International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 10 No. 6s, 2024
https://theaspd.com/index.php

Study Of Natural Radioactivity And Radiological Parameters Of ^{238}U, ^{232}Th And ^{40}K In Soil Samples

Jayashri B. Mutagar[1], Nagaraj Channappa[2], Basavaraj Rachappa Kerur[1*]
[1, 2, 1*]Department of Physics Gulbarga University Kalaburagi, Karnataka, India-585106

Abstract:
Gamma spectrometry was used to study of the activity concentrations of primordial radionuclides ^{238}U, ^{232}Th, and ^{40}K. The natural radioactivity levels in soil samples from the Basapura and Doni in Gadag District, Karnataka. The average activity concentrations in Basapur soils were found to be 30.98 ± 0.37 Bq kg^{-1} for ^{238}U, 51.88 ± 0.12 Bq kg^{-1} for ^{232}Th, and 552.41 ± 1.98 Bq kg^{-1} for ^{40}K, while in Doni soils the respective averages were 23.02 ± 14.40 Bq kg^{-1}, 38.60 ± 11.12 Bq kg^{-1}, and 187.56 ± 146.16 Bq kg^{-1}. The results indicate that the activity concentrations of ^{238}U and ^{232}Th in both regions lie within the worldwide recommended limits, while ^{40}K shows relatively higher variations due to differences in mineral composition and soil fertility. The calculated radiological hazard indices, including absorbed dose rate (D), Radium Equivalent Activity (Raeq)and annual effective dose equivalent (μSvy^{-1}), indicate that the natural radioactivity levels in the study area do not pose a significant radiological health risk to the local population.
Keywords: Natural radioactivity; Soil samples; ^{238}U, ^{232}Th and ^{40}K Gamma-ray spectrometry; Radiological parameters; Environmental risk assessment.

1. INTRODUCTION

Natural radioactivity in soil arises from the decay of primordial radionuclides such as uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K). These radionuclides are naturally present in the Earth's crust and contribute to external and internal radiation exposure. Monitoring their activity concentrations is essential for assessing radiological hazards and ensuring environmental safety [1].The distribution of these radionuclides varies based on the geological formations and mineral compositions of different regions. Karnataka, particularly the Gadag district, is geologically rich in granite and lateritic soils, which are known to contain elevated levels of natural radioactivity [2]. The present study aims to measure the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in soil samples from Basapura and Doni using gamma spectrometry. The assessment of absorbed dose rates and radiological hazard indices will help determine potential health risks to the local population and contribute to a better understanding of radiation exposure levels in the region [3 4].Several previous studies have focused on natural radioactivity in Indian soils and their radiological impact on human health [5]. The findings of these studies provide a basis for comparison and help in understanding regional variations in radiation levels. By conducting this study, we aim to contribute valuable data for environmental monitoring and establish baseline radioactivity levels for the study area.

2. MATERIALS AND METHODS

2.1Study Area and Sample Collection:

Soil samples were collected from Basapura and Doni in Gadag District, Karnataka. The region is characterized by granite and lateritic soil formations, which influence the natural radioactivity levels. A total of 20 soil samples were collected from different locations, ensuring a representative data set.The collection and preparation of samples followed the ASTM standard procedure.

2.2 Sample Preparation:

The collected soil samples were air-dried for 48 hours, followed by oven-drying at 110°C for 24 hours to remove moisture content. The dried samples were then sieved through a 2-mm mesh to obtain uniform granularity. Each sample was then stored in airtight polyethylene containers for four weeks to allow for secular equilibrium between radon and its progeny.

2.3Gamma Spectrometry Analysis

Gamma activity measurements were conducted using a gamma-ray spectrometer equipped with a 4" × 4" NaI (Tl) scintillation detector. To minimize background radiation from the surroundings and cosmic rays, the detector was enclosed within a 3-inch-thick lead shield. The gamma-ray spectra were recorded using a 1k PC-based multichannel analyser (winTMCA 32) integrated with a spectroscopy amplifier. The system's efficiency calibration was performed using standard reference materials for uranium, thorium, and potassium, obtained

from the International Atomic Energy Agency (IAEA). These standards were sealed in 250 mL cylindrical containers, maintaining identical geometry as the soil samples. The analysis of complex gamma spectra from the detector, corresponding to ^{238}U, ^{232}Th, and ^{40}K, was performed using the least squares method. The radionuclide activity in the soil samples was determined based on the gamma photo peaks at 1764 keV (^{214}Bi for (238U), 2614 keV (^{208}Tl for ^{232}Th), and 1460 keV (^{40}K). Each sample was counted for 60,000 seconds to ensure spectra with reliable statistics. Background gamma spectra were also recorded and subtracted to obtain the net count rate for each sample. The activity concentrations of radionuclides were calculated using the peak intensity (counts per second) of the gamma lines and the detector efficiency, employing the appropriate mathematical relations.

