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Estimation of Natural Radioactivity Concentrations of 238u, 232th and 40k in Soil Samples from Belagavi District, Karnataka, India

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Abstract:
The natural radioactivity concentrations of Uranium (238U), Thorium (232Th), and Potassium (40K) in soil samples from Belagavi District in Karnataka, India were measured to assess the radiological impact on the environment and public health. Soil samples were collected from two different locations within the district, and the radioactivity levels of U, Th, and K were determined using NaI (Tl) a High-Resolution Gamma Spectrometer. The average activity concentrations of Uranium, Thorium, and Potassium were found to be 26.84 ± 0.16 Bq/kg, 48.33 ± 0.09 Bq/kg, and 150.71 ± 1.61 Bq/kg, respectively, in Savadatti soil samples, and 22.87 ± 0.19 Bq/kg, 54.43 ± 0.11 Bq/kg, and 219.99 ± 1.77 Bq/kg, respectively, in Belavadi soil samples. These results were compared with global and regional reference values to evaluate the radiological risk. The calculated Radium Equivalent Activity (Ra eq), External Hazard Index (H ex), were used to assess the potential health risks associated with the radioactivity levels in the soil. The study revealed that the radiological indices in the soil samples were within the safe limits, although certain areas showed slightly elevated concentrations. This study contributes to the understanding of natural radioactivity in the selected region and emphasizes the need for continuous monitoring to safeguard environmental and public health. The findings are compared with global safety limits set by international organizations like UNSCEAR.

Keywords: *Soil Samples; Natural Radioactivity; Radioactive isotopes (238U, 232Th 40K); and NaI (Tl) a High-Resolution Gamma Spectrometer.*

1. Introduction

Natural radioactivity is a fundamental component of the Earth's environment, primarily arising from the decay of naturally occurring radioactive isotopes such as uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K). These radionuclides are present in varying concentrations in soil and rocks, contributing to terrestrial background radiation (UNSCEAR, 2000). Their presence and distribution in soil depend on the geological and environmental conditions of a region (IAEA, 1989). The study of natural radioactivity is critical for understanding the radiological hazards associated with soil, which can have implications for human health, agriculture, and construction. Exposure to ionizing radiation from these radionuclides can occur through external irradiation and internal exposure, primarily through ingestion or inhalation (OECD, 1979). The Belagavi District in Karnataka, India, offers a unique opportunity to study natural radioactivity due to its diverse geological features, including igneous, metamorphic, and sedimentary formations. Previous studies in Karnataka and nearby regions have highlighted variations in natural radioactivity due to geological diversity (Gupta et al., 2013). Assessing the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in soil samples from this region is essential to: Establish baseline data on natural radioactivity for future environmental monitoring and studies (Veerappa et al., 2018). Evaluate Radiological Hazards: Gain insights into the distribution and mobility of radionuclides in the region's soils (Ramasamy et al., 2009; El-Gamal et al., 2007). This investigation is particularly relevant as Belagavi is an agriculturally and industrially significant district. Understanding the levels of natural radioactivity in its soil is crucial for ensuring public safety and sustainable development (Singh et al., 2005). [1-5].This study aims to measure the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in soil samples from various locations in Belagavi District using NaI (Tl) high-resolution gamma-ray spectrometry. The results will be used to calculate radiological hazard indices and compare

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them with international safety standards to evaluate potential risks. [5-10]

2. Materials and Methods

2.1 Sample Collection and Preparation

Soil samples were collected from two Talukas (Savadatti and Belavadi) of Belagavi District in Karnataka, India. Soil samples were collected from at depths ranging from 0–15 cm using a stainless steel auger. Approximately 2–3 kg of soil was taken from each sampling site. Each sample was labelled based on its collection depth and assigned a unique site code for identification. The collected soil samples were air-dried for several days to remove moisture. The dried samples were sieved using a 200-mesh-sized sieve to obtain a fine powder. This process ensured uniformity and was repeated for all samples from the different sites. The sieved soil was ground both manually and using a ball mill to achieve finer consistency. The pulverized soil was transferred into plastic containers, sealed using "Araldite," and stored for 4–5 weeks at room temperature. This period allowed radon and its posterity to reach secular equilibrium with radium. After the completion of the dormancy period, the samples were subjected to gamma spectrometric analysis.

2.2 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 238U, 232Th and 40K 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 214Bi, 208Tl and 40K, 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 relationThe radioactivity concentration of the radionuclides in the sample was calculated using the following equation.

