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Assessment of Radiation Hazard Indices Due To Natural Radionuclides in Soil and Vegetation Samples at Federal University Dutsin-Ma, Katsina, Nigeria

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ABSTRACT

Naturally occurring radioactive materials (NORMs) like Potassium-40, Radium-226, and Thorium-232 are commonly found in rocks, soils, and plants. Monitoring these radionuclides in the environment is vital for evaluating human exposure, especially in institutions and residential settings. Excessive Radium-226 causes anaemia, cataracts, and bone cancer, due to its deposition in bone tissue after exposure. (ATSDR, 1990; IAEA, 2015). Thorium-232, poses a significant risk of respiratory diseases, including lung cancer, and may lead to genetic mutations in body cells over time (ATSDR, 1990; ICRP, 2008) Potassium-40, could result in hyperkaliemia, contributing to metabolic disorders, kidney diseases, and diabetes (UNSCEAR, 2000). This study determined the concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in soil and vegetation samples at the Federal University Dutsin-Ma main campus using gamma spectroscopy. In soil, activity concentrations ranged from 20.36–47.86 Bq/kg for ^{226}Ra, 21.03–64.57 Bq/kg for ^{232}Th, and 81.56–234.84 Bq/kg for ^{40}K, with means of 33.43, 43.16, and 164.32 Bq/kg, respectively. Compared to UNSCEAR global averages, ^{226}Ra and ^{232}Th were slightly higher, while ^{40}K was lower. In vegetation, values ranged from 13.73–43.91 Bq/kg (^{226}Ra), 16.67–50.96 Bq/kg (^{232}Th), and 19.63–75.61 Bq/kg (^{40}K), with averages of 25.06, 33.10, and 37.30 Bq/kg. All radiological hazard indices (Raeq, Hin, Hex, Iγ, Iα) in both media remained below international safety limits. Soil Raeq ranged from 62.90–158.28 Bq/kg (mean: 107.80 Bq/kg), and vegetation Raeq from 40.23–108.94 Bq/kg (mean: 75.27 Bq/kg). Although vegetation from the Faculty of Life Sciences exhibited higher uptake, overall radiological risk is minimal. These findings are valuable for environmental safety and potential food chain exposure assessment.