$$\text{Activity (Bq)} = \frac{\text{Net area under the photo peak (cps)}}{\text{Efficiency (\%)}}$$

- **Calculation of Radiological Hazard Indices** The radiological parameters were determined using standard formulas:
- **Absorbed Dose Rate (D)** was calculated to assess the external radiation exposure risk.

$$D\ (nGy/h) = 0.604\ C_U + 0.462\ C_{Th} + 0.0417\ C_K$$

- **Radium Equivalent Activity (Raeq)**:It is calculated using the formula:

$$Raeq\ (Bq/kg) = C_U + 1.43\ C_{Th} + 0.077\ C_K$$

- **Annual Effective Dose Equivalent (μSvy^{-1})** was derived to assess potential health risks due to prolonged exposure.

$$AEDE\ (mSv/y) = D\ (nGy/h) \times 8760\ h/y \times 0.7\ Sv/Gy \times 0.2 \times 10^{-3}$$

3. RESULTS AND DISCUSSION:

The studied activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in the soil samples from Basapur and Doni regions are summarized below. In Basapur soils, the activity of ^{238}U ranged from 22.14 ± 0.09 to 43.95 ± 0.21 Bq kg^{-1} with an average of 30.98 ± 0.37 Bq kg^{-1}. The ^{232}Th activity varied between 35.90 ± 0.08 and 80.61 ± 0.18 Bq kg^{-1} (average 51.88 ± 0.12 Bq kg^{-1}), while ^{40}K showed a relatively high concentration range of 140.41 ± 1.97 to 157.69 ± 2.90 Bq kg^{-1}, averaging 552.41 ± 1.98 Bq kg^{-1}. The elevated ^{40}K activity in Basapur may be attributed to the potassium-rich minerals and agricultural inputs such as fertilizers. In Doni soils, ^{238}U activity concentrations ranged from 17.20 ± 14.70 to 28.20 ± 19.10 Bq kg^{-1}, averaging 23.02 ± 14.40 Bq kg^{-1}. The ^{232}Th activity varied from 29.60 ± 7.70 to 42.80 ± 9.40 Bq kg^{-1} (average 38.60 ± 11.12 Bq kg^{-1}), while ^{40}K ranged between 159.60 ± 179.40 and 205.40 ± 160.20 Bq kg^{-1}, with a mean of 187.56 ± 146.16 Bq kg^{-1}. The lower average values in Doni compared to Basapur suggest possible lithological and geochemical variations in the parent rock material and soil composition. Overall, the activity concentrations of radionuclides in both areas are within the global average ranges reported by UNSCEAR (2000). This indicates that the natural radioactivity levels in the analyzed soil samples are normal and do not pose significant radiological hazards to the local population.

- **Radiological Parameters**

The radiological parameters such as absorbed dose rate (D), radium equivalent activity (Raeq), and annual effective dose equivalent (AEDE) were calculated to assess the radiation exposure level in the studied soil samples. The results are summarized in Table 3. The absorbed dose rate (D) in air at 1 m above the ground surface varied from 86.03 nGy h^{-1} to 141.12 nGy h^{-1}. These values are within the worldwide average range reported by UNSCEAR (2000), indicating moderate natural background radiation levels in the study area. The variation in dose rate may be attributed to the differences in the concentration of natural radionuclides such as ^{238}U, ^{232}Th, and ^{40}K in the soil samples.

The radium equivalent activity (Raeq) ranged between 77.80 Bq kg^{-1} and 141.12 Bq kg^{-1}. Raeq is a single index that represents the total radioactivity due to ^{238}U, ^{232}Th, and ^{40}K, assuming uniform radiation hazard. The obtained values are well below the recommended safety limit of 370 Bq kg^{-1} suggested by the OECD (1979), which implies that the radiation hazard from soil in this region is minimal and safe for habitation. The annual effective dose equivalent (AEDE) was found to vary from 0.19 µSv y^{-1} to 0.31 µSv y^{-1}, which is significantly below the global average value of 0.07 mSv y^{-1} (70 µSv y^{-1}) recommended by UNSCEAR. This indicates that the radiation exposure to the local population from terrestrial gamma radiation is negligible and does not pose any significant health risk. Overall, these findings suggest that the study area exhibits low to moderate natural background radiation levels, well within the permissible limits recommended for public safety.

