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Radiological Assessment of Soil Samples from Gwong Cooperative Rice Field in Kaduna, Northwest Nigeria: Implications for Agricultural Workers and Public Health

*Moses I.F.[12], Kolo M.T.[2] Olarinoye I.O.[3]Umoette I.J.[1]
[1]*Dosimetry and Radiation Protection Department, Nuclear Technology Center, Nigeria Atomic Energy Commission (NAEC), Abuja*
[2]*Department of Physics, Federal University of Technology, Minna, Niger State*
[3]*Department of Physics, Federal University of Technology, Minna, Niger State*
[*]*Correspondence Author e-mail: mosesfmig@yahoo.co.uk*

-----ABSTRACT-----
This study investigates the activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) and associated radiological parameters in soil samples from the Gwong Cooperatives rice farm located in Jama'a Kaduna State, Nigeria. A total of 20 soil samples were collected and analyzed using High-Purity Germanium (HPGe) gamma spectrometry. The results activity concentrations of showed that ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples ranged from 314.23 ± 16.25 Bqkg^{-1} to 390.18 ± 20.16 Bqkg^{-1} for ^{226}Ra, for ^{232}Th it ranged from 103.52 ± 5.49 to 155.63 ± 8.65 Bqkg^{-1}, and for ^{40}K it ranged from 482.01 ± 25.50 to 957.33 ± 50.63 Bqkg^{-1}. The mean activity concentrations were 353.02 ± 17.74 Bqkg^{-1} for ^{226}Ra, 142.48 ± 7.55 Bqkg^{-1} for ^{232}Th, and 887.79 ± 46.80 Bqkg^{-1} for 40K. The computed radiological parameters revealed that the absorbed dose varied from 224.35 to 313.97nGyh^{-1}with the mean value of 285.19±20.37 nGyh^{-1} .The annual effective dose varied from 275.14 to 385.05μSvy-^{1}while the Radium equivalent varied from 483.14 to 686.06 Bqkg^{-1}with a mean value of 349.81±25.55 μSvy-^{1}. The excess lifetime cancer risk (ELCR) ranged from 1.12 × 10^{-3} to 1.96 × 10^{-3}, with a mean of 1.28 × 10^{-3}. Comparisons with global averages and other regional studies indicated that the radiological parameters in the Gwong Cooperative Rice Farm area above acceptable limits. These findings emphasize the need for continuous monitoring of radiation levels in agricultural areas to ensure the safety of workers, consumers, and the environment. The study contributes valuable data to the growing body of knowledge on environmental radiation and its potential health risks in Nigeria's agricultural sector.

***KEYWORDS**: Gwong Cooperative rice farm, Radiological parameters and Excess lifetime cancer risk*

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I. INTRODUCTION

Humans are continuously exposed to ionizing radiation from both natural and artificial sources, which have become integral to life on Earth [1]. The primary natural sources of this exposure include cosmic rays and gamma radiation emitted by radionuclides in the decay series of Uranium-238 (^{238}U) and Thorium-232 (^{232}Th), as well as Potassium-40 (^{40}K). For most individuals, exposure to natural radiation exceeds that from artificial sources [1]. Natural radioactivity is present in various geological materials such as the Earth's crust, rocks, soils, plants, water, and air [2]. The concentration of naturally occurring radioactive materials (NORMs) is predominantly influenced by geological and geographical factors, with variations in soil composition observed based on regional geology [1, 2]. Accurate measurement of radionuclide concentrations in soil is essential for evaluating background radiation levels [2]. Radionuclides are introduced into the soil through processes such as rainfall, atmospheric deposition, mining and industrial activities, agricultural practices (including fertilizers), nuclear fallout, leaching from waste sites, volcanic eruptions, river sediment deposition, and weathering processes [3]. Each of these mechanisms contributes to the distribution of natural and artificial radionuclides in the environment, with their concentration levels varying according to both geographical and anthropogenic factors [4]. Studies indicate that different rock types exhibit distinct levels of radioactivity—igneous rocks generally have higher radiation levels, while sedimentary rocks show lower levels [1].

