K , are the average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K respectively. The calculated values of absorbed gamma dose rate in soil varied from 19.87 to 47.79nGyh^{-1} with an average value of 33.23 nGyh^{-1} which is lower than the world average of 55nGyh^{-1}, and lies within the reported average value of 18-93 nGyh^{-1} [2].
Using conversion coefficient from absorbed dose in air to effective dose rate as 0.7Sv.Gy^{-1} and outdoor occupancy factor 0.2 the annual effective dose (E) in mSvy^{-1}, is calculated using the equation 6 [2].

$$E = Dose\ rate\ in\ air\ (nGyh^{-1}) \times 8760hy^{-1} \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6} \rightarrow 6$$

The annual effective dose rate in soil sample was varied from 2.437 to 5.861 μSvy^{-1}, with an average value of 4.075 μSvy^{-1}, which is less than the world average value of 80μSvy^{-1} [2]. The annual effective dose rate and its average values were lower than the limit defined by European Commission, public control set ICRP, UNSCEAR and NEA-OECD [10,15-17]. Therefore, soil samples in the study area do not pose any radiation hazard to health when used in construction of houses, buildings and other facilities.

CONCLUSION

The study of ^{226}Ra, ^{232}Th and ^{40}K in soil samples of in some locations of Chamarajanagar district, in Karnataka state India, is carried out by using the gamma ray spectrometry method. The activity concentrations of radionuclides in the soil samples of the study area varied in the range from 4.85-14.15$Bqkg^{-1}$, 21.59-47.27$Bqkg^{-1}$, 19.87-47.79$Bqkg^{-1}$, respectively for ^{226}Ra, ^{232}Th and ^{40}K. Annual effective dose due to gamma radiation emitted by ^{226}Ra, ^{232}Th and ^{40}K present in soil varies from 2.44-5.86μSvy^{-1}. The radiological parameters such as Radium equivalent activity (Ra_{eq}), External hazard index (H_{ex}), Gamma absorbed dose rat were calculated and it was found that the studied values are within the guidelines limits.

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