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Evaluation of Radiological Risks Due to Natural Radioactivity in Soils from Swampy Agricultural Farmlands in Kokona, Nigeria

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Abstract: In this study, the radioactivity concentration levels of ^{238}U, ^{232}Th, and ^{40}K in soils from swampy agricultural farmlands in Kokona, Nigeria were investigated. The systematic random sampling technique was used to collect ten soil samples. The samples were prepared and analyzed for activity concentration levels using a NaI(Tl) detector. The result shows that the activity concentration levels of ^{238}U, ^{232}Th, and ^{40}K ranged from 4.57±0.54 Bq/kg to 45.09±4.99 Bq/kg with mean value of 23.62±73 Bq/kg, 5.27±0.31 Bq/kg to 13.23±0.79 Bq/kg with mean value 8.80±0.52 Bq/kg, 386.618.80 ±20.17 Bq/kg to 1908.11±96.16 Bq/kg with mean value 875.51±45.04 Bq/kg respectively. The calculated value of gamma dose rate, estimated external hazard index, excess life cancer risk, and annual gonadal dose equivalent ranged from 31.413 nGy/h to 86.538 nGy/h with a mean value of 49.464 nGy/h, 0.166 to 0.441 with a mean value of 0.261, 0.039 mSv/y to 0.077 mSv/y with mean value of 0.061 mSv/y, 0.135 to 0.371 with a mean value of 0.212, and 231.605 µSv/y to 449.766 µSv/y with a mean value of 362.797 µSv/y, respectively. Radionuclide activity concentrations in the soil samples varied within the study area due to the differences in the geological structure or formation of the area. The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K estimated in this study are lower than the world average. The calculated AEDE is lower than the threshold dose limit of 1 mSv/y for the member of the public. Therefore, farming activities in the study area pose no significant radiological hazard to the populace
Keywords: Radiological Risks, Swampy Agricultural Farmlands.

1 Introduction

Radiation is all around us. It is part and parcel of human life and has two main sources viz: Natural sources and artificial sources. The Earth has been radioactive since its creation. Radioactive elements such as uranium, radium, and radon are present in soil, air, and water [1, 2]. The naturally occurring radionuclides present in soil include ^{226}Ra, ^{232}Th, and ^{40}K. Knowledge of the distribution of these radionuclides in soil and rock is of great importance for radiation protection and measurements [3-7]. It was found that exposure to some radiation resulting from certain nuclides such as ^{40}K is fairly constant and uniform for all individuals everywhere; other exposures vary widely depending on location; for instance, cosmic rays are more intense at higher altitudes. Besides, concentrations of ^{238}U and ^{232}Th in soils have higher values in localized areas [1, 3]. Soils and rocks contribute to environmental radioactivity in two ways. First, the external dose is received by direct exposure to gamma radiation (whole-body dose) and in some cases by beta radiation (skin dose). Secondly, an internal dose is received by inhalation of the radioactive daughters of radon (a noble gas), which is released from the soil. Radon gas contributes more than half of the background radiation in regions having very high natural radionuclide concentrations, such as uranium and thorium [8-12].

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The radionuclides discharged into the earth from atomic structures – Independent of typical activity or mishap, may lead to potential radiation exposure of the adjacent biota and people. Because of the dry and wet discharge of soil and vegetation, radioactive substances discharged and flow into the atmosphere, enter the earth's environment, bringing about contact with people or biota or both; thus, investigation on radionuclides in farming zones is of general concern, the soil situations for farm produce will to a great extent decide the nature of the foodstuff delivered [13-14]. A fundamental feature of soil is its capacity to keep up and store radioactive isotopes over a drawn-out period. These isotopes can be brought into the earth through different outer sources. The food people eat changes starting with one place, then on to the next, starting with one individual, and then onto the next. Averagely happening radio-nuclides enter the food chain generally from the earth. In this manner, changes in soil radio-nuclides are the significant wellspring of geographic inconstancy [15-16].

Thus, it is important to know the radioactivity concentration level in soil. This work centered on some agricultural soils around farmlands where food crops are cultivated. These crops followed the food chain by deriving their nutrients from the plants, the plants derive their nutrients from the soil and the soil may probably contain highly radioactivity-concentrated substances as the case may be. This study aimed to evaluate the activity concentration levels in swampy agricultural farmlands in Kokona, Nasarawa State, Nigeria.

2 Materials and Methods

Study Area

Nasarawa State is predominantly rural with an economy centered on arable agriculture for the production of cash crops such as yams, sesame seeds, and soya beans, and to a lesser extent, small-scale mining. The study was conducted in rural villages surrounding the administrative center of Kokona, which is a local government area in Nasarawa State. The geology of Nasarawa State consists of Basement Complex and Sedimentary rocks. Kokona LGA is underlain by Basement Complex rocks composed of granites and gneiss. Figure 1 shows the map of the study area.