Activity (Bq)

$$\frac{\text{Net Area under the photopeak (cps)} \times 100 \times 100}{\text{Efficiency (\%)} \times \text{BR (\%)}}$$

3. Results and Discussion

The activity concentration of ^{238}U, ^{232}Th and ^{40}K were measured in the soil samples collected from two Talukas (Savadatti and Belavadi) of Belagavi District in Karnataka, India high resolution gamma ray spectrometry. This study is aimed to establish the naturally occurring radionuclides within the site. The average activity concentration was found to be 26.84 ± 0.16 Bq/kg for ^{238}U, 48.33 ± 0.09 Bq/kg for ^{232}Th, and 150.71 ± 1.61 Bq/kg for^{40}K, respectively, in Savadatti soil samples, and 22.87 ± 0.19 Bq/kg, 54.43 ± 0.11 Bq/kg, and 219.99 ± 1.77 Bq/kg, respectively, in Belavadi soil samples. The results, as summarized in (Table 1and Table 2). The activity concentration was evaluated and was compared with two Talukas (Savadatti and Belavadi) of Belagavi District. The study provides information on the concentration of radionuclides and Background radiological assessments of the Belagavi District. A comparison between the two Talukas indicates that the concentration of ^{238}U is higher in Savadatti, while Belavadi shows elevated levels of ^{232}Th and ^{40}K. The higher ^{40}K activity in Belavadi can be attributed to the potassium-rich minerals in the soil, consistent with findings in other regions with similar geological characteristics. The variation in ^{232}Th concentrations might reflect in thorium-bearing minerals across the sites. Such data are critical for assessing background radiation levels and potential radiological risks in the region. Figure 1 shows Activity Concentration of 238U, 232Th and 40K of Savadatti in Belagavi Figure 2 Activity Concentration of 238U, 232Th and 40K of Belavadi in Belagavi DistrictThe measured values are within the global averages reported. Table 1 Activity Concentration of 238U, 232Th and 40K of Savadatti in Belagavi District.

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Table 1 Activity Concentration of ^{238}U, ^{232}Th and ^{40}K of Savadatti in Belagavi District

SL.No	Sample Code	Concentration Activity ($BqKg^{-1}$)		
		^{238}U	^{232}Th	^{40}K
1	SL060101	20.00±0.20	50.00±0.10	230.00±1.70
2	SL060102	20.00±0.20	50.00±0.10	210.00±1.60
3	SL060103	20.00±0.20	50.00±0.10	180.00±1.70
4	SL060104	21.34±0.19	62.82±0.11	203.90±2.10
5	SL060105	18.14±0.17	60.00±0.11	194.93±1.98
6	SL060106	27.52±0.24	50.59±0.11	210.62±1.7
7	SL060107	31.25±0.19	54.74±0.12	252.44±1.7
8	SL060108	21.05±0.18	55.49±0.11	232.49±1.7
9	SL060109	26.64±0.19	56.04±0.12	249.97±1.83
10	SL060110	22.80±0.18	54.46±0.12	236.49±1.80
Average		**22.87 ±0.19**	**54.43±0.11**	**219.99 ± 1.77**

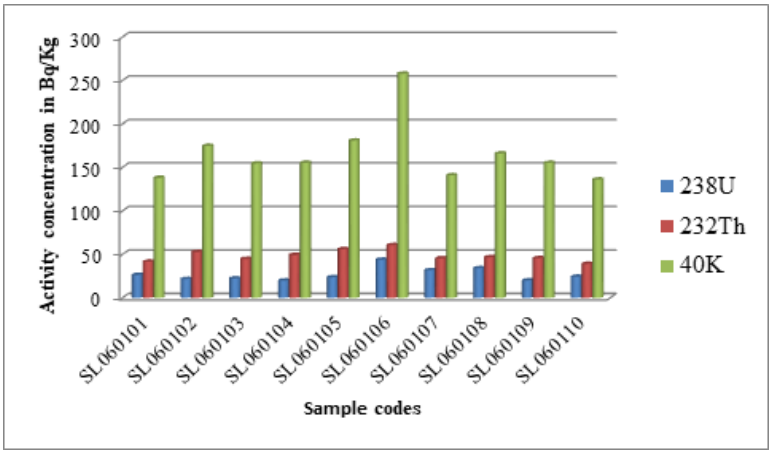

Figure 1 Activity Concentration of ^{238}U, ^{232}Th and ^{40}K of Savadatti in Belagavi District

