FUDMA Journal of Engineering and Technology

ISSN: 3092-9385

https://sites.google.com/fudutsinma.edu.ng/fjet

Volume 1, Issue 2, 2025, 491-500

Impact Assessment of Natural Radionuclides in Cassava Tubbers Harvested from a Farmlands Around Quarry in Moniya Ibadan, Nigeria

Emmanuel O. AGBENYI[1], Adefope OWOJORI[2], Oluwadare J. AKINDUGBAGBE[3], Babatunde ADEBO[4], Chigbo I. OKEREKE[5]

[1*]Department of Standard Secondary Dosimetry Laboratory, National Institute of Radiation Protection and Research, Ibadan, Oyo State, Nigeria

[2,3,4]Department of Physics, Lead City University, Ibadan, Oyo State, Nigeria

[5]Department of Science Laboratory, Federal College of Animal Health and Production Technology, Ibadan, Nigeria

[1*]agbenyiodahemmanuel@gmail.com, [2]fope2010@gmail.com, [3]jakindugbagbe@gmail.com, [4]adebo.babatunde@lcu.edu.ng, [5]igwechigbo@gmail.com

Abstract

Quarry activities can be used to evaluate natural radionuclide concentrations in surrounding soil, which could pose risks to human health when cultivated crops within the quarry site are consumed. This study assessed the radiological impact on cultivated crops and soil on farm around quarry (FAQ) and farm far from quarry (FFQ), located near a quarry site in Moniya, Ibadan, Nigeria. A total of six soil samples and six cassava samples were randomly collected and analysed using a NaI(Tl) gamma-ray spectrometer. In the soil samples, (^{40}K) activity concentrations were 412.28 ± 68.85 Bq/kg (SFAQ, S, represent Soil in this context) and 275.15 ± 22.67 Bq/kg (SFFQ), (^{226}Ra) concentrations were 37.49 ± 10.51 Bq/kg and 53.16 ± 15.37 Bq/kg, while (^{232}Th) recorded 32.31 ± 8.26 Bq/kg and 47.44 ± 10.14 Bq/kg for SFAQ and SFFQ respectively. In cassava, ^{40}K concentration from 206.03 ± 108.89 Bq/kg (CFAQ, C, represent Cassava in context) and 356.89 ± 64.24 Bq/kg (CFFQ). ^{226}Ra range from 24.57 ± 25.13 Bq/kg (CFAQ) and 41.31 ± 13.14 Bq/kg (CFFQ), while ^{232}Th concentration were 10.51 ± 9.11 Bq/kg and 22.44 ± 9.59 Bq/kg respectively. Some ^{226}Ra and ^{232}Th concentrations exceeded global averages. The estimated annual effective dose from soil was 0.13 mSv/y in (SFAQ) and 0.16 mSv/y in (SFFQ), while that of cassava was 0.06 mSv/y. AED from cassava was 0.06 mSv/y in (CFAQ) and 0.12 mSv/y in (CFFQ). Radium equivalent activity (Raeq) values were below the 370 Bq/kg safety limit: 115 Bq/kg (SFAQ), 142 Bq/kg (SFFQ), 55 Bq/kg (CFAQ), and 101 Bq/kg (CFFQ). The estimated annual effective dose from the soil samples were above the UNSCEAR global average of 0.07 mSv/y. Although some radionuclide levels exceeded global benchmarks, the overall cancer risk associated with quarry activities in these farmlands appears low and poses no risk. However, the elevated dose values suggest the need for further investigation into potential long-term health implications for communities around the quarry site.