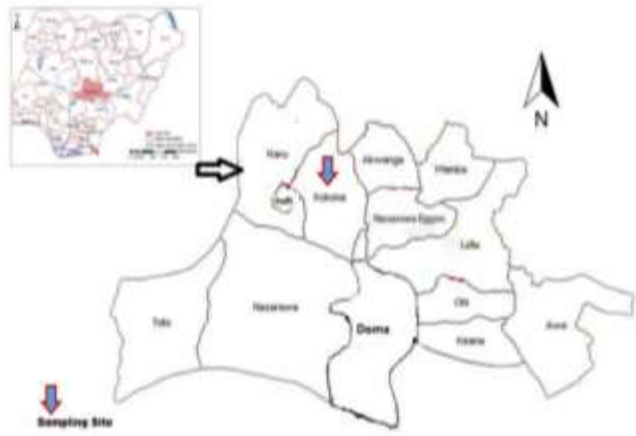

Fig. 1: Study Area.

Sampling Technique

The Sampling technique that was used for sample collection is systematic random sampling. This is a probability sampling method in which sample members from a larger population are selected according to a random starting point but with a fixed, periodic interval. This interval called the sampling interval, is obtained by dividing the population size by the desired sample size. This study was carried out in the year July 2023.

Method of Sample Collection

Ten soil samples were collected from some selected swampy agricultural farmlands in Kokona, Nasarawa state, Nigeria. The collected samples each were approximately 4 kg in wet mass and were immediately transferred into a high-density polyethylene zip-lock plastic bag to prevent cross-contamination. Each sample was marked with a unique identification number (sample ID) for traceability and its position coordinates were recorded for reference purposes using GPS.

Method of Sample Preparation

A total of ten soil samples were collected from the study area. All samples were dried for 4 to 6 days to ensure that moisture was completely removed. All samples were crushed, homogenized, and passed through a 200 µm sieve, which was the optimum size suitable for the analysis. Samples were placed in polyethylene beakers of 250 cm^3 volume each and weighed. The beakers were completely sealed for 4 weeks to attain secular equilibrium of radium, thorium, and their progenies.

Method of Data Analysis

The activity concentration levels of soil samples were obtained using a NaI(Tl) detector at the Centre for

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Radiation Protection and Training. Evaluation of radiological hazards depending upon the activity concentration of primordial radioactive elements, various radiological hazards delivered to the surrounding living biota are calculated based on the following hazard parameters;

Table1: Measured Elevation and exposure of soil from swampy agricultural Farmland in Kokona, Nasarawa State.

S/n	Sample Code	Longitude	Latitude	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)	Elevation (cm)
1	S1	8°49’56.20’’N	7°58’45.68’’E	9.82±1.22	5.27±0.31	608.92±31.68	268
2	S2	8°48’55.56’’N	7°55’27.71’’E	BDL	13.23±0.79	798.00±41.60	296
3	S3	8°48’25.36’’N	7°59’34.18’’E	23.47±2.79	8±0.48	520.84±27.10	288
4	S4	8°47’43.26’’N	8°00’04.71’’E	27.47±3.26	7.13±0.42	386.61±20.17	317
5	S5	8°41’50.18’’N	8°00’34.69’’E	4.57±0.45	8.57±0.49	578.45±29.24	311
6	S6	8°46’10.77’’N	8°00’49.22’’E	BDL	6.82±0.41	1148.46±58.95	331
7	S7	8°44’56.90’’N	8°00’29.86’’E	45.09±4.99	6.71±0.40	899.33±46.69	304
8	S8	8°42’37.53’’N	8°00’26.69’’E	21.85±2.60	11.63±0.69	971.17±50.30	272
9	S9	8°39’57.26’’N	7°59’44.29’’E	BDL	11.54±0.67	1908.11±96.16	283
10	S10	8°39’28.43’’N	7°59’16.68’’E	33.34±3.80	9.12±0.55	935.25±48.50	288
	Mean			**23.62±73**	**8.80±0.52**	**875.51±45.04**	

i. **Absorbed Dose Rate (D):** The total absorbed dose rate (D) in nGy/h is calculated using the following formula [17-18]:

$$D\ (nGy/h) = 0.462\ A_U + 0.604\ A_{Th} + 0.0417\ A_K \quad (1)$$

where, A_U, $A_{Th,}$ and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in $Bqkg^{-1}$ [2].

ii. **External Hazard Indices (H_{ex}):** The gamma-ray radiation hazards due to the specified indices using the relationship given by [19-20];

$$HI_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (2)$$

where, A_U, $A_{Th,}$ and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in Bq kg^{-1}. The recommended value by the UNSCEAR (2000) report for the hazard indices is less than unity.

iii. **Annual Effective Dose Equivalent (AEDE):** The annual effective dose equivalent (AEDE) in outdoor air is determined as [21-22]:

$$AEDE\ (mSv/y) = D\ (nGy/h) \times 8760\ h \times 0.2 \times 0.7\ Sv/Gy \times 10^{-6} \quad (3)$$

where 8760 is the time in hours for one year, and 10^{-6} is the factor converting from nano to milli [3].