These values are within internationally recommended safety limits, indicating minimal radiological risk. Comparisons with global average values suggest that the study area has moderate levels of natural radioactivity as

shown in figure 1. The presence of these radionuclides is attributed to geological formations and mineral compositions in the region [6 7 8].

Table 1: Activity concentrations, of ^{238}U, ^{232}Th, and ^{40}K of Basapur of Gadag District soil samples

SL.NO.	Sample Code	Activity concentrations (BqKg^{-1})		
		^{238}U	^{232}Th	^{40}K
1	SL080121	23.93±00.30	80.61±00.18	957.69±02.90
2	SL080122	26.45±00.25	50.53±00.15	826.15±02.40
3	SL080123	22.14±00.09	39.27±00.13	726.61±02.11
4	SL080124	24.74±00.24	46.16±00.14	783.37±01.41
5	SL080125	36.43±00.26	56.65±00.16	708.56±02.51
6	SL080126	34.14±00.17	46.77±00.10	166.18±1.72
7	SL080127	42.52±00.20	56.67±00.12	140.41±01.97
8	SL080128	23.71±00.14	35.90±00.08	190.93±01.40
9	SL080129	43.95±00.21	60.77±00.13	158.01±02.07
10	SL080130	31.88±01.65	45.54±00.10	141.12±01.65
Average		30.98±00.37	51.88±00.12	552.41±01.98
Minimum		22.14±00.09	35.90±00.08	140.41±01.97
Maximum		43.95±00.21	80.61±00.18	157.69±02.90

Table: 2 Activity concentrations, of ^{238}U, ^{232}Th, and ^{40}K of Doni of Gadag District soil samples

SL.NO.	Sample code	Activity concentrations		
		^{238}U	^{232}Th	^{40}K
1	SL080101	22.60±12.70	29.60±07.70	167.40±136.10
2	SL080102	24.10±15.10	37.30±17.80	184.30±132.00
3	SL080103	24.50±16.20	42.30±19.20	201.40±153.00
4	SL080104	17.20±14.70	42.00±09.30	205.40±160.20
5	SL080105	17.50±15.00	42.80±09.40	195.30±153.30
6	SL080106	24.60±11.90	36.20±08.20	185.70±128.80
7	SL080107	26.70±09.70	38.50±08.10	195.00±135.30
8	SL080108	23.10±17.30	43.90±14.00	159.60±179.40
9	SL080109	21.70±12.20	34.40±07.90	196.90±153.80
10	SL080110	28.20±19.10	39.00±09.62	184.60±130.20
	Average	**23.02± 14.40**	**38.60 ±11.12**	**187.56±146.16**
	Minimum	**17.20±14.70**	**29.60±07.70**	**159.60±179.40**
	Maximum	**28.20±19.10**	**42.80±09.40**	**205.40±160.20**

Table 3: The Gamma absorb dose rate , Radium equivalent, annual effective dose rate of ^{238}U, ^{232}Th, and ^{40}K of Basapur and Doni for Gadag District soil samples

Samples collected places	Gamma absorb dose rate (D) nGyh^{-1}	Radium equivalent, annual effective dose rate (Raeq) Bqkg^{-1}	Annual Effect of dose μSvy^{-1}
Basapur	40.59	89.74	0.19
	63.59	141.12	0.31
	52.59	116.97	0.25
Doni	35.29	77.80	0.21
	45.24	100.48	0.27
	41.16	91.41	0.24