Keywords: *Radionuclide, activity concentrations, radiological risk assessment, environmental contamination, radioactivity.*

1.0 Introduction

Human beings are constantly exposed to radiations from naturally-occurring radionuclides such as (^{40}K, ^{235}U, ^{232}Th) and their respective progenies within the environment. Naturally-occurring radionuclides can be classified as either primordial (present from ancient times) or cosmogenic (produced by cosmic rays). These radiations could either be derived from primordial or cosmic sources. Within the last few decades, the inventory of radionuclides has increased due to more anthropogenic activities. (man-made action). Today, over 95% of the total radiation exposure in humans have been attributed to natural source origins, while the rest (about 5%) have been attributed to artificial origins (Tawfic *et al*., 2021). These artificial sources have led to more waste generations and disposals, hence, contribute significantly to the increased levels of human radiation exposures (Jibiri *et al*., 2.014)

Human radiation exposure could either be external or internal exposure due to the concentration of naturally occurring radioactive materials (NORMS) in the immediate environment. External exposure could result from gamma radiations from natural radionuclides like potassium (^{40}K), uranium (^{235}U), radium (^{226}Ra) and thorium (^{232}Th) and radiations (energetic alpha, beta, gamma, protons, neutron radiations) from cosmic sources. The gamma radiation from natural radionuclides primarily contribute to the external exposure on land or low altitudes while cosmic rays contribute to exposure within high-altitudes. Internal exposure is primarily derived from inhalation of airborne radiation contaminants, and from ingestion through radiation-contaminated food, drinking water or other ingested items (Ademola *et al*., 2014). Background Radiation is an integral part of the natural system since creation, human in the environment have been under permanent exposure to ionizing radiation from cosmic rays, terrestrial materials, and internal radioactive isotopes. While this exposure is mostly low and minor but not hazardous, it cumulative effects can influence long-term health effects on the living cells and tissues, which may lead to differing effects on radiosensitive organs of the body.

Received: 02/08/2025; Revised: 18/08/2025; Accepted: 31/08/2025; Published: 22/09/2025

Natural background radiation is responsible for radiation dose received by the general population worldwide. Soil is a major source of natural radioactivity that is responsible for the transfer of radionuclides that could pose hazard to the populace. These radionuclides at low concentration can have potential impacts on the environment, human health and may have a long-term health risk (Eke *et al.,* 2024) Soils and rocks are primary sources of terrestrial radiation though volcanic activities and rocks endowed with phosphate, granite and salt naturally contain NORM radionuclides (Jegede *et al.*, 2025).

The natural radioelements such as uranium, thorium and potassium are widely distributed in crustal rocks. Potassium is a major element insert' that is widely distributed in crustal rocks, for instance, calcium rich granites may contain up to 2.5% of potassium. Thorium occurs predominantly as a tetravalent cation and as a trace constituent in phosphates, simple and multiple oxides and silicates, as well in the major rock-forming minerals such as monazite, thorianite (ThO_2) and thorite ($ThSiO_4$) among others.

Uranium is found in rocks of different mineral species (like apatite, sphene and zircon) as a secondary/accessory mineral This distribution of Uranium in such rocks is associated with isomorphous mineral substitution, absorption or inclusion process ultimately determines the way it is integrated in trace quantities (Hazen et al., 2022) The natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on geological and geographical conditions and appear at different levels in soils of each region in the world (IAEA 2018). When rocks are disintegrated through natural process, radionuclides are carried to soil by rain. Soil serves as a direct source of radionuclides that could leads to contamination of all agricultural products (Osman 2024; Mlwilo *et al.*, 2007). The radioactivity of soils is determined by the radionuclides in the parent rock and the nature of processes involved in the formation of the soils. These radionuclides are embedded in different layers and are not uniformly distributed in soil (Tawfic *et al.,* 2021).