iv. **Annual Gonadal Dose Equivalent (AGDE):** Annual gonadal dose equivalent (AGDE) due to the specific activities of ^{238}U, ^{232}Th, and ^{40}K is calculated using the formula given as:

$$AGDE\ (\mu Sv/y) = 3.09\ A_U + 4.18 A_{Th} + 0.314\ A_K \quad (4)$$

3 Result and Discussion

The data of activity concentration for ^{238}U, ^{232}Th, and ^{40}K of soil in swampy agricultural farmland in Kokona Nasarawa State are presented in Table 1. A Sodium Iodide doped Thallium (NaI(Tl)) detector was used to determine the activity concentration levels of the soil sample collected. The measured exposure rate and their point and elevation for the soil sample are shown in Table 1. The activity concentration levels of ^{338}U, ^{232}Th, and ^{40}K in the soil sample collected from the study area are presented in Table 1, and the calculated radiological hazard parameters (Gamma dose rate, External hazard indices, Annual gonadal dose rate, and Excess life cancer risk) are presented in Tables 2.

Table 1 presents the activity concentration levels of ^{338}U, ^{232}Th, and ^{40}K in the soil samples collected from the study area. The activity of ^{238}U, ^{232}Th and ^{40}K ranged from 4.57±0.54 Bq/kg to 45.09±4.99 Bq/kg with mean value of 23.62±73Bq/kg, 5.27±0.31Bq/kg to 13.23±0.79 Bq/kg with mean value 8.80±0.52 Bq/kg, 386.618.80 ±20.17Bq/kg to 1908.11±96.16 Bq/kg with mean value 875.51±45.04

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Bq/kg respectively. The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in the soil samples from the study area are compared with results published with the World average and are presented in Table 2.

Table 2: Comparison of the results of the present study with similar published data

Reference	Country	^{238}U	^{232}Th	^{40}K
Present study	Nigeria (Nasarawa State)	23.6	8.8	875.5
UNSCEAR (2000)	World Average	35	30	420

The radiological hazard assessment has been carried out by evaluating the Gamma dose rate, External hazard indices, Annual effective dose rate, Annual gonadal dose rate, and Excess life cancer risk for the soil samples are presented in Table 3.

Table 3: Calculated Radiological Hazard Parameter.

Sample Code	D(nGy/h)	HI(ex)	AEDE(mSv/y)	ELCR	AGDE (µSv/y)
S1	33.112	0.173	0.041	0.142	243.573
S2	41.268	0.217	0.051	0.177	305.873
S3	37.394	0.203	0.046	0.161	269.506
S4	33.119	0.182	0.041	0.142	236.081
S5	31.413	0.166	0.039	0.135	231.605
S6	52.01	0.265	0.064	0.223	389.124
S7	62.386	0.334	0.077	0.268	449.766
S8	57.492	0.305	0.071	0.247	420.243
S9	86.538	0.441	0.106	0.371	647.384
S10	59.911	0.319	0.073	0.257	434.81
Mean	**49.464**	**0.261**	**0.061**	**0.212**	**362.797**

From Table 3, calculated value of gamma dose rate, estimated external hazard index, excess life cancer risk, and annual gonadal dose equivalent ranged from 31.413 nGy/h to 86.538 nGy/h with a mean value of 49.464 nGy/h, 0.166 to 0.441 with mean value of 0.261, 0.039 mSv/y to 0.077 mSv/y with mean value of 0.061 mSv/y, 0.135 to 0.371 with a mean value of 0.212, and 231.605 µSv/y to 449.766 µSv/y with a mean value of 362.797 µSv/y, respectively.

Radionuclide activity concentrations in the soil samples varied within the study area due to the differences in the geological structure or formation of the area. The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K estimated in this study are lower than the world average (UNSCEAR, 2000). The mean absorbed dose rate from terrestrial gamma rays calculated is 49.464 nGy/h. This is much lower than the worldwide average of 59 nGy/h (UNSCEAR, 2000). The calculated mean value of external hazard indices is 0.261 mSv/y. This value is lower than unity, posing no significant radiological threat to the population in the area. The mean AEDE value is 0.061 mSv/y. This value is below the worldwide average of 0.48 mSv. The International Commission on Radiation Protection (ICRP) recommends the AEDE limit of 1 mSv/y for individual members of the public and 20 mSv/y for radiation workers. In South Africa, the dose constraint applicable to the average member of a critical group from a single source within the exposed population is 0.25 mSv per annum. This means that the AEDE average values from Kokona were considered safe to the population.

4 Conclusions

The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in soil from swampy agricultural farmland in Kokona, Nasarawa State have been studied using NaI (Tl) gamma-ray spectrometry. The results obtained showed that the non-uniform distribution of natural radionuclides in the soil samples and artificial radionuclides was not detected in any sample measured. The mean activity concentrations of ^{238}U and ^{232}Th in the soil samples from the study area were estimated and were found to be lower than the world average, while the concentration of ^{40}K is higher than the world average. The results of this study area show that there are lower levels of uranium and thorium in the areas than the worldwide average while potassium is higher than the worldwide average. Therefore, farming activities in the study area pose no significant radiological hazard to the populace.

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