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Radioactivity measurements of Soil samples from Devadurga and Lingasugur of Raichur District of Karnataka, India

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Abstract- **Naturally occurring radioactivity measurement, radiation monitoring of the region, dose assessment and interpretation of radiological related parameters are crucial aspects from the public awareness and environmental safety point of view. The ionizing radiations (γ-rays) emitted from radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K present in environmental materials contributes significantly to the radiation dose received by the public. Gamma spectrometry based high efficiency 4"X4" NaI(Tl) detector was employed for estimating activity concentrations of the gamma emitting radioelements. The spectra from the detector were recorded using a PC based 1k multichannel analyzer system (WinTMCA 32). Each sample spectra was acquired for a counting period of 60,000 sec (16.67 h). Assuming the daughter products of ^{226}Ra and ^{232}Th in equilibrium, the activity concentration of these radionuclides were estimated by using the prominent gamma photo peaks of daughter products. Using these activity dose related radiological parameters were calculated for all the samples. The activity concentrations of the radionuclides and the dose related parameters for the samples were found to be comparable with the global literature values. The data generated from our study will contribute to the base line radiological data of the region.**
Index Terms: Absorbed dose, Activity, Natural radioactivity, Radionuclides and Scintillation detector,

I Introduction

Radiations are present everywhere and human beings have always been continuously exposed to radiations knowingly or unknowingly, nature itself being one of the important sources of radiations. The studies have shown that the important source of radiations are the naturally occurring radionuclides such as ^{232}U, ^{232}Th decay series and singly occurring ^{87}Rb, ^{40}K etc [1, 2]. Gamma radiations emitted from naturally occurring radioisotopes, such as ^{40}K and ^{238}U, ^{232}Th and their decay products that are present in environmental materials such as soil, rock, water, granite, building materials etc., constitute the terrestrial background radiation and are a significant source of collective dose for the human beings [3]. The contribution of other nuclides to the total activity is negligible. Once present in the environment, these radionuclides, whether natural or artificial, are available for uptake by plants and animals and so make their way into the food chain [4]. The contribution of radiation from sediment to human exposure can either be whole body due to external radiation originating directly from primordial radionuclides present in sediment or internal due to inhalation [5]. Soil is an important environmental material which is used for many purposes such as building raw materials and products, for land filling in playgrounds, for streets etc. contains natural radionuclides contributing to the indoor and outdoor exposure. Therefore, measurement of radionuclides in soil samples of the study area is necessary as the data produced in this paper may be used as baseline data for future environmental assessments. The present study estimates the external gamma dose rate, which creates a public awareness about the radiation and provides the necessary information about the radiological protection.

II Study Area

The study has been carried out over two talukas of the Raichur district namely Devadurga and Lingasugur, covering an approximate area of 2500 square kilometers between 16.02, and 16.50 north latitude and 76.55 and76.92 east longitude. The study area has been divided into four sampling stations for administrative convenience. Devadurga and Lingasugur forms part of Krishna catchment in northern part, while southern part forms the Lower Tungabhadra catchment area and is perennial in nature. Geomorphologically, continuous range of hills are absent in the district but a few cluster of hills are seen towards east, west, northwest, centre and southwest. Study area can be broadly classified into three major zones viz, (a) The northern rugged plateau,(b) The southern lower plains with inselbergs and isolated hillocks and(c) Valley fills [6]. The northern part of the district is characterized by expanses of level and treeless surface punctuated and there by flat and undulating hillocks, black soils and basaltic rocks are observable. The average elevation of the study area is 430 m above mean sea level. The change in the environmental radioactivity level contributes to the collective radiation dose to the general population. Therefore, an accurate assessment of possible radiological risks to human health of this region is essential. Hence, the measurement of the activity concentration levels of naturally occurring radionuclides in soils, building materials etc. and their assessment has been carried out and presented in the present paper.

III Materials and methods

Sample collection and preparation

Forty samples were collected from nine sampling stations of the study region. The ASTM standard procedure was followed for soil sample collection and preparation where surface soil over an area 50 cm * 50 cm and 5 cm depth was mixed thoroughly and about 2-3 kg of each sample was collected. The geographic coordinates and elevation was recorded with a Garmin portable hand held GPS. After collection of sample pebbles, dried leaves, roots and other mixed materials were removed. The samples were placed in a hot air oven for drying at 110˚C for 24 h to ensure that the moisture is completely removed. All samples were pulverized to get fine powder and unevenly sieved through a 200-mesh sieve to separate the crushed soil particles. Each pulverized sieved sample was then transferred to a 250 mL cylindrical Plastic (PVC) box. The boxes were filled fully, sealed with an adhesive, coded, weighed and then stored for a period of four to five weeks to attain secular equilibrium of radon (^{222}Rn) and its daughter products before subjecting to gamma spectrometric analysis.