Rock quarrying and the crushing of stone is now an increasing global mining activity which have also posed environmental concerns to most economically vibrant countries. This is largely due to the contribution of quarry products in soil contamination, air pollution, and other harmful effects on natural ecosystem. This quarry activities often accumulates significant radionuclide material in the air and soil (Nieder *et al.*, 2018). Furthermore, quarrying operations are known to have impacted irreversibly on the ecosystems and its associated biome (Angela et al., 2016). The random distribution of radionuclides over large areas in a quarry soil often varies from soil to soil and when blasting and milling activities are carried out in a quarry site but ultimately radionuclides excavated from underground rocks seep into the soil and then absorbed by crops planted on farmlands. A significant amount of radionuclide material may seep from the soil to plants within the environment. This effect can spiral into the food chain through crops planted within the area. Crops planted around quarry site could take in deposited radionuclide from the soil, thus increases the radionuclide activities of the plants and its product. plants have the ability to absorb radionuclides from soil and transmit them to humans through edible plants, making it easy for them to accumulate in the food chain.

When ionizing radiation is accumulated in individual tissues, this action may cause changes in individual cells as a result of energy deposited (Jegede et al., 2025). Ionizing radiation has enough energy to remove tightly bond electrons from atoms thus creating a free radical. Free radicals may produce chemical toxins that may break DNA strands (Gebicki *et al.*, 2021). This process is the basic physical mechanism that gives rise to radiological detriment or harm. One widely grown crop, known to thrive well around quarry site is Cassava (Manihot esculenta) (Ihejirika et al., 2021)

Cassava is one of the essential tuber crops, serving as major staple crop in Nigeria. Cassava and its product are found in the daily meals of Nigerians. Currently, cassava is undergoing a transition from just a subsistent crop found on the field of peasant farmers to a commercial crop grown in plantations. Cassava is very widely cultivated and its derivatives such as starch are applicable in many types of products such as foods, confectionery, sweeteners, glues, plywood, textiles, paper, biodegradable products, monosodium glutamate, and drugs. Cassava chips and pellets are used in animal feed and alcohol production. Animal feed and starch production are only minor uses of the crop in Nigeria. Cassava, in its processed form, is a reliable and convenient source of food for tens of millions of rural and urban dwellers in Nigeria (Sengar *et al.*, 2022)

2.0 Methodology

2.1 Materials

Gps, Marinelli Beaker, Soil Samples, Cultivated Cassava Tuber Samples, Polythene bag, NaI(Tl) gamma Spectrometer Spring balance Shovel

2.2 Methods

2.2.1 Study area

This study was carried out at a farmland which is located behind the perimeter fence of Pacesetter Quarry and Asphalt plant. The quarry is situated at Km 25, Moniya-Iseyin Road, Ojedeji Village Moniya, Akinyele Local Government, Ibadan. The farm is located on Latitude 7°38'24.42" and Longitude 3°48'21.30"*E*. The quarry plant was established in 2004. The area is naturally endowed with varieties of mineral deposits; tantalite, sand and gravel. The stones which are granite may contain a relatively high concentration of natural radioactivity (Tawfic et al., 2021). This area is also known for its agricultural activities because the land is rich in mineral nutrients and is suitable for agricultural purposes. Farming is the major occupation of the inhabitants. The activities of quarry which includes blasting, milling and grinding might have enhanced the level of radionuclides in the soil of the farmland. Among the crops planted are cassava, yams, tomatoes and maize, e.t.c.