Keywords: FUDMA, NORMs, Radiation Hazards, Soil, Vegetation

INTRODUCTION

Radionuclides have been essential constituents of the earth, since its creation. Human beings are continually exposed to ionizing radiation from naturally occurring radionuclides known to be present in varying proportions in rocks and soil of different geological formations around the world (UNSCEAR, 2000). This natural radiation comes from two main sources: cosmogenic radionuclides (^{3}H, ^{14}C, etc) and long-lived primordial radionuclides, also called naturally occurring radioactive materials (NORMs) (^{40}K, ^{238}U, and ^{232}Th) and their daughters also called naturally occurring radioactive materials (NORMs). The amount of these cosmogenic radionuclides is basically constant because of equilibrium between their rate of creation by cosmic radiation and their radioactive decay (Mikhail, 2008). Although the amount of primordial radionuclide keeps decreasing slowly with time due to radioactive decay, quite a significant amount still remains in the earth crust today and onward due to their long half-lives. Their concentrations and associated exposure in different environments depend primarily on the geology and geographical conditions of such environments (Dawood, 2011). The measurement of natural gamma radioactivity levels is paramount in implementing precautionary measures whenever the source is found to exceed the recommended limits. The most common radiation induced health effects are incidence of cancers and genetic effects. Lung cancer induction is the most common effect due to inhalation radiation exposure (WHO, 2009). As of February 2025, As of April 2026, the Federal University Dutsin-Ma (FUDMA) hosts about 35,000 undergraduate and postgraduate students across its two campuses with about 4000 teaching and non-teaching staff. The university community, including students and staff, interacts extensively with the environment, and staff members are allotted plots of land for seasonal farming in the main campus. These activities emphasize the potential risk of exposure to Naturally Occurring Radioactive Materials (NORMs), which are present in rocks, soils, plant, water, and air (Namadi *et al*., 2025). The concentrations and impacts of these radionuclides, including Potassium-40 (K-40), Radium-226 (Ra-226), and Thorium-232 (Th-232), require careful study to ensure the safety of the campus population and neighboring communities. Excessive levels of Radium-226 have been linked to severe health effects such as anaemia, cataracts, and bone cancer, particularly due to its deposition in bone tissue after exposure (ATSDR, 1990; IAEA, 2015). Thorium-232, when inhaled in dust form during activities like farming or construction, poses a significant risk of respiratory diseases, including lung cancer, and may lead to genetic mutations in body cells over time (ATSDR, 1990; ICRP, 2008). Potassium-40, though essential for biological functions, may become harmful when its levels exceed normal biological thresholds. Elevated potassium concentrations could result in hyperkaliemia, contributing to metabolic disorders, kidney diseases, and diabetes (UNSCEAR, 2000). The farming practices carried out by staff on campus land, coupled with the possibility of consuming contaminated vegetation, increase the likelihood of radionuclide exposure. This exposure is not limited to the university community but could also affect neighboring communities reliant on agricultural produce from the area. For instance, the bioaccumulation of NORMs in crops could create a pathway for these radionuclides to enter the food chain, posing risks of chronic health conditions over time (Ajayi and Kuforiji, 2001; IAEA, 2015). Additionally, the degradation of local soil and water quality by NORMs can further compound these risks, necessitating continuous monitoring and statistical analysis to evaluate and mitigate exposure levels. Understanding the distribution of NORMs in soil and vegetation in FUDMA campuses is thus critical. The implications for public health emphasize the importance of conducting thorough measurements, applying statistical analyses, and implementing preventive measures to safeguard the university population and its surroundings. The goal of this research was to measure and analyse natural radioactivity and other radiological parameters in the Federal University Dutsin-ma campus, Katsina state, Nigeria. Similar radiological analysis research was carried out by Namadi et al., (2025) to investigate the radiological nature of Federal University Dutsin-Ma take-off and Main campuses using a Digital Radiation Meter to measure terrestrial gamma radiation and corresponding annual effective doses and Excess Life Cancer Risk (ELCR). Also, Namadi et al., (2021) investigated radiological nature of Kankara Mining site in Katsina State.

MATERIALS AND METHODS

Study Area

Dutsin-Ma is a Local Government Area in Katsina State, North-Western Nigeria. It lies on latitude 12°26'N and longitude 07°29'E. It is bounded by Kurfi and Charanchi LGAs to the north, Kankia LGA to the East, Safana and Dan-Musa LGAs to the West, and Matazu LGA to the Southeast.

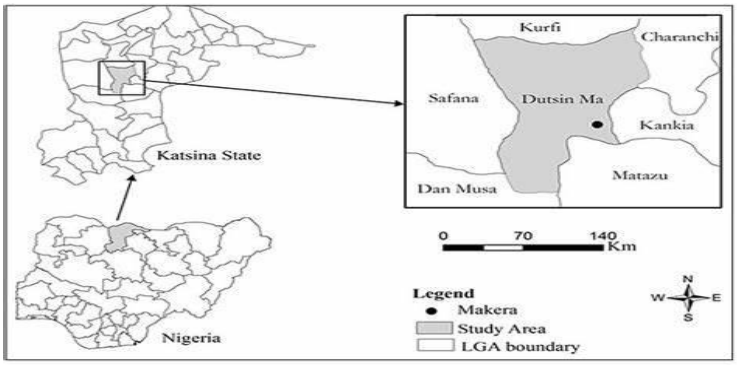

Figure 1: Geographical of Map of Nigeria, indicating Katsina state and Dutsin-Ma (Oyebamiji et al., 2019)

The Federal University Dutsin-Ma was established on 7th February, 2011 along with eight other Federal Universities to tackle the challenges of inadequate enrolment space for eligible University applicants in some educationally less privileged states who don't have Federal Universities. With the support of the State Government, the permanent as well as the take-off site were identified; with the take-off site located in Dutsin-Ma town while the main campus at Kilometer-Sixty Katsina-Kankara road in Dutsin-Ma Local Government Area of Katsina State (FUDMA, 2015).