The correlation between radiation exposure and cancer is well-established, with epidemiological studies providing evidence of a dose-response relationship [4]. This suggests that even a slight increase in radiation dose can elevate cancer risk. The linear no-threshold model posits that even low doses of radiation may contribute to cancer development [4, 5]. A key metric used to assess cancer risk in populations is the excess lifetime cancer risk (ELCR), which estimates the probability of developing cancer over a lifetime of exposure to radiation [6]. Monitoring environmental radioactivity, including that in soil, is essential for determining the levels of natural radionuclides and assessing the associated health risks [7]. Additionally, research highlights that soil serves as a continuous source of radiation exposure and acts as a medium for transferring radionuclides into biological systems, posing potential risks to both human health and the environment [7, 8]. Therefore, it is crucial to assess regions with high agricultural potential and dense populations to evaluate their radiation exposure levels. The Gwong Cooperative rice farm was selected for this study, as, to the best of our knowledge; no previous research has assessed the radioactivity levels in soil samples from this farm in Gwong Cooperative rice, Kaduna State.

Kaduna State, Nigeria, was chosen due to its significance as a major rice-producing region, with Gwong Cooperative rice farm being one of the largest, spanning approximately 6 hectares and producing up to 8 metric tons of rice per hectare for local consumption and export [9]. Moreover, rice is a staple crop, and Gwong Cooperative rice farm plays a crucial role in Nigeria's food security [9]. Given the scale of production, intensive agricultural practices are inevitable, potentially leading to environmental concerns, such as radioactive contamination from fertilizers, pesticides, or natural sources. It is, therefore, imperative to evaluate whether the radioactivity levels in the soil of this farm comply with international safety standards to protect workers, consumers, and the surrounding community from harmful radiation exposure. Monitoring radioactivity levels on this farm is essential for ensuring food safety, environmental protection, and public health. Since rice, a staple food for millions absorbs nutrients and minerals from the soil—including any radionuclides present [10]—measuring the radioactivity levels is crucial for assessing the potential transfer of radionuclides such as uranium, thorium, and potassium from the soil to the rice plants, which could lead to internal exposure through consumption [10]. The International Commission on Radiological Protection (ICRP) recommends reducing risk from both internal and external exposure through the application of the ALARA (As Low As Reasonably Achievable) principle. Consequently, it is vital to monitor the radioactivity levels on this farm to ensure compliance with this principle, safeguarding agricultural workers, the surrounding environment, and the health of consumers.This study, therefore, aims to measure the activity concentrations of natural radionuclides—Radium-226 (^{226}Ra), Thorium-232 (^{232}Th), and Potassium-40 (^{40}K)—in soil samples from Gwong Cooperative rice farm, assess the associated radiological hazard indices posed by the soil samples from this farm.

II.MATERIAL AND METHODS

The study was carried out at Gwong cooperative Rice Farm, located in Jema'a , Kaduna State, North West Nigeria. Gwong cooperative Rice Farm is a large-scale commercial farm known for producing high-yield rice through different farming techniques. A total of twenty soil samples were collected from various locations across the farm, with precise coordinates recorded using a GPS Garmin 76S device. The samples were at a depth of 150 mm below the surface, placed in polythene bags, and labeled accordingly [9]. A map of Kaduna State, Nigeria, indicating the sample locations, is shown in figure 1