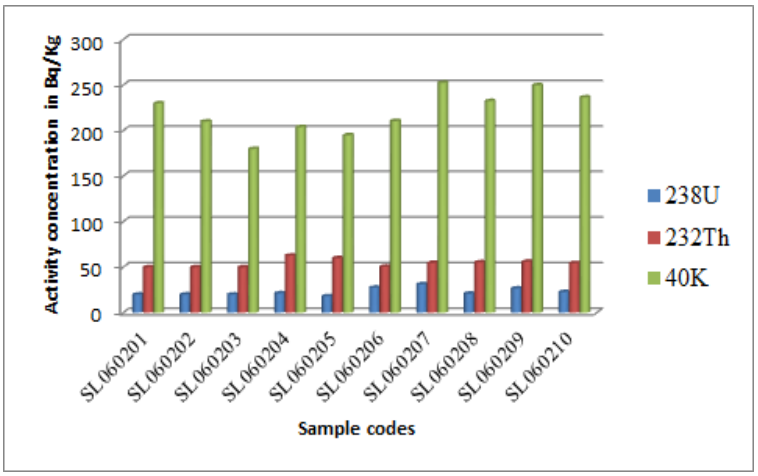

Figure 2 Activity Concentration of ^{238}U, ^{232}Th and ^{40}K of Belavadi in Belagavi Distric

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In Savadatti, the average activity concentrations were 26.84 ± 0.16 Bq/kg for 238U, 48.33 ± 0.09 Bq/kg for 232Th, and 150.71 ± 1.61 Bq/kg for40K, respectively. Conversely, the soil samples from Belavadi exhibited average activity concentrations of 22.87 ± 0.19 Bq/kg for 238U, 54.43 ± 0.11 Bq/kg for 232Th, and 219.99 ± 1.77 Bq/kg for40K. These differences highlight the spatial variability in the natural radionuclide distribution within the district, likely influenced by local geological formations and soil composition as shown in (Figure1 and Figure 2). A comparison between the two Talukas indicates that the concentration of 238U is higher in Savadatti, while Belavadi shows elevated levels of 232Th and 40K. The higher 40K activity in Belavadi can be attributed to the potassium-rich minerals in the soil, consistent with findings in other regions with similar geological characteristics. The variation in 232Th concentrations might reflect differences in thorium-bearing minerals across the sites. The study's results provide essential baseline data on the activity concentrations of naturally occurring radionuclides in Belagavi District. Such data are critical for assessing background radiation levels and potential radiological risks in the region. The measured values are within the global averages reported by UNSCEAR for most regions, indicating no immediate radiological hazards (Campbell et al. 1999). However, the observed variability underscores the importance of localized studies for accurate environmental and radiological assessments. Overall, this investigation contributes to the understanding of natural radioactivity in Belagavi District and provides foundational information for future environmental monitoring and land-use planning. Further studies are recommended to explore the geological factors contributing to the observed differences and to monitor any potential changes over time (Ravichandran 2010 & Faruqi et al., 2010). The radiological hazard indices, including radium equivalent activity (Raeq absorbed dose rate (D), Hex nGyh-1 , Hin nGyh-1and Iγr were calculated to assess the radiological risks associated with the soil samples collected from the two Talukas (Savadatti and Belavadi) of Belagavi District. The results indicate that these hazard indices were generally below the recommended safety limits, suggesting no significant radiological risk to the local population under current conditions as shown in (Table 3). The radiological hazard indices for the soil samples from Belagavi District indicate that the measured values of Radium Equivalent Activity (Raeq), absorbed dose rate (D), External Hazard Index (Hex), Internal Hazard Index (Hin), and Gamma Radiation Activity Index (Iγr) are generally within the recommended safety limits, suggesting no immediate radiological threat to the local population. The Raeq values ranged from 96.77 to 130.30 Bq/kg, which are well below the globally recommended threshold of 370 Bq/kg (UNSCEAR, 2000), indicating that the overall radiological hazard from these materials is low. Similarly, the absorbed dose rates (D) ranged from 43.19 to 67.73 nGy/h, which are consistent with typical background radiation levels found in various regions worldwide (UNSCEAR, 2000). These values are within the acceptable range of 60 nGy/h, a limit often used for evaluating safe radiation exposure levels (OECD 2004). The External Hazard Index (Hex) values ranged from 0.16 to 0.40, which are well below the recommended safety limit of 1.0 (IAEA 2010), further confirming that the materials do not pose a significant external radiation hazard. Likewise, the Internal Hazard Index (Hin) values, ranging from 0.31 to 0.51, are also below the threshold of 1.0 (UNSCEAR, 2000), indicating a minimal risk of internal radiation exposure from inhalation or ingestion of radionuclides. Finally, the Gamma Radiation Activity Index (Iγr) values ranged from 0.32 to 0.53, which are within the safety limit of $I\gamma r \leq 1.0$, confirming that the gamma radiation levels are within acceptable limits for the materials under study. These findings suggest that the radiological background in Belagavi District is within the global averages and does not pose any immediate health risks based on current radiological standards. However, ongoing monitoring is recommended to detect any potential changes over time due to environmental factors or human activities (Sharma et al., 2012). Table 2 shows Activity Concentration of 238U, 232Th and 40K Belavadi of in Belagavi District Table 3 shows The Radiological Hazard Indices, Including Radium Equivalent Activity (Raeq Absorbed Dose Rate (D) External Hazard Index, Internal Hazard Index And Gamma Radiation Activity. [11-13]. and Background radiological assessments of the Belagavi District. A shield to reduce background radiations originating from the surrounding and cosmic rays. The gamma ray spectrum was recorded using 1k PC based multichannel analyzer.