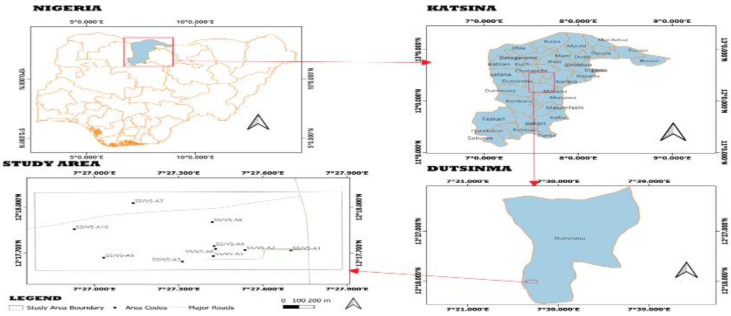

Figure 2: Satellite View of Federal University Dutsin-Ma Main Campus (Google maps, 2024; modified)

Materials Used In Gamma Spectroscopy

Soil and vegetation samples, Polythene Bag, Hand auger, Digger, shovel, surgical gloves, drilling machine, indelible ink, masking tape, tissue paper, candle wax, plastic container, sieve, hydraulic pressure system, geographical positioning (GPS), gamma spectrometry system (Sodium iodide activated with thallium).

Methods

Soil Sample Collection

Soil samples were collected within the university. The soil samples were taken using a mechanical hand auger to a depth of 5-10 cm. At each sampling location, soil sample was taken into labeled plastic bags. One kilogram (1 kg) of each sample was collected for analysis.

Vegetation Sample Collection

In locations where soil samples were collected, vegetation samples were collected with each sample collected within a grid area of 1m x 1m. The samples were also packaged in plastic bags and labelled with identification marks. The coordinates of each sampling location that corresponded to the soil samples earlier discussed were recorded for traceability (Kamunda, 2017).

Sample Preparation for Gamma Radioactivity Measurements

The sample preparation method was adopted from Ibeanu, (1999). Each of the soil sample as well as the plant sample was sealed in a polyethylene bag, firmly tied and labelled to avoid cross contamination of the samples. Samples were spread on cardboard sheets and “all foreign materials” were removed. The samples were dried in a thermostatically controlled laboratory oven at 110 °C for 12–18 h to remove moisture prior to gamma spectrometric analysis. The samples were then grinded into a fine powder and sieved using 2 mm sieve. The homogenized samples were filled into 25 g plastic containers (7.2 cm diameter by 6 cm height) which were hermetically sealed with the aid of PVC tape to prevent the escape of airborne ^{222}Rn and ^{220}Rn from the samples. The dimensions of the plastic containers were chosen in such a way that it suited the optimal soil mass of 350 g for analysis of bulk samples. The samples were then sealed and stored for over 24 days to allow secular equilibrium to be reached between radon and its daughters. Precautions were taken during grinding to minimize the loss of radon progenies by reducing dust generation and promptly sealing the pulverized samples in hermetically closed containers. The IAEA reference materials for gamma spectrometry (RGK-1, IAEA-448 and RGTh-1) were prepared exactly as the samples.

Gamma Spectrometric Analysis

The NaI(Tl) detector, situated at low background laboratory of the Center for Energy Research and Training, Ahmadu Bello University, Zaria, was used for the gamma spectrometric measurements. The detector has a 6 cm thick lead shield, cadmium lined assembly with copper sheets for the detection of background radiation. The detector has pulse resolving time of about 0.25 s, an incorporated preamplifier and a 1 kV external source which permits its use for high counting rates. The detector was coupled to a computer based multichannel analyser Maestro program from ORTEC for the acquisition and analysis of the gamma spectra. The detector was calibrated with the prepared IAEA reference materials RGK-1, IAEA-448 and RGTh-1 for the quantitative determination of ^{40}K, ^{238}U and ^{232}Th respectively in the soil samples. Each of the prepared samples was counted for 30,000 seconds in the outlined detector geometry in order to mitigate the influence of background radiation from radioactive contaminants within the shielding materials of the detector assembly. The spectral energy windows used for the analysis of the NORMs were presented in Table 2.1. The obtained data in counts per second were converted to conventional units of Bq/kg using calibration factors to determine the activity concentration of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K.