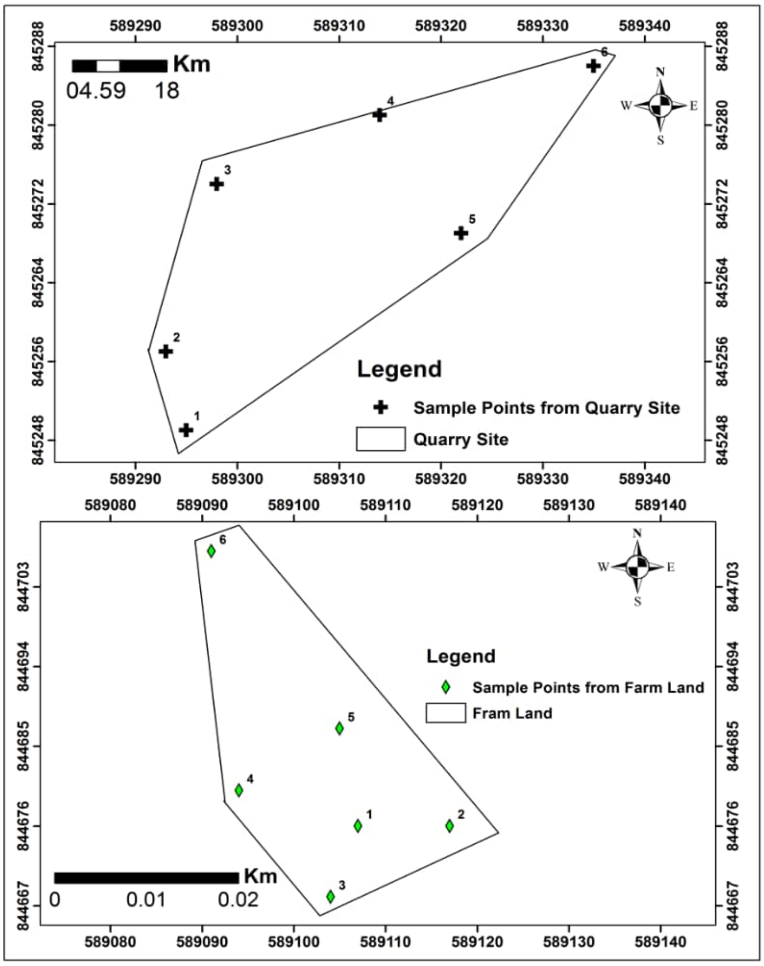

Figure 1: Map of the study area

2.2.2 Samples Collection and Preparation

Soil and cassava samples were collected randomly from the farmland 40m close to quarry site and 200m far from the quarry site. The soil samples were collected to a depth of about 0.1m (10cm). The samples were sealed in polythene bags. In the laboratory, a total of twenty-four samples were prepared, which consist of six soil and six cassava samples from farmland around the quarry site (SFAQ and CFAQ) and six soil and six cassava samples from farmland far from quarry site (SFFQ and CFFQ). The soil and cassava tuber samples were sundried, pulverized and weighted and sealed in Marinelli beaker and kept for 28 days for secular equilibrium.

The radionuclide analysis was carried out using a NaI(Tl) gamma spectrometer. Radium-226 activity was determined using the 1764.54 keV peak of its progeny (Bismuth-214). The activity of Th-232 was estimated using Tl-208 progeny (2614.5 keV) and the activity of K-40 was estimated using gamma ray energy of 1460.82 keV, The Activity of a radionuclide are reported in units of Becquerel per kilogram (Bq/kg) or Becquerel per litre (Bq/l) (IAEA 2019)

The activity concentrations of the samples were estimated based on the relative efficiency approach using the background count, standard count and the measurement count,

$$A = \frac{N}{\varepsilon . Y . m . t} \quad (1)$$

where N is the net count (sample-background), ε is the efficiency of the detector, Y is gamma yield, *m* is mass in kg and t is time in seconds

3.0 Results and Discussion

The results obtained are shown in Tables 1., 2, 3 and 4 for samples collected for soil and cassava in farmland around quarry and farmland far from quarry respectively.

The activity concentration of K-40 in soil samples from farmland around the quarry ranged between 360.36 ± 19.90 – 501.52 ± 27.18 Bq/kg with mean values of 412.28 ± 68.85Bq/kg.