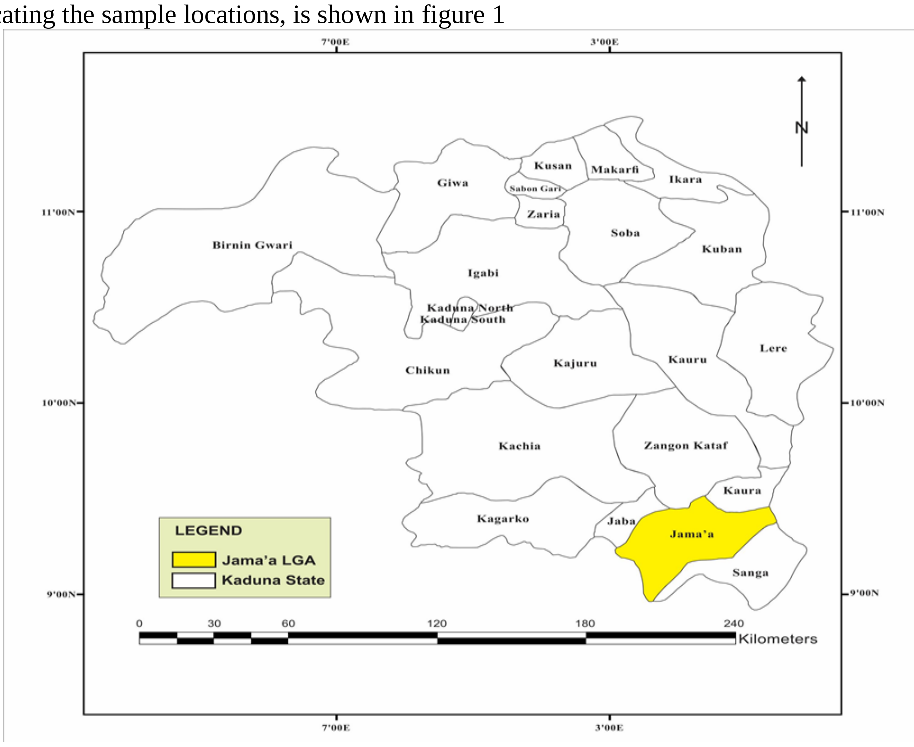

Figure 1: Map of Kaduna State showing study area

Subsequently, the soil samples were transported to the Nigeria Institute of Radiation Research and Protection (NIRPR) at the University of Ibadan. Upon arrival, the samples were air-dried and then oven-dried at 100°C to remove moisture until a constant weight was achieved. The samples were then ground, homogenized, and sieved using a 1.00 mm mesh sieve [9]. The sieved soil samples, weighing 0.5 kg each, were placed into Marinelli beakers, hermetically sealed, and labeled. The sealed samples were stored in a dry environment for 28 days to ensure the attainment of radioactive secular equilibrium between Radium-226 (226Ra), Thorium-232 (232Th), and their short-lived daughter products [11]

Calibration and Gamma Spectrometric Analysis

The radioactivity levels in soil samples were quantified utilizing a High-Purity Germanium (HPGe) detector manufactured by Canberra, selected for its superior resolution and efficiency in gamma-ray detection. The detector was interfaced with a multichannel analyzer (MCA) to facilitate the acquisition and interpretation of gamma spectra. To suppress interference from ambient radiation, the HPGe detector was encased within a lead-brick shielding assembly. Spectral analysis was conducted using the Genie 2000 software suite. Efficiency and energy calibrations were carried out using a standard mixed radionuclide source, contained within a 550 mL Marinelli beaker. This calibration source comprised isotopes including ^{241}Am, ^{109}Cd, ^{57}Co, ^{60}Co, ^{113}Sn, ^{203}Hg, ^{88}Y, and ^{137}Cs. Baseline background radiation measurements were recorded over a two-hour period every 48 hours prior to sample analysis, and the resulting background spectra were subtracted from the sample data to isolate the net activity attributable solely to the soil samples.Each soil sample was subjected to a 10-hour counting interval to ensure statistically robust data acquisition. The resulting gamma spectra were evaluated for characteristic emissions corresponding to ^{226}Ra, ^{232}Th, and ^{40}K. Activity concentrations were derived from prominent photopeaks observed at 1,764 keV for ^{226}Ra, 2,614 keV for ^{232}Th, and 1,460 keV for ^{40}K

Radionuclide Concentration and Radiological parameters

Radionuclide concentration *C* in Bkg^{-1} is given by equation 1 [11]

$$C(Bgkg^{-1}) = \frac{N}{I_\gamma \varepsilon MT} \quad (1)$$

Where *N*represents the net peak area (in counts per second),$I\gamma$ is the absolute gamma emission probability (intensity) corresponding to the specific gamma-ray energy of interest, $\mathcal{E}$ denotes the absolute photo peak detection efficiency at that energy, T is the live counting time (in seconds), and *M* is the mass of the sample (in kilograms).