Table 1: Spectral Energy Used In the Gamma Spectrometric Analysis

Element analysed	Isotope used	Gamma energy (keV)	Energy windows (keV)
^{40}K	^{40}K	1460.0	1380-1510
^{226}Ra	^{214}Bi	1764.0	1690-1820
^{232}Th	^{208}Tl	2614.5	2590-2710

Assessment of Radiation Hazard Indices Due To Norms

Assessment of Radium Equivalent Activity (Ra_{eq})

Radium equivalent activity was used as a common radiological index to provide the actual activity level of NORMs in the sample due to their non-uniform distribution. It is a widely used index to assess the radiation hazards and it was estimated on the fact that 370 Bq.kg^{-1} of ^{226}Ra, 259 Bq.kg^{-1} of ^{232}Th and 4810 Bq.kg^{-1} of ^{40}K produce the same gamma-ray dose rate. Ra_{eq} was computed using equation 1 below. It has a permissible maximum value of 370 Bq.kg^{-1} which corresponds to an effective dose of 1 mSv for the general public (UNSCEAR, 2000; Ajayi, 2009).

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_k \qquad (1)$$

WhereA_{Ra}, A_{Th} and A_k are the activity concentration of ^{226}Ra, ^{232}Th and ^{40K} in Bq.kg^{-1} respectively.

Internal, External, Gamma and Alpha Indices

Another important radiation hazard indices namely, internal hazard index (H_{in}), external hazard index (I_{ex}), alpha index and gamma index were also evaluated in this work. These indices are very critical in assessing hazard from radon and its short- lived products in the environmental materials used in building to the respiratory organs They were evaluated using Equations 2, and 3, respectively (UNSCEAR, 2000). Human beings are usually exposed to ionizing radiation in form of γ-ray and α-particles, mainly from ^{226}Ra, ^{232}Th and ^{40}K present in environmental matrix (Qureshi *et al.*, 2014). Both gamma representative index (I_γ) and alpha representative index (I_α) were calculated using Equations 4 and 5 respectively (Xinwei *et al.*, 2006).

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \qquad (2)$$

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \qquad (3)$$

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \leq 1 \qquad (4)$$

$$I_\alpha = \frac{A_{Ra}}{200} \leq 1 \qquad (5)$$

RESULTS AND DISCUSSION

Table 2: Activity Concentrations of ^{226}ra, ^{232}th And ^{40}k in Soil Samples From Fudma Main Campus and Worldwide Average

S/No.	Sample ID	Area Location	Activity Concentration (Bqkg^{-1})		
			^{226}Ra	^{232}Th	^{40}K
1.	SS-A01	University Gate	33.01±2.78	34.05±2.46	143.13±4.96
2.	SS-A02	Senate Building	47.86±2.20	64.57±2.24	234.84±4.94
3.	SS-A03	University Library	28.05±2.78	53.67±2.51	209.36±5.55
4.	SS-A04	University Clinic	30.21±2.68	35.88±1.26	81.56±4.88
5.	SS-A05	Faculty of Physical Sciences	37.97±3.54	47.81±2.41	154.96±2.89
6.	SS-A06	Faculty of Life Sciences	24.48±1.27	27.48±1.53	129.08±3.27
7.	SS-A07	Faculty of Health Sciences	42.94±5.57	45.61±2.01	193.98±2.52
8.	SS-A08	Faculty of Engineering	20.36±2.47	51.78±2.14	174.50±2.95

S/No.	**Sample ID**	**Area Location**	**Activity Concentration (Bqkg^{-1})**		
			^{226}Ra	**^{232}Th**	**^{40}K**
9.	SS-A09	Female Hostel	46.22±3.38	49.74±3.71	196.33±3.03
10.	SS-A10	Male Hostel	23.16±2.12	21.03±1.46	125.49±2.47
		MINIMUM	20.36±2.47	21.03±1.46	81.56±4.88
		MAXIMUM	47.86±2.20	64.57±2.24	234.84±4.94
		AVERAGE	33.43	43.16	164.32
		WORLDWIDE AVERAGE	30.00	35.00	400.00