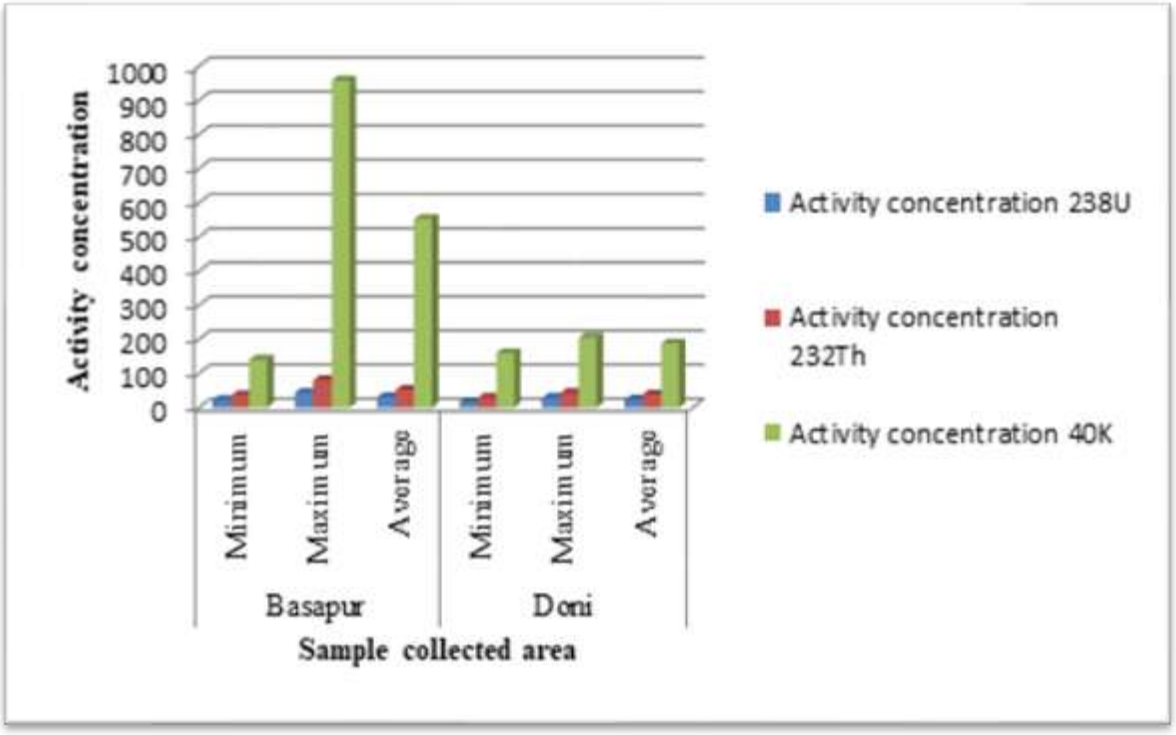

Figure 1: Activity concentrations, of ^{238}U, ^{232}Th, and ^{40}K of Basapur and Doni for Gadag District soil samples

4. CONCLUSION

The analysis of soil samples from Basapura and Doni reveals levels of natural radioactivity, with activity concentrations of ^{238}U, ^{232}Th, and ^{40}K remaining within the recommended safety limits prescribed by UNSCEAR (2000). The calculated radiological hazard indices (Gamma absorb dose rate (D), Radium equivalent, annual effective dose rate (Raeq) and annual effective dose) indicate that the studied region does not pose significant radiological health risks to the local population. This investigation provides valuable baseline data for environmental radiation monitoring and can serve as a reference for future radiological and environmental studies in Karnataka and other regions of similar geological characteristics.

Acknowledgement

The authors express their heartfelt gratitude to Gulbarga University, Kalaburagi, for providing the instrumentation facilities and support to carry out this research work.

REFERENCES

1. UNSCEAR (2000). Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly with Scientific Annexes. United Nations, New York.
2. Radhakrishna, B. P., &Vaidyanadhan, R. (1997). Geology of Karnataka (2nd ed.). Geological Society of India, Bangalore, pp. 123–126.
3. El-Arabi, A. M. (2007). Gamma spectroscopic analysis and associated radiation hazards of building materials used in Egypt. Radiation Measurements, 42, 94–100.
4. Kerur, B. R., Rajeshwari, T., Anilkumar, S., Narayani, K., &Rekha, A. K. (2012). Natural radioactivity in granite mining areas of Karnataka.
5. Birajalaxmi, D. (2010). Assessment of radioactivity in environmental samples: A review. BARC Newsletter, 313, 28–37.
6. Rajesh, S., Avinash P R, B. R. Kerur, & S. S. Anilkumar. (2014). Assessment of natural radioactivity levels in soil samples of Bidar district by Gamma Spectrometry. ISBN 978-81-929777-0-6.
7. ICRP (1991). *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60, Pergamon Press, Oxford.
8. WHO (2005). *Quality Control Methods for Medicinal Plant Materials*. World Health Organization, Geneva