Gamma Spectrometric Analysis

Measurements of gamma activity were performed with a 4"X4" NaI (Tl) scintillation detector based gamma ray spectrometer. The detector is enclosed in a 3" thick lead shield to reduce background radiations originating from the surrounding and cosmic rays. The gamma ray spectrum was recorded using 1k PC based multichannel analyzer (winTMCA 32) with a built in spectroscopy amplifier. Efficiency calibration for the system was carried out using the standards (uranium, thorium and potassium) procured from International Atomic Energy Agency (IAEA). These standard materials were packed and sealed in a 250 mL cylindrical container, the same geometry as that for samples. The analysis of complex gamma spectra of samples from the detector due to ^{238}U, ^{232}Th and ^{40}K was carried out by least squares method. The determination of radionuclide activity in the soil sample was based on the, 1764 keV, 2614 keV and 1460 keV gamma photo peaks emitted from ^{214}Bi, ^{208}Tl and ^{40}K, respectively. The samples are counted for a period of 60,000 s to obtain gamma spectra of good statistics. Background gamma spectrum also was recorded and subtracted to get the net count rate for each sample. The activity concentrations of the sample were calculated from the peak intensity (cps) of each gamma line and the efficiency of the detector using the relation

$$Activity\,(Bq) = \frac{Net\ \ Area\ \ under\ \ the\ \ photopeak\ \ (cps)}{Efficiency\ \ (\%)}$$

IV Results and discussion

Activity concentration

The estimated activity concentrations of the three primordial radionuclides ^{238}**U** ,^{232}Th, and ^{40}K obtained for each of the samples collected from the study region are summarized in table 1. The activity of ^{238}U, ^{232}Th and ^{40}K for all the samples was found to lie in the range from 10- 85 Bq/kg, 18-285 Bq/kg and 135-1646 Bq/kg respectively. In almost all the soil samples the thorium concentration was observed to be higher compared to that of ^{238}U. This is because radium is more susceptible to solubility, whereas thorium is less soluble hence adsorbed to soil [7]. Some soil samples showed a high activity of ^{40}K.. It may be due to the fact that the samples were collected from areas near the cultivated lands. The potassium activity for the soil samples was also comparable with the world median values. The estimated values of mean activities of ^{238}U ,^{232}Th and ^{40}K in soil were found to be comparable within the range of worldwide values [8]. A comparison of the values obtained in the present work with other literature data are shown in table 2 and shows the activity concentration of the primordial radionuclides for the soil samples from Devadurga and Lingasugur are well within the national and world average values as presented in the UNSCEAR. In accordance with it some soil samples of the study area showed low activity and some high and moderate activity. To represent the activity levels of ^{238}U, ^{232}Th and ^{40}K by a single quantity, a common radiological index called radium equivalent activity has been introduced and calculated by the relation [9]

$$Ra_{eq} = C_{Ra} + {}^{A}C_{Th} + {}^{B}C_{K}$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively and A, B are constants 1.43, 0.077 respectively. It is observed from the present study that the radium equivalent activity for the soils of study region is well below the recommended limit of 370 Bq/kg. The value of Ra_{eq} greater than 370 Bq/kg shows a higher gamma dose rate

Absorbed gamma dose rate assessment

The absorbed gamma dose rates due to the primordial radionuclide concentrations were calculated for all the samples. The absorbed gamma dose rates due to terrestrial gamma rays at 1 m above the earth's surface were calculated from the concentrations of ^{238}U,^{232}Th and ^{40}K and the conversion factors of 0.604, 0.462 and 0.0417 respectively were used as given by [UNSCEAR.]

$$D = \left(0.604\,C_{Th} + 0.462\,C_{Ra} + 0.0417\,C_{K}\right) nGy\,h^{-1}$$

where C_{Th}, C_{Ra} and C_K are the average activity concentration of ^{232}Th, ^{238}U and ^{40}K respectively. The estimated absorbed gamma dose rates for all the samples are shown in table 1. The annual effective dose can be estimated using the conversion factor of 0.7 $SvGy^{-1}$ to absorbed dose rate as given by UNSCEAR.

$$AED = D \times 8760 \times 0.7$$

The calculated results are presented in table 1. The mean absorbed gamma dose rate was found to lie in the range 27-279 nGy h^{-1}. The annual effective dose associated for all the samples was estimated. These values are within the permissible dose equivalent limit of 1 mSv y^{-1} for the general public [10].