Discussions

Table 2a presents the activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in soil samples collected from various locations within the FUDMA main campus. The measured concentrations ranged from 20.36 to 47.86 Bq/kg for ^{226}Ra, 21.03 to 64.57 Bq/kg for ^{232}Th, and 81.56 to 234.84 Bq/kg for ^{40}K. The highest values for all three radionuclides were recorded at the Senate Building, indicating a potential concentration of naturally occurring radioactive materials (NORMs) in that area. The average activity concentrations across all samples were 33.43 Bq/kg for ^{226}Ra, 43.16 Bq/kg for ^{232}Th, and 164.32 Bq/kg for ^{40}K. When compared to the global averages reported by UNSCEAR 30 Bq/kg for ^{226}Ra, 35 Bq/kg for ^{232}Th, and 400 Bq/kg for ^{40}K the FUDMA campus shows slightly elevated levels of ^{226}Ra and ^{232}Th, but significantly lower levels of ^{40}K. These findings suggest the local geology is moderately enriched in uranium and thorium series radionuclides, while potassium-bearing minerals may be less prevalent.

Table 3: Activity Concentrations of ^{226}Ra, ^{232}Th And ^{40}K in Vegetation Samples From FUDMA Main Campus and Worldwide Average

S/No.	**Sample ID**	**Area Location**	**Activity Concentration (Bqkg^{-1})**		
			^{226}Ra	**^{232}Th**	**^{40}K**
1.	VS-A01	University Gate	32.98±2.79	30.86±1.49	48.01±4.40
2.	VS-A02	Senate Building	14.46±1.51	16.67±1.51	25.04±3.00
3.	VS-A03	University Library	43.91±2.48	32.85±3.59	56.10±4.51
4.	VS-A04	University Clinic	26.09±3.61	33.88±4.45	30.95±3.30
5.	VS-A05	Faculty of Physical Sciences	22.81±1.26	19.74±2.85	75.61±4.04
6.	VS-A06	Faculty of Life Sciences	34.93±2.16	49.90±2.63	34.48±3.14
7.	VS-A07	Faculty of Health Sciences	13.73±1.09	36.34±2.20	29.08±2.20
8.	VS-A08	Faculty of Engineering	19.10±1.41	50.96±3.37	19.63±1.96
9.	VS-A09	Female Hostel	26.49±2.87	32.27±3.31	24.06±2.51
10.	VS-A10	Male Hostel	16.10±2.33	27.57±2.17	30.02±3.73
		MINIMUM	13.73±1.09	16.67±1.51	19.63±1.96
		MAXIMUM	43.91±2.48	50.96±3.37	75.61±4.04
		AVERAGE	25.06	33.10	37.30
		WORLDWIDE AVERAGE	30.00	35.00	400.00

Table 3 illustrates the activity concentrations of the same radionuclides ^{226}Ra, ^{232}Th, and ^{40}K but in vegetation samples collected from corresponding locations. Here, the activity concentrations ranged from 13.73 to 43.91 Bq/kg for ^{226}Ra, 16.67 to 50.96 Bq/kg for ^{232}Th, and 19.63 to 75.61 Bq/kg for ^{40}K. The highest concentration of ^{226}Ra was found at the University Library, while ^{232}Th peaked at the Faculty of Engineering, and ^{40}K was highest at the Faculty of Physical Sciences. The average values 25.06 Bq/kg for ^{226}Ra, 33.10 Bq/kg for ^{232}Th, and 37.30 Bq/kg for ^{40}K are lower than both the soil values and global averages. These results reflect the selective uptake of radionuclides by plants, which depends on several factors including root depth, soil-to-plant transfer coefficients, species-specific absorption traits, and the chemical form of the radionuclides in the soil. Notably, ^{40}K, despite being essential for plant nutrition, remains significantly below the global average of 400 Bq/kg, hinting at limited availability or uptake from the soil.

