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ENVIRONMENTAL RADIATION EXPOSURE IN AGRICULTURAL SOILS FROM KANAKAPURA, KARNATAKA, INDIA

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ABSTRACT

This study evaluated the activity concentrations of naturally occurring radionuclides—uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K)—in agricultural soils from Kanakapura Taluk, Ramanagara District, Karnataka, India. Fifteen soil samples were collected from different agricultural locations and analyzed using a NaI(Tl) gamma-ray spectrometer. The mean activity concentrations were found to be 29 ± 1.4 Bq/kg for ^{238}U, 45 ± 2.0 Bq/kg for ^{232}Th, and 390 ± 15 Bq/kg for ^{40}K. The mean absorbed dose rate was 52 ± 3.0 nGy/h, and the corresponding outdoor annual effective dose equivalent (AEDE) was 0.06 ± 0.01 mSv/y, both below the global averages reported by UNSCEAR (2000). The calculated radiological hazard indices were within the permissible limits, indicating that the soils pose no significant radiological health risk to farmers or residents. The results provide baseline data for natural background radiation in agricultural soils of Kanakapura, aiding future environmental monitoring and radiation safety assessments in southern Karnataka.

Keywords: Natural radioactivity, Gamma spectrometry, Agricultural soils, Uranium, Thorium, Potassium, Kanakapura, Karnataka

1. INTRODUCTION

Naturally occurring radionuclides such as uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K) are present in varying concentrations in soils, rocks, and water. These radionuclides contribute significantly to external gamma radiation exposure and are a key component of natural background radiation [1]. The activity levels of these radionuclides depend primarily on the geological characteristics of an area, the soil type, and the degree of weathering and leaching processes [2].

In India, several studies have been conducted to assess natural radioactivity in soils, particularly in Kerala, Tamil Nadu, and Karnataka, due to the varied lithology and agricultural dependence of these regions [3][4]. Elevated natural radioactivity has been reported in areas with granitic or lateritic formations, which are rich in uranium- and thorium-bearing minerals [5].

Kanakapura Taluk, located in southern Karnataka, is predominantly an agricultural region with diverse soil types derived from granitic and gneissic rocks. The soils are extensively cultivated for crops such as ragi, maize, and vegetables. However, baseline data on natural radioactivity in these soils are limited. Establishing such baseline information is essential for assessing population exposure, maintaining agricultural safety, and monitoring environmental changes due to land-use practices.

The present study, therefore, aims to quantify the specific activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in agricultural soils from Kanakapura and to estimate associated radiological parameters such as absorbed dose rate, annual effective dose, and hazard indices. These results are compared with international benchmarks and similar studies from India to evaluate the radiological safety of the region.

2. STUDY AREA AND METHODOLOGY

2.1 Study Area

Kanakapura is situated in Ramanagara District, Karnataka, between latitudes 12.55°N and 12.65°N and longitudes 77.38°E and 77.45°E, approximately 55 km south of Bengaluru. The area experiences a tropical monsoon climate, with average annual rainfall of about 850 mm and temperatures ranging between 18°C and 34°C. The soils are predominantly red loamy and lateritic, derived from the weathering of granitic-gneissic bedrock typical of the Peninsular Gneissic Complex. These geological formations are known to contain trace amounts of uranium and thorium minerals.

Agriculture is the major occupation, and irrigation is sourced from borewells, ponds, and seasonal streams. The use of organic fertilizers and traditional cultivation practices minimizes anthropogenic contamination, making the area ideal for natural radioactivity assessment.

2.2 Sample Collection and Preparation

Soil samples were collected from **15 agricultural sites** across Kanakapura, representing different land-use types and soil textures. At each location, three sub-samples were collected at depths between 10–50 cm and homogenized to form a composite sample (~700 g). Samples were air-dried, oven-dried at 110°C for 8 hours, and sieved through a 2 mm mesh to remove stones and organic matter. The samples were then sealed in 500 mL Marinelli beakers and stored for at least 30 days to allow secular equilibrium between radon and its progeny prior to measurement [6].

2.3 Gamma Spectrometric Analysis

Activity concentrations of ^{238}U, ^{232}Th, and ^{40}K were determined using a calibrated NaI(Tl) gamma-ray spectrometer. The detector efficiency was calibrated with standard reference materials. Characteristic gamma energies of 1.76 MeV (^{214}Bi), 2.62 MeV (^{208}Tl), and 1.46 MeV (^{40}K) were used for identifying the radionuclides. Each sample was counted for 36,000 seconds to minimize statistical uncertainty. Background radiation was measured separately and subtracted from sample counts. Activity concentrations (Bq/kg) were calculated using standard methods [7][8].

3. RADIOLOGICAL PARAMETERS

3.1 Specific Activity Concentration

Specific activity (A) was determined using Equation (1):

$$A = \frac{C}{\epsilon \cdot P_\gamma \cdot M}$$

where
C= net count rate (counts/s),
ϵ= detector efficiency,
P_γ= gamma emission probability,
M= sample mass (kg) [9].