V Conclusions

Main sources of external radiation exposure are Uranium and Thorium, their decay products and ^{40}K. The internal exposure is due to radon and its radioactive daughters, present in the environment, which has the maximum contribution towards the average effective dose received by human beings. Devadurga and Lingasugur sampling station shows the higher activity among the sampling station .If the annual gamma dose rate from soil samples is less than 1 mSv and Ra_{eq} is less than 370 Bq/kg, Relative contributions to the Ra_{eq} rate owing to ^{238}U, ^{232}Th and ^{40}K for the samples is shown in fig 1.Then the external hazard index (H_{ex}) is always less than one. For insignificant radiation hazard the indices should be less than unity. The internal exposure to radon (^{222}Rn), an inert gas enters through inhalation and affects the respiratory system. The present study is well in accordance with the condition of unity and pose that the soil of the study area is safe to be used for construction purposes. Further measurements over more environmental samples of this region are being continued. And the present study showed a wide distribution of ^{238}U, ^{232}Th and ^{40}K activity concentration among the samples. The concentration of ^{238}U, ^{232}Th and ^{40}K in the soil samples were found to be little higher values in comparison to other places of India and world literature values. Similarly, the health hazard indices for all the samples were within the limits. The present study reveals that the radiological parameters estimated were due to activity of natural radionuclides and well comparable with the national and international values. The data produced in the present work can be used as baseline radiological data for future investigations and programs.

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Table 1: Activity concentrations of ^{238}U, ^{232}Th and ^{40}K, and dose rate

SL No	Sampling Station	Activity (Bq kg^{-1})			Absorbed Dose (nGyh^{-1})	Range AED Outdoor (mSvy^{-1})	
		^{238}U	^{232}Th	^{40}K		Estimated	Measured
1	Devadurga (10)	14 - 85	22-285	256-1646	63 -279	0.078 - 0.343	0.069-0.315
2	Kavital (10)	14 - 52	30 - 72	190-1550	35-132	0.044 - 0.162	0.052-0.154
3	Lingasugur (10)	10 - 33	18 - 47	241 - 799	34 - 55	0.042 - 0.068	0.052-0.069
4	Mudgal (10)	13 - 58	25-138	135-1118	27-138	0.034 - 0.170	0.035-0.154

Table 2. Comparison of radionuclides concentrations (Bq/ kg) for soil samples of present study with other literature data.

Location (Soil samples)	Activity (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
Present Study	30.9	60.6	551.5
Bidar [11]	32.45	37.21	251.61
Bangalore[12]	26.2	53.1	635.1
Gudalore, Tamilnadu [13]	17-62	19-272	78-596
All India [14]	31	63	394
Southwestern Region(Nigeria)[15]	54.5	91.1	286.5
China [8]	2 - 690	1 - 360	9 - 1800
USA [8]	4-140	4 - 130	100-700
World Average [8]	35	45	420

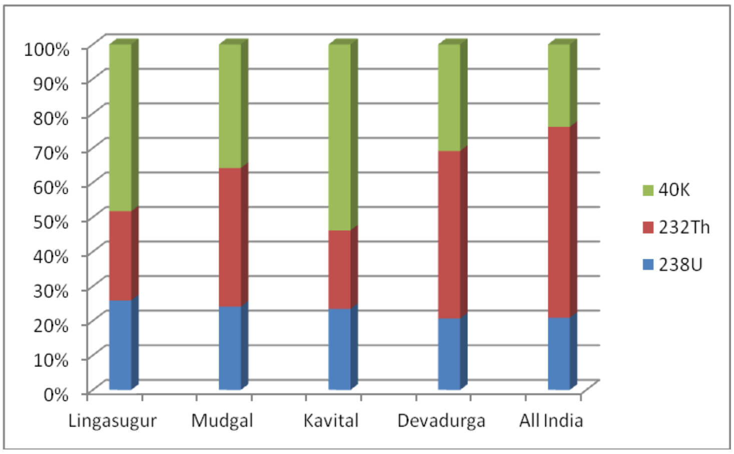

Figure 1.Comparison of Relative contributions to the R_{aeq} rate owing to ^{238}U, ^{232}Th and ^{40}K for the all the sampling stations and Indian value.