Absorbed Dose Rate

The absorbed dose rate in air at a height of 1 meter above the ground surface was computed in accordance with the methodology recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000). This parameter serves as an indicator of external radiation exposure to the human body, providing a basis for assessing potential radiological health risks associated with the activity concentrations of ^226Ra, ^232Th, and ^40K in soil. The absorbed dose rate (*AR*), expressed in nanograys per hour (nGy·h⁻ ¹), was determined using Equation 2 [11].

$$AR\ (nGyh^{-1}) = 0.462A_{Ra}+0.604A_{Th}+0.0417A_k \quad (2)$$

Annual Effective Dose (AED)

The annual effective dose in unit of µSvy^{-1} was obtained by converting the total absorbed dose in nGyh^{-1} and multiplies by occupancy factor OF, of one year expressed in seconds, using equation 3[11]:

$$AED = AR\ \times OF\ \times CF \quad (3)$$

Where; *AED* is the annual effective dose, *CF* is the conversion factor for absorbed dose in air to external effective dose in adults and is given as 0.7 Sv/Gy, *AR* is the calculated absorbed dose rate at 1m above the ground and OF is the occupancy factor, which is given as 0.2 (assuming that individuals spend 20% of their time outdoors) × number of hours per annum. Thus, *OF* becomes:

$$OF = 0.2\ \times 24\ \times 365 days\ \approx 17650\ hy^{-1} \quad (4)$$

Radium Equivalent Activity (Ra_{eq})

The radium equivalent activity (Ra_eq) is computed under the assumption that activity concentrations of 370 Bq·kg⁻ ¹ for ^226Ra, 259 Bq·kg⁻ ¹ for ^232Th, and 4810 Bq·kg⁻ ¹ for ^40K yield an equivalent gamma dose rate. This parameter provides a single index to represent the combined radiological effect of these radionuclides. The radium equivalent activity is calculated using the following expression, presented as Equation 5 [12].

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_k \quad (5)$$

Where, A_{Ra} is the activity concentration of ^{226}Ra in Bqkg^{-1}, $A_{Th}$is the activity concentration of ^{232}Th in Bqkg^{-1} and A_K is the activity concentration of ^{40}K in Bqkg^{-1}.

Internal Radiation Hazard Index (H_{in})

The internal radiation hazard index (H_{in}**)** is employed to account for the radiological risks associated with the inhalation of radon (^222Rn) and its short-lived progeny. It specifically aims to limit the permissible concentration of ^226Ra to levels that ensure internal exposures remain within safe bounds—approximately half the values considered acceptable for external exposure alone. The internal hazard index is computed using the expression provided in Equation [6] [13]

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \quad (6)$$

where; A_{Ra}, A_{Th} and A_K are the specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively.

External Radiation Hazard Index (H_{ex})

The estimation of the external hazard index (Hex) is a crucial parameter in assessing the radiological suitability of materials used in the construction of dwellings. The external hazard index, which pertains to gamma radiation, is calculated using Equation 7 [14].

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \leq 1 \quad (7)$$

Where; A_{Ra}, A_{Th} and A_K are the specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively.

Representative Gamma Index

The gamma index is used to estimate the level of gamma radiation hazard associated with the natural radionuclides in the specific samples under investigation. The expression proposed by [15] is given as follows:

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \quad (8)$$

Where; A_{Ra}, A_{Th} and A_K are as defined previously above.

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Excess Life Time Cancer Risk (ELCR)

The ELCR is a prediction of the probability of cancer development by individual over a lifetime due to exposure to low-level radiation [16]. It is estimated using equation 9:

$$ELCR = AED \times DL \times RF \times 10^{-3} \quad (9)$$

where *AED* is the annual effective dose, DL is average lifetime duration assumed to be 70 years [14] and RF represents fatal cancer risk factor per Sievert taken to be 0.05 Sv^{-1} as contained in ICRP-103 publication [16,17]

Data Analysis

The results obtained from the gamma spectrometric analysis were statistically analyzed, and the activity concentrations of the radionuclides were compared with global averages provided by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000) and other relevant literature. Radiological parameters were evaluated and compared with international safety limits to assess potential health risks to workers and the general public. Descriptive statistics, including the mean and standard deviations, were computed using SPSS software for data analysis.

III.RESULTS AND DISCUSSION

Table 1 presents the activity concentrations of radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in the collected soil samples, along with the corresponding geographical locations. These data provide insight into the spatial distribution of natural radioactivity across the study area. The Code KAS representsGwong Cooperative Rice Farm Kaduna.

Table 1: Activity Concentration of ^{226}Ra (BqKg^{-1}) ^{232}Th (BqKg^{-1}) ^{40}K (BqKg^{-1}) Radionuclides in soil samples from Gwong Cooperative Rice Farm Kaduna.