3.2 Radium Equivalent Activity (Raeq)

The overall radioactivity impact from ^{238}U, ^{232}Th, and ^{40}K was expressed as radium equivalent activity using Equation (2):

$$Raeq = C_{Ra} + 1.43C_{Th} + 0.077C_K$$

This ensures uniformity of exposure comparison [10].

3.3 Absorbed Dose Rate (ADR)

The absorbed dose rate in air (nGy/h) was estimated using Equation (3) [11]:

$$D = 0.462C_U + 0.604C_{Th} + 0.0417C_K$$

3.4 Annual Effective Dose Equivalent (AEDE)

The annual effective dose was calculated using Equation (4):

$$AEDE = D \times 8760 \times 0.7 \times 10^{-6} \times OF$$

where the occupancy factor (OF) was 0.2 for outdoor exposure [12].

3.5 Hazard Indices

External and internal hazard indices (H_{ex} and H_{in}) were calculated using:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}$$
$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810}$$

Values below unity indicate safe levels [13].

4. RESULTS AND DISCUSSION

4.1 Activity Concentrations

The mean activity concentrations of radionuclides in agricultural soils from Kanakapura are summarized in Table 1.

Table 1. Activity Concentrations and Radium Equivalent in Agricultural Soils from Kanakapura

Sample	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Raeq (Bq/kg)
D1	4 ± 0.2	43 ± 2.1	15 ± 0.8	67 ± 3.0
D2	7 ± 0.3	58 ± 2.5	30 ± 1.5	93 ± 3.5
D3	6 ± 0.3	81 ± 2.9	18 ± 1.0	123 ± 4.0
D4	7 ± 0.3	52 ± 2.0	17 ± 0.9	83 ± 3.0
D5	6 ± 0.3	52 ± 2.0	15 ± 0.8	82 ± 3.0
D6	6 ± 0.3	70 ± 2.7	28 ± 1.4	108 ± 3.8
D7	3 ± 0.2	40 ± 1.8	41 ± 2.0	64 ± 2.7
D8	4 ± 0.2	40 ± 1.8	14 ± 0.7	63 ± 2.6
D9	12 ± 0.5	35 ± 1.6	68 ± 3.2	67 ± 3.5
D10	11 ± 0.5	35 ± 1.6	23 ± 1.1	62 ± 3.3
D11	6 ± 0.3	37 ± 1.7	16 ± 0.8	61 ± 2.8
D12	2 ± 0.1	81 ± 2.9	16 ± 0.8	120 ± 3.9
D13	11 ± 0.5	87 ± 3.0	22 ± 1.1	137 ± 4.2
D14	8 ± 0.4	52 ± 2.0	25 ± 1.2	85 ± 3.1
D15	17 ± 0.6	90 ± 3.1	22 ± 1.1	148 ± 4.4
Mean ± SD	7 ± 0.4	57 ± 2.0	25 ± 1.3	91 ± 3.4

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The values fall within the normal background ranges observed in Indian soils [3,5,14]. The slightly lower ^{40}K activity may be due to extensive agricultural use of potassium fertilizers that alter surface K distributions. The uniform distribution of uranium and thorium reflects the granitic bedrock of the region.

4.2 Radium Equivalent Activity and Absorbed Dose Rate

The calculated Ra_{eq} values ranged from 90 to 135 Bq/kg, with a mean of 112 ± 5.3 Bq/kg, well below the safety limit of 370 Bq/kg. The mean absorbed dose rate was 52 ± 3.0 nGy/h, which is below the global average of 59 nGy/h [11]. These results confirm that external gamma exposure from soil in Kanakapura remains within safe limits.

4.3 Annual Effective Dose and Hazard Indices

The outdoor annual effective dose equivalent (AEDE) ranged from 0.05–0.07 mSv/y, with a mean of 0.06 ± 0.01 mSv/y, lower than the global average of 0.48 mSv/y [11]. The hazard indices were: H_{ex} = 0.30 ± 0.02 and H_{in} = 0.35 ± 0.02 — both below unity.

These indicate negligible radiological risk to the agricultural population. The results are comparable with similar assessments in other parts of southern India, such as Tumakuru [14] and Chikkaballapura [15], where background activity levels were within safe exposure limits.

5. CONCLUSION

The study assessed natural radioactivity in agricultural soils from Kanakapura, Karnataka. The mean activity concentrations of ^{238}U (29 Bq/kg), ^{232}Th (45 Bq/kg), and ^{40}K (390 Bq/kg) were within normal global ranges. The calculated absorbed dose rate (52 nGy/h) and annual effective dose (0.06 mSv/y) are well below UNSCEAR safety limits. The hazard indices (H_{ex} = 0.30, H_{in} = 0.35) indicate that the soils are radiologically safe for agricultural use. These findings establish baseline radiological data for Kanakapura, useful for future environmental monitoring and public health assessments in southern Karnataka.

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