Ra - 226 ranged between 21.93 ± 5.25 - 54.45 ± 10.80 Bq/kg with mean values of 37.49 ± 10.51 Bq/kg. Th -232 ranged between 15.76 ± 1.62 – 40.45 ± 3.59 Bq/kg with mean values of 32.31 ± 8.26 Bq/kg. In the sample collected from farmland far from the quarry, the activity concentration of K-40 in soil ranged between 241.58 ±14.97 – 309.82 ± 18.37 Bq/kg with mean values of 275.15 ± 22.67 Bq/kg, Ra - 226 ranged between 35.50 ±8.26 - 80.01 ± 13.89 Bq/kg with mean values of 53.16 ± 15.37Bq/kg. Th -232 ranged between 26.95 ± 2.52 – 56.35 ± 4.53 Bq/kg. with mean values of 47.44 ± 10.14 Bq/kg.

The activity concentration of K-40 in cassava samples from farmland around the quarry ranged from 63.34 ± 4.90 - 365.35 ± 21.18 Bq/kg with mean values of 206.03 ±108.89 Bq/kg, respectively. Ra - 226 ranged between BDL - 64.85 ± 14.75 Bq/kg with mean values of 24.57 ± 25.13 Bq/kg and 24.57 ± 25.13Bq/kg, respectively.

Th -232 ranged between 2.27 ± 0.17 - 28.72 ± 2.52 Bq/kg with mean value of 10.51 ± 9.11 Bq/kg. In the cassava sample collected from farmland far from the quarry, the activity concentration of K-40 in cassava ranged between 269.47 ± 16.99 - 479.11 ± 26.39 Bq/kg with mean values of 356.89 ± 64.24 Bq/kg. Ra -226 ranged between BDL - 57.80 ± 12.79 Bq/kg with mean values of 41.31 ± 13.14 Bq/kg and Th-232 ranged between BDL - 30.34 ± 2.55 Bq/kg with mean values of 22.44 ±9.59 Bq/kg.

Table 1: Activity concentration of natural radionuclides in soil of farm around quarry (SFAQ)

	Sample Name	K- 40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
	1	465.08 ± 25.81	54.45 ± 10.80	40.45 ± 3.59
	2	360.36 ± 19.90	21.93 ± 5.25	33.77 ± 2.74
	3	501.52 ± 27.18	35.48 ± 7.14	38.52 ± 3.14
	4	376.49 ± 20.89	46.99 ± 8.31	15.76 ± 1.62
	5	463.32 ± 25.79	33.10 ± 7.42	36.42 ± 3.17
	6	306.88 ± 17.72	32.99 ± 6.93	28.92 ± 2.49
Range		306.88- 501.52	21.93 - 54.45	15.76 - 40.45
Mean ±Std. Dev		412.28 ± 68.85	37.49 ± 10.51	32.31 ± 8.26

Table 2: Activity concentration of natural radionuclides in soil of farm far from quarry (SFFQ)

	Sample Name	K- 40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
	1	298.03 ± 17.38	62.66 ± 12.06	56.35 ± 4.53
	2	267.58 ± 16.29	55.16 ± 10.53	55.12 ± 4.48
	3	271.43 ± 16.82	35.50 ± 8.26	26.95 ± 2.52
	4	241.58 ± 14.97	36.68 ± 8.25	43.48 ± 3.67
	5	262.45 ± 15.74	48.93 ± 10.62	48.82 ± 3.94
	6	309.82 ± 18.37	80.01 ± 13.89	53.89 ± 4.32
Range		241.58 - 309.82	35.50 - 80.01	26.95 - 56.35
Mean±Std. Dev.		275.15 ± 22.67	53.16 ± 15.37	47.44 ± 10.14

Table 3: Activity concentration of natural radionuclides in cassava of farmland around quarry (CFAQ)

	Sample Name	K- 40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
	1	92.47 ± 5.36	BDL	14.30 ± 1.24
	2	179.26 ± 10.13	BDL	2.44 ± 0.21
	3	63.34 ± 4.90	26.59 ± 5.92	6.40 ± 0.46