Sample Code	Coordinates	^{226}Ra (Bq kg^{-1})	^{232}Th (Bq kg-1)	^{40}K (Bq kg-1)
KAS1	09°24.196"; 008°09.147"	351.45 ± 8.16	135.47± 7.17	887.86 ± 46.96
KAS2	09°24.204"; 008°09.136"	380.16 ± 19.65	144.46 ± 7.69	943.50 ± 49.90
KAS3	09°24.208"; 008°09.123"	338.30 ± 17.49	103.52 ± 5.49	612.13 ± 32.38
KAS4	09°24.210"; 008°09.109"	318.22 ± 16.45	151.50 ± 8.03	482.01 ± 25.50
KAS5	09°24.194";008°09.105"	336.21 ± 17.38	146.81 ± 7.78	883.36 ± 46.72
KAS6	09°24.185"; 008°09.100"	314.23 ± 16.25	142.86 ± 7.55	820.37 ± 43.39
KAS7	09°24.176"; 008°09.090"	331.68 ± 17.14	146.01 ± 7.68	922.76 ± 48.81
KAS8	09°24.166"; 008°09.099"	350.50 ± 18.11	140.04 ± 7.42	940.40 ± 49.74
KAS9	09°24.153"; 008°09.114"	334.85 ±12.16	137.58 ± 7.24	930.77 ± 49.23
KAS10	09°24.144"; 008°09.130"	315.33 ± 16.30	139.37 ± 7.33	886.11 ± 46.87
KAS11	09°24.163"; 008°09.136"	367.93 ± 19.01	142.43 ± 7.55	945.15 ± 49.99
KAS12	09°24.178"; 008°09.141"	388.81 ± 20.09	141.55 ± 7.50	933.96 ± 49.40
KAS13	09°24.189"; 008°09.144"	348.43 ± 18.00	148.36 ± 7.85	947.13 ± 50.09
KAS14	09°24.192"; 008°09.133"	390.18 ± 20.16	155.63 ± 8.65	952.28 ± 50.37
KAS15	09°24.181"; 008°09.126"	379.74 ± 19.62	148.49 ± 7.79	956.56 ± 50.59
KAS16	09°24.169"; 008°09.117"	338.13 ± 17.48	145.08 ± 7.69	919.47 ± 48.63
KAS17	09°24.178"; 008°09.104"	359.56 ± 18.58	144.04 ± 7.59	917.49 ± 48.53
KAS18	09°24.188"; 008°09.110"	375.07 ± 19.38	150.63 ± 7.95	936.04 ± 49.51
KAS19	09°24.197"; 008°09.115"	368.76 ± 19.06	142.38 ± 7.54	921.12 ± 48.72
KAS20	09°24.187"; 008°09.120"	373.56 ± 19.30	143.43 ± 7.56	957.33 ± 50.63
Minimum		**314.23±16.25**	**103.52±5.49**	**482.01±25.50**
Maximum		**390.18±20.16**	**155.63±8.65**	**957.33±50.63**
Mean ±SD		**353.02±17.74**	**142.48±7.55**	**887.79±46.80**

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples from KAS show significant variation, with the ranges for ^{226}Ra, ^{232}Th, and ^{40}K being 314.23 ± 16.25 to 390.18 ± 20.16 BqKg^{-1}, 103.52 ± 5.49 to 155.63 ± 8.65 BqKg^{-1}, and 482.01 ± 25.50 to 957.33 ± 50.63 Bq/kg, respectively. The mean activity concentrations are 353.02 ± 17.74 BqKg^{-1} for ^{226}Ra, 142.48 ± 7.55 BqKg^{-1} for ^{232}Th, and 887.79 ± 46.80 BqKg^{-1} for ^{40}K. When compared with global averages provided by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which are typically 35 BqKg^{-1} for ^{226}Ra, 40 BqKg^{-1} for ^{232}Th, and 400 BqKg^{-1} for ^{40}K, the activity concentration levels at KAS are considerably higher. Specifically, the mean values for ^{226}Ra, ^{232}Th, and ^{40}K are significantly elevated, being more than 10 times the global average for ^{226}Ra, over 3 times higher for ^{232}Th, and nearly 2.2 times higher for ^{40}K. The elevated levels of ^{226}Ra, ^{232}Th, and ^{40}K in the soil at KAS could be attributed to several factors. First, the geological composition of the area may naturally enrich the soil with these radionuclides; particularly the study area has igneous and metamorphic rock formations known to contain higher concentrations of natural radioactive materials. Additionally, the specific geographical location of the farm in KAS, with its unique soil characteristics, could contribute to the elevated levels. Kaduna is known to be a hub of mining and industrial activities [18]. This could also introduce or concentrate naturally occurring radioactive materials into the soil. Agricultural practices, such as the use of phosphate-based fertilizers, which often contain trace amounts of uranium and thorium, might further contribute to the radionuclide levels. Furthermore, natural processes like weathering and atmospheric deposition could also lead to the accumulation of these materials [18]. Thus, the higher concentrations of radionuclides in the soil could result from a combination of geological, agricultural, and environmental factors.