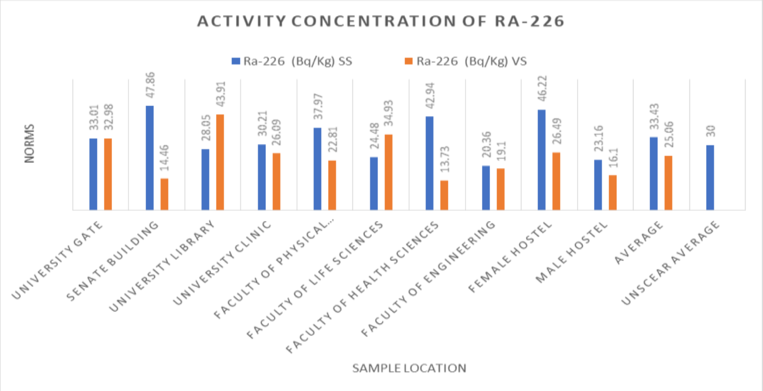

Figure 2: Activity Concentration of Ra-226 in Soil and Vegetation Samples

Figure 2 provides a comparative visual of ^{226}Ra concentrations in soil (SS) and vegetation (VS). The graph clearly shows that soil samples contain higher concentrations than vegetation at all locations, with soil values ranging up to 47.86 Bq/kg (Senate Building) compared to a maximum of 43.91 Bq/kg in vegetation (University Library). The differences reflect the low bioavailability of radium, which is known to bind strongly with soil particles, limiting its mobility and uptake by plants. The consistent disparity between the two matrices underlines radium's low transfer factor and reinforces the concept that terrestrial exposure from radium is largely confined to the soil rather than the food chain. This trend is crucial when considering long-term external exposure risks, especially in areas of human activity.

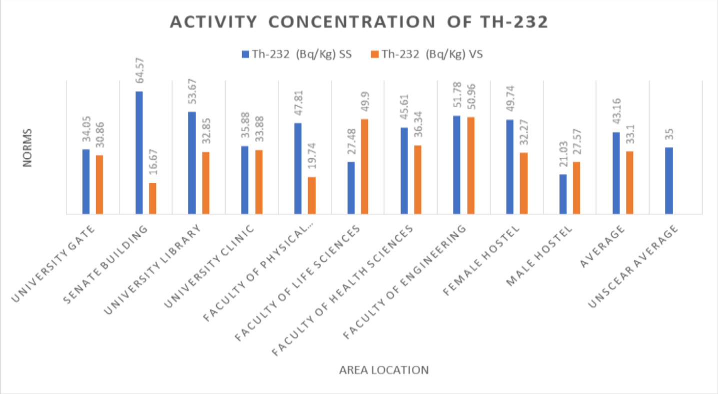

Figure 3: Activity Concentration of Th-232 in Soil and Vegetation Samples

Figure 3 shows the concentrations of ^{232}Th in both soil (SS) and vegetation samples (VS). The soil concentrations peak at 64.57 Bq/kg (Senate Building) while that of vegetation shows a maximum at 50.96 Bq/kg (Faculty of Engineering), again highlighting soil as the dominant reservoir. Thorium's environmental behavior is governed by its poor solubility and strong adsorption to clay minerals and organic matter. The chart confirms this, as thorium shows limited translocation into plant tissues despite its moderate abundance in soils. Notably, certain areas like the University Clinic and Faculty of Life Sciences show relatively high thorium values in both matrices, suggesting specific soil-plant interaction mechanisms. This data is valuable in evaluating internal exposure pathways, particularly ingestion, through plant-based foods.