4	313.34 ± 25.27	1.88 ± 0.42	8.94 ± 0.80
5	222.39 ± 14.88	64.85 ± 14.75	2.27 ± 0.17
6	365.35 ± 21.18	4.96 ± 1.10	28.72 ± 2.52
Range	63.34 - 365.35	BDL - 64.85	2.27 - 28.72
Mean & STD	206.03 ± 108.89	24.57 ± 25.13	10.51 ± 9.11

BDL: Below detectable limits

Table 4: Activity concentration of natural radionuclides in cassava of farmland far from quarry (CFFQ)

Sample Name	K- 40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
1	479.11 ± 26.39	BDL	BDL
2	373.82 ± 20.72	BDL	BDL
3	324.72 ± 20.87	48.56 ± 11.34	8.94 ± 0.80
4	365.35 ± 22.93	22.97 ± 5.44	30.34 ± 2.55
5	328.84 ±18.46	35.89 ± 6.69	BDL
6	269.47 ± 16.99	57.80 ± 12.79	28.04 ± 2.42
Range	269.47- 479.11	BDL - 57.80	BDL - 30.34
Mean ± Std. Dev.	356.89 ± 64.24	41.31 ± 13.14	22.44 ± 9.59

BDL: Below detectable limits

Table 5: Comparison of Activities concentration of natural radionuclides in Soil and Cassava with the world Standard limits

Sample Tag		Radioactivity		
		^{40K} (Bq/kg)	^{226Ra} (Bq/kg)	^{232Th} (Bq/kg)
SFAQ	Min	360.36 ± 19.90	21.93 ± 5.25	15.76 ± 1.62
	Max	501.52 ± 27.18	54.45 ± 10.80	40.45 ± 3.59
	Mean(±SD)	412.28 ± 68.85	37.49 ± 10.51	32.31 ± 8.26
SFFQ	Min	241.58 ± 14.97	35.50 ± 8.26	26.95 ± 2.52
	Max	309.82 ± 18.37	80.01 ± 13.89	56.35 ± 4.53
	Mean(±SD)	275.15 ± 22.67	53.16 ± 15.37	47.44 ± 10.14
CFAQ	Min	63.34 ± 4.90	BDL	2.27 ± 0.17
	Max	365.35 ± 21.18	64.85 ± 14.75	28.72 ± 2.52
	Mean(±SD)	206.03 ± 108.89	24.57 ± 25.13	10.51 ± 9.11
CFFQ	Min	269.47 ± 16.99	BDL	BDL
	Max	479.11 ± 26.39	57.80 ± 12.79	30.34 ± 2.55
	Mean(±SD)	356.89 ± 64.24	41.31 ± 13.14	22.44 ± 9.59
World Average values		420	33	45

BDL: Below detectable limits

Received: 02/08/2025; Revised: 18/08/2025; Accepted: 31/08/2025; Published: 22/09/2025