IV. RADIOLOGICAL PARAMETERS

Based on the activity concentrations analyzed, various radiological parameters have been calculated to assess the potential radiological risks associated with the soil samples. These parameters include the external hazard index (Hex), gamma index, and excess lifetime cancer risk (ELCR), which are essential for evaluating the safety of the environment in terms of radiation exposure. Table 2 summarizes these calculated radiological parameters for the soil samples from KAS

Table 4: Radiological Parameters in soil samples from Gwong cooperative rice farm, Kagoma, Kaduna state

Sample Code	Absorbed Dose ($nGyh^{-1}$)	AED (μSvy^{-1})	Ra_{eq} ($Bqkg^{-1}$)	H_{in}	H_{ex}	AGDE (μSvy^{1})	Iγr	ELCR ($x10^{-3}$)
KAS1	281.22	344.89	613.54	2.50	1.65	1931.03	4.28	1.21
KAS2	302.22	370.64	659.39	2.72	1.80	2074.79	4.60	1.30
KAS3	224.35	275.14	533.46	2.26	1.44	1670.27	3.71	1.96
KAS4	257.54	315.85	571.46	2.31	1.54	1767.92	3.96	1.12
KAS 5	280.84	344.42	614.17	2.50	1.66	1929.94	4.30	1.21
KAS6	265.67	325.82	581.69	2.33	1.57	1825.35	4.07	1.23
KAS7	279.91	343.28	611.52	2.45	1.65	1924.97	4.29	1.20
KAS8	285.72	350.41	623.17	2.54	1.69	1964.32	4.37	1.22
KAS9	281.29	344.97	602.56	2.43	1.62	1899.86	4.23	1.21
KAS10	266.81	327.22	582.86	2.34	1.57	1835.18	4.08	1.12
KAS11	295.42	362.30	644.38	2.64	1.74	2029.04	4.50	1.27
KAS12	304.07	372.91	483.14	2.73	1.79	2086.33	4.63	1.31
KAS13	290.08	355.75	633.51	2.53	1.70	1994.19	4.43	1.25
KAS14	313.97	385.05	686.06	2.80	1.85	2155.21	4.79	1.35
KAS15	304.00	372.83	665.71	2.72	1.80	2083.25	4.65	1.30
KAS16	282.19	364.08	616.39	2.48	1.66	1939.96	4.31	1.27
KAS17	291.38	357.35	636.19	2.59	1.72	2001.22	4.45	1.25
KAS18	303.28	371.94	662.55	2.69	1.78	2082.52	4.62	1.30
KAS 19	294.78	361.52	643.29	2.63	1.74	2063.02	4.49	1.27
KAS20	299.13	366.85	652.37	2.66	1.75	2054.44	4.56	1.28
Minimum	**224.35**	**275.14**	**483.14**	**2.26**	**1.44**	**1670.27**	**3.71**	**1.12**
Maximum	**313.97**	**385.05**	**686.06**	**2.80**	**1.85**	2086.33	**4.79**	**1.96**
Mean ±SD	**285.19±20.37**	**349.81±25.55**	**615.87±48.12**	**2.54±0.16**	**1.44±0.10**	**1965.64±122.59**	**4.3±0.27**	**1.28±0.17**