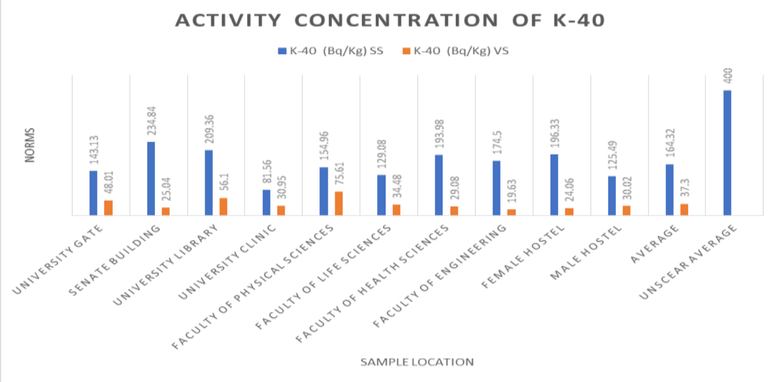

Figure 4: Activity Concentration of K-23 in Soil and Vegetation Samples

Figure 4 focuses on the activity concentrations of ^{40}K and reveals a more dynamic interaction between soil and vegetation compared to radium and thorium. In soil, concentrations reach up to 234.84 Bq/kg at the Senate Building, while in vegetation, the maximum observed is 75.61 Bq/kg at the Faculty of Physical Sciences. The higher uptake in some vegetation samples, relative to the other radionuclides, is expected due to potassium's essential role in plant physiology. However, all values fall well below the global benchmark of 400 Bq/kg. This discrepancy may be attributed to nutrient-poor soils or differences in mineralogy. The figure emphasizes the moderate translocation potential of potassium isotopes, which, while greater than that of thorium and radium, remains influenced by environmental and biological constraints.

Table 4: Radium Equivalent Activity (Ra_{eq}), Internal, External, Gamma and Alpha Indices for Soil Samples

Serial No	Sample Code	Area Location	Ra_{eq} (Bq/Kg)	H_{in}	H_{ex}	I_γ	I_α
1.	SS-A01	University Gate	92.72	0.34	0.25	0.66	0.17
2.	SS-A02	Senate Building	158.28	0.56	0.43	1.12	0.24
3.	SS-A03	University Library	120.92	0.40	0.33	0.86	0.14
4.	SS-A04	University Clinic	87.80	0.32	0.24	0.61	0.15
5.	SS-A05	Faculty of Physical Sciences	118.27	0.42	0.32	0.83	0.19
6.	SS-A06	Faculty of Life Sciences	73.72	0.27	0.20	0.52	0.12

Serial No	Sample Code	Area Location	Ra_{eq} (Bq/Kg)	H_{in}	H_{ex}	I_{γ}	I_{α}
7.	SS-A07	Faculty of Health Sciences	123.10	0.45	0.33	0.67	0.21
8.	SS-A08	Faculty of Engineering	107.84	0.35	0.29	0.77	0.10
9.	SS-A09	Female Hostel	132.47	0.48	0.36	0.94	0.23
10.	SS-A10	Male Hostel	62.90	0.23	0.17	0.45	0.12
		MINIMUM	62.90	0.23	0.17	0.45	0.10
		MAXIMUM	158.28	0.56	0.43	1.12	0.24
		AVERAGE	107.80	0.38	0.29	0.76	0.17
		WORLD AVERAGE	370.00	1.00	1.00	1.00	1.00

Table 4 details radiological hazard indices for soil samples, including Radium Equivalent Activity (Ra_{eq}), internal (H_{in}) and external (H_{ex}) hazard indices, gamma (I_{γ}) and alpha (I_{α}) indices. Ra_{eq} values ranged from 62.90 Bq/kg (Male Hostel) to 158.28 Bq/kg (Senate Building), well below the international limit of 370 Bq/kg. The mean Ra_{eq} was 107.80 Bq/kg. All other indices H_{in} (0.23–0.56), H_{ex} (0.17–0.43), I_{γ} (0.45–1.12), and I_{α} (0.10–0.24) also remained below unity, the internationally accepted threshold for safe use of materials. These results indicate that the radiological risk posed by soil at FUDMA is within acceptable limits. However, the elevated values in areas like the Senate Building and Female Hostel highlight the need for continuous site monitoring, particularly before any developmental or residential projects.

Table 5: Radium Equivalent Activity (Ra_{eq}), Internal, External, Gamma and Alpha Indices for Vegetation Samples

Serial Number	Sample Code	Area Location	Ra_{eq} (Bq/Kg)	H_{in}	H_{ex}	I_{γ}	I_{α}
1.	VS-A01	University Gate	80.81	0.31	0.22	0.56	0.16
2.	VS-A02	Senate Building	40.23	0.15	0.11	0.28	0.07
3.	VS-A03	University Library	95.21	0.38	0.26	0.66	0.22
4.	VS-A04	University Clinic	76.92	0.28	0.21	0.53	0.13
5.	VS-A05	Faculty of Physical Sciences	56.86	0.22	0.15	0.4	0.11
6.	VS-A06	Faculty of Life Sciences	108.94	0.39	0.29	0.75	0.17
7.	VS-A07	Faculty of Health Sciences	67.94	0.22	0.18	0.47	0.07
8.	VS-A08	Faculty of Engineering	93.48	0.30	0.25	0.65	0.10
9.	VS-A09	Female Hostel	74.49	0.27	0.20	0.52	0.13
10.	VS-A10	Male Hostel	57.84	0.20	0.16	0.40	0.08
	MINIMUM		40.23	0.15	0.11	0.28	0.07
	MAXIMUM		108.94	0.39	0.29	0.75	0.22
	AVERAGE		75.27	0.27	0.20	0.52	0.13