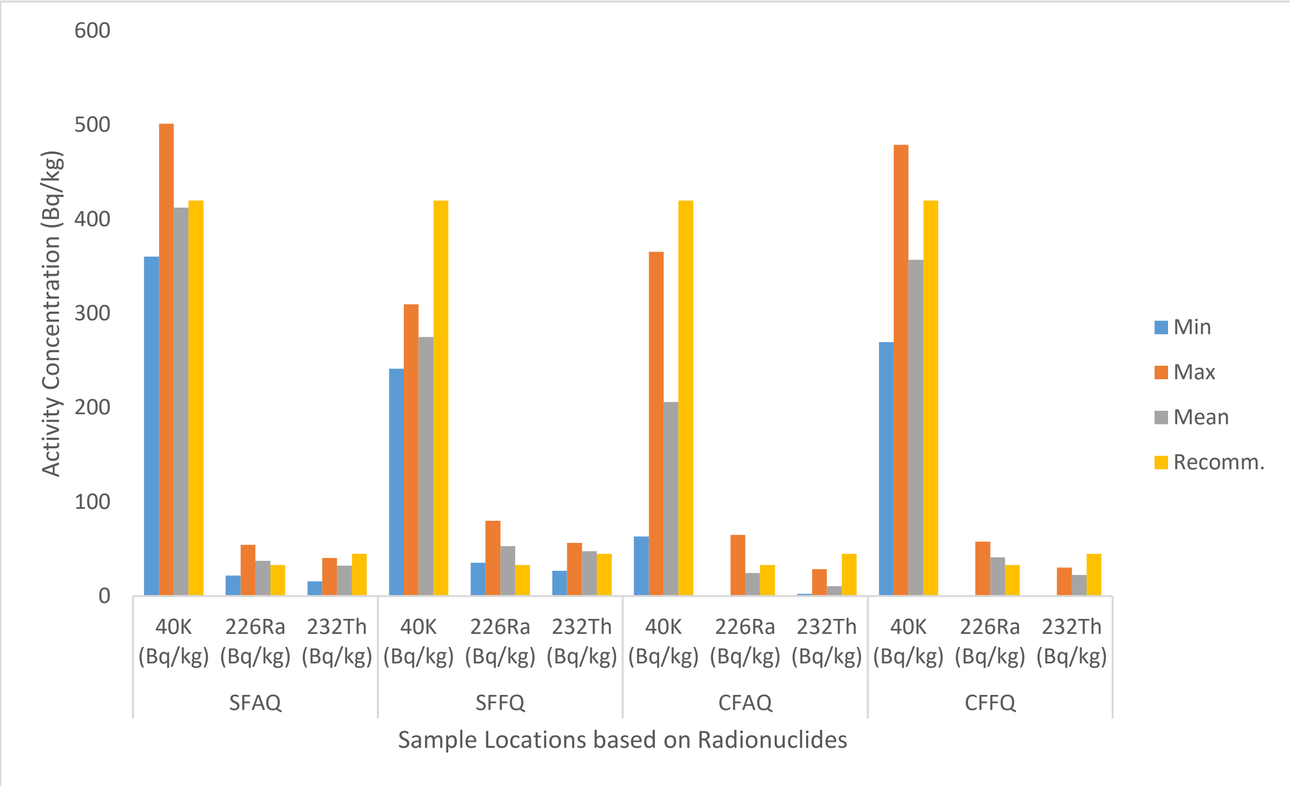

Figure 2: Graphical representation of comparison of activity concentration of natural radionuclides in soil and cassava with the world average values

3.1 Absorbed Dose and Effective dose

The absorbed dose rate in air resulting from the activity concentration of the three radionuclides in the samples was calculated using,

$$D_{OUT}\ (nGyh^{1}\ ) = aA_U + bA_{Th} + cA_K \quad (2.0)$$

where A_U, A_{Th} and A_K are the activity concentrations of U-238, Th-232 and K-40 in Bq/kg, respectively. The values of a, b and c are dose conversion factors for U-238, Th-232 and K-40 are given as 0.462, 0.604 and 0.0417 (nGy /h per Bq/kg), respectively

The gamma absorbed dose rate and annual effective dose is presented in Table 6 and 7. The mean absorbed dose rate due to radionuclides in the samples was 54.02 nGy/h in (SFAQ) and this was lower than 64.68 nGy/h (SFFQ), which is about 18% higher than the world average of 55 nGy/h and for the mean samples of cassava was 26.29 nGy/h in (CFAQ) and 47.52 nGy/h for CFFQ. The annual effective dose result is presented in table 1.6 and 1.7. The range is between 0.056± 0.003 and 0.085 ±0.004 mSv, mean effective dose is 0.066± 0.010mSv for (FAQ) and (FFQ) range is 0.054 ± 0.004 - 0.101 ± 0.004 mSv, 0.079 ± 0.020 mSv. The annual Effective dose was calculated from the dose rate of the two farmlands using equation,

$$AED\ (mSv/y) = D(nGy/h) \times 8760 \times 0.200 \times 0.700\ (Sv/Gy) \times 10^{-6} \quad (3.0)$$