The Absorbed Dose in this study area ranged from 224.35$nGyh^{-1}$to 313.97$nGyh^{-1}$, with a mean value of 285.19 ± 20.37 $nGyh^{-1}$. This level of absorbed dose is significantly higher than the global average of 60$nGyh^{-1}$ from natural radiation, indicating that the study area experiences an elevated level of radiation. The Annual Effective Dose ranged from 275.14μSvy^{-1} to 385.05μSvy^{-1}, with a mean of 349.81 ± 25.55μSvy^{-1}. Although this is lower than the global average of around 2400 μSvy^{-1}, which includes all natural and artificial sources, it is still significant enough to pose health risks for individuals exposed over long periods. The mean value suggests that the exposure in this area is somewhat elevated compared to other regions. ForRadium Equivalent (Raeq), the values vary between 483.14 $Bqkg^{-1}$ and 686.06$Bqkg^{-1}$, with a mean of 615.87 ± 48.12$Bqkg^{-1}$. The recommended safe limit for Raeq is typically 370 $Bqkg^{-1}$, and the mean value of 615.87$Bqkg^{-1}$exceeds this limit, indicating that the radionuclide concentration in the soil poses a potential radiological hazard. The elevated Raeq levels suggest that individuals in this area may be exposed to more radiation than is considered safe for long-term habitation. TheInternal Hazard Index (Hin), which ranges from 2.26 to 2.80, with a mean of 2.54, also exceeds the internationally accepted safe limit of 1. This index measures the radiation hazard due to the inhalation or ingestion of radionuclides, and the elevated mean suggests that the internal radiation risk is concerning for individuals who consume food or water from the area or are frequently exposed to the soil. Similarly, the External Hazard Index (Hex) ranges from 1.44 to 1.85, with a mean of 1.44, which is slightly above the acceptable limit of **1**. This indicates that the external radiation exposure in the area may be higher than safe levels, and it is important to monitor and control exposure to mitigate risks. TheAnnual Gonadal Dose Equivalent ranges from 1670.27μSvy^{-1} to 2086.33μSvy^{-1}, with a mean of 1965.64μSvy^{-1}. This value is notably higher than the global average, which typically remains much lower. The gonadal dose equivalent is crucial because it assesses the risk of radiation exposure to reproductive organs, and prolonged exposure at these levels may pose significant risks to human health, particularly in terms of fertility. TheRepresentative Gamma Index (Iγ) ranges from 3.71 to 4.79, with a mean of 4.3, exceeding the safety limit of 1. The gamma index provides a measure of the potential gamma radiation hazard from the soil, and these values indicate a significantly elevated gamma radiation level that could have long-term health effects on individuals in the area. Finally, the Excess Lifetime Cancer Risk (ELCR) varies between 1.12 $x10^{-3}$ and 1.96 x 10^{-3}, with a mean of 1.28 x 10^{-3}. This is higher than the internationally recommended threshold of 1 x 10^{-3} for acceptable risk. The elevated ELCR suggests that individuals in the study area may have an increased risk of developing cancer over their lifetime due to prolonged exposure to the radiological hazards present in the environment.

IV CONCLUSION

The analysis of the activity concentrations of radionuclides in the soil samples from KAS has revealed that the levels of natural radiation in the area are significantly elevated when compared to global averages. The radiological parameters, including absorbed dose, annual effective dose, radium equivalent, internal and external hazard indices, and excess lifetime cancer risk, all indicate that the farm is exposed to higher-than-normal radiation levels. These findings suggest that prolonged exposure to these elevated radiation levels may pose a potential health risk, particularly in terms of increased cancer risk, fertility concerns, and general radiation-induced health effects for both farm workers and the surrounding community. It underscores the importance of addressing potential radiological hazards to protect workers, consumers, and the general population. Furthermore, this study calls for appropriate mitigation measures and policies that can reduce radiation exposure, ensuring a safe working environment for farm employees and preventing any potential health impacts from exposure to hazardous radiation levels.

CONTRIBUTION TO KNOWLEDGE

Theauthors of this work believe that this study has contributed to knowledge. First, it provides a detailed analysis of the radiological hazards associated with agricultural practices in Nigeria, an area that has received limited attention in previous research. This work fills an important gap by assessing the radioactivity levels in a large-scale rice farm, which is significant given the vital role rice farming plays in ensuring food security for the nation. Second, the study highlights the potential risks linked to high radionuclide concentrations in soils and their impact on human health, agriculture, and the environment. By establishing baseline data on radiation levels, the study provides critical information for the development of safety standards and regulations regarding radiation exposure in agricultural regions.For sectors such as agriculture, environmental protection, and public health in Nigeria, this study offers valuable insights into the need for continuous monitoring of soil radiation levels, particularly in areas with large-scale farming activities.

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