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Table 2 Activity Concentration of ^{238}U, ^{232}Th and ^{40}K Belavadi of in Belagavi District

SL.No	Sample Code	Concentration Activity ($BqKg^{-1}$)		
		$^{238}U^{*}$	^{232}Th	^{40}K
1	SL060201	26.49±0.15	41.71±0.09	138.19±1.51
2	SL060202	21.77±0.17	52.88 ±0.10	174.80±1.68
3	SL060203	22.46±0.16	44.93±0.92	154.67±1.61
4	SL060204	19.95±0.16	49.51±0.09	155.38±1.57
5	SL060205	23.84±0.18	56.15±0.11	181.08±1.77
6	SL060206	43.91±0.16	60.77±0.13	258.01±1.92
7	SL060207	31.88±0.17	45.54±0.11	141.12±1.65
8	SL060208	34.14±0.17	46.77±0.10	166.18±1.72
9	SL060209	20.11±0.16	45.90±0.11	155.34±1.52
10	SL060210	24.39±0.14	39.23±0.09	136.24±1.53
Average		**26.84±0.16**	**48.33±0.09**	**150.71±1.61**

Table 3 The Radiological Hazard Indices, Including Radium Equivalent Activity (Raeq Absorbed Dose Rate (D) External Hazard Index, Internal Hazard Index And Gamma Radiation Activity

SampleNo.	D $nGyh^{-1}$	$Ra_{eq}Bqkg^{1}$	$HexnGyh^{1}$	H_{in} $nGyh^{-1}$	$I_{\gamma r}$
1	43.19	96.77	0.26	0.33	0.34
2	49.28	110.77	0.29	0.35	0.34
3	43.96	105.15	0.26	0.32	0.39
4	45.59	102.70	0.27	0.33	0.39
5	52.47	118.08	0.31	0.38	0.36
6	67.73	150.67	0.40	0.51	0.53
7	48.11	107.86	0.29	0.37	0.38
8	50.95	113.81	0.30	0.39	0.40
9	39.29	97.70	0.26	0.31	0.34
10	36.96	90.97	0.24	0.31	0.32
11	49.03	109.21	0.17	0.34	0.39
12	48.19	107.67	0.17	0.34	0.38
13	46.94	105.36	0.16	0.33	0.37
14	56.26	126.87	0.34	0.40	0.45
15	27.46	119.23	0.32	0.37	0.42
16	51.95	116.07	0.31	0.38	0.41
17	58.01	128.95	0.34	0.43	0.42
18	52.93	118.30	0.31	0.37	0.45
19	56.57	130.30	0.34	0.41	0.46
20	53.28	118.87	0.32	0.38	0.42

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Conclusion

The study of natural radioactivity levels in soil samples from Belagavi District has provided valuable insights into the activity concentrations of uranium-238 (238U, thorium-232 and potassium-40 The results revealed spatial variations in radionuclide concentrations, influenced by local geological formations, with most values within global averages reported by UNSCEAR, except for a few sites with elevated levels due to geological anomalies. Radiological hazard indices such as radium equivalent activity, absorbed dose rate, and annual effective dose were generally below recommended safety limits, indicating no significant radiological risk to the local population under current conditions. The findings emphasize the role of geological and environmental factors in shaping natural radioactivity distribution, with regions exhibiting higher activity concentrations likely associated with uranium- and thorium-rich minerals. This research establishes crucial baseline data for Belagavi District, supporting future environmental monitoring and sustainable land use planning. It also underscores the importance of further investigations into areas with higher activity concentrations to understand potential risks and mitigate them effectively. Regular monitoring of natural radioactivity and public education on its implications are recommended to ensure ongoing environmental safety and public health. This study serves as a foundation for understanding natural radioactivity in the region and contributes to the global database on terrestrial radiation levels.

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Conflicts of Interest

The authors declare no conflicts of interest.

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