Table 5 presents similar hazard indices for vegetation samples. Ra_{eq} values ranged from 40.23 Bq/kg (Senate Building) to 108.94 Bq/kg (Faculty of Life Sciences), with a mean of 75.27 Bq/kg. Internal hazard indices (H_{in}) ranged between 0.15 and 0.39, and external indices (H_{ex}) from 0.11 to 0.29, all safely below the recommended limits. Gamma index (I_{γ}) values varied from 0.28 to 0.75, and alpha index (I_{α}) from 0.07 to 0.22. While the values are consistently lower than those from soil, the vegetation at the Faculty of Life Sciences showed relatively high values across several indices, which could suggest enhanced radionuclide uptake in that location. Although the overall radiological risk from vegetation is minimal, the data is essential for understanding radionuclide dynamics in the biosphere and their possible introduction into the food chain.

Certain locations exhibited elevated values for specific indices due to differential contributions from ^{226}Ra, ^{232}Th, and ^{40}K, which influence the radiological parameters differently. The Faculty of Life Sciences consistently showed relatively higher values across several indices, possibly due to localized geological heterogeneity, enhanced mineralization, and greater retention of radionuclides in the soil matrix. Additionally, the presence of vegetation, laboratory-related activities, and possible use of phosphate-containing materials may have contributed to radionuclide accumulation in the area. These findings suggest that spatial variations in natural radioactivity within the campus are influenced by both environmental and geological factors.

CONCLUSION

In this study, we have quantified the activity concentrations of naturally occurring radionuclides ^{40}K, ^{226}Ra, and ^{232}Th in both soil and vegetation samples collected from various locations on the main campus of Federal University Dutsin-Ma. The findings indicate that soil samples generally exhibited higher radionuclide concentrations than vegetation, consistent with the limited mobility and bioavailability of these radionuclides in terrestrial ecosystems. Specifically, average concentrations in soil were 164.32 Bq/kg for ^{40}K, 33.43 Bq/kg for ^{226}Ra, and 43.16 Bq/kg for ^{232}Th, slightly exceeding the global averages for radium and thorium but significantly lower for potassium. These values suggest a moderate radiological enrichment of uranium- and thorium-series elements in the campus environment. Vegetation samples demonstrated markedly lower values, averaging 37.30 Bq/kg, 25.06 Bq/kg, and 33.10 Bq/kg for ^{40}K, ^{226}Ra, and ^{232}Th respectively, indicating limited translocation from soil to plant tissues. This differential uptake highlights the influence of geochemical and biological factors on radionuclide distribution. In Soil samples, Ra_{eq} values ranged from 62.90 Bq/kg to 158.28 Bq/kg below the international limit of 370 Bq/kg. The mean Ra_{eq} was 107.80 Bq/kg. All other indices H_{in} (0.23–0.56), H_{ex} (0.17–0.43), I_{γ} (0.45–1.12), and I_{α} (0.10–0.24) also remained below unity. For vegetation samples, Ra_{eq} values ranged from 40.23 Bq/kg to 108.94 Bq/kg, with a mean of 75.27 Bq/kg. Internal hazard indices (H_{in}) ranged between 0.15 and 0.39, and external indices (H_{ex}) from 0.11 to 0.29, all safely below the recommended limits.

Gamma index (I_γ) values varied from 0.28 to 0.75, and alpha index (I_α) from 0.07 to 0.22. These results indicate that the radiological risk posed by soil at FUDMA is within acceptable limits. However, the elevated values in areas like the Senate Building and Female Hostel highlight the need for continuous site monitoring, particularly before any developmental or residential projects.

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