Where, AED is the annual effective dose and consideration is given to the conversion coefficient from absorbed dose in air to effective dose (0.700 Sv/Gy) and the outdoor occupancy factor of 0.200, as specified by UNSCEAR 2000 (Annex B) and ICRP 103 (2007). The AED value is below (ICRP, 2012) recommended for public dose limit of 1 mSv/year for public

Table 6: Absorbed dose rate (D_R) and the outdoor effective dose (A_d) of natural radionuclides from soil in farmland around quarry (SFAQ)

Sample Number	D (nGy/h)	A_d (mSv/y)
1	68.98 ± 15.46	0.085 ± 0.004
2	45.56 ± 5.52	0.056 ± 0.001
3	60.57 ± 13.55	0.074 ± 0.004
4	46.93 ± 9.95	0.058 ± 0.003
5	56.61 ± 13.97	0.069 ± 0.004
6	45.51 ± 10.66	0.056 ± 0.003

Received: 02/08/2025; Revised: 18/08/2025; Accepted: 31/08/2025; Published: 22/09/2025

Sample Number	D (nGy/h)	A_d (mSv/y)
Range	45.51 - 68.98	0.056 - 0.085
Mean ±Std.Dev	54.02 ± 8.83	0.066 ± 0.01

Table 7: Absorbed dose rate (D_R) and the effective dose (A_d) from soil in farmland far from quarry (SFFQ)

Sample no	D (nGy/h)	A_d (mSv/y)
1	75.41± 15.76	0.092 ± 0.004
2	69.93 ± 15.13	0.085 ± 0.004
3	44.00 ± 11.36	0.054± 0.004
4	53.28 ± 4.9	0.065 ± 0.001
5	63.04 ± 15.08	0.077 ± 0.000
6	82.43 ± 16.49	0.101 ± 0.004
Range	44.00 - 82.43	0.054 - 0.101
Mean± Std. Dev.	64.68 ±13.03	0.079 ± 0.016

Table 8: Comparison of absorbed dose and effective dose with the world standard limits

Sample Tags	**Stat.**	**D_R (nGyh^{-1})**	**AED (mSv/y)**
SFAQ	Min	34.6777	0.09
	Max	70.5011	0.17
	Mean(±SD)	54.0277	0.13
SFFQ	Min	42.7527	0.10
	Max	83.9195	0.21
	Mean(±SD)	64.6874	0.16
CFAQ	Min	4.0124	0.01
	Max	62.5427	0.15
	Mean(±SD)	26.2908	0.06
CFFQ	Min	11.2369	0.03
	Max	65.0078	0.16
	Mean(±SD)	47.5213	0.12
World average values		**55**	**1**

3.2 Committed Effective dose (EDi) due to ingestion of Radionuclides in cassava

$$EDi = \sum A_C A_i C_f \quad (4.0)$$

where EDi is the annual effective dose(mSv/y), Ai is the annual intake of cassava consumed (kg y $^{-1}$), A_c is the activity concentration of radionuclide (in Bq/kg), C_f, is the ingestion dose conversion factor for the radionuclides of interest, 2.80 x 10^{-7} Sv/Bq for Ra-226, 2.30 x 10^{-7} Sv/Bq for Th-232 and 6.20 x10^{-9} Sv/Bq for K-40. (IAEA 2011). There are no data available on the consumption rate of various food crops in Nigeria. The consumption rate per capital for the food samples considered in this work is taken from data available from Food and Agricultural Organization (FAO 2006).

the outdoor effective dose results are presented in table 9 and 10, the average effective dose of radionuclides in (CFAQ) ranged between 0.212 ± 0.005 mSv– 2.807 ± 0.541 mSv with mean value of 1.11 ± 0.98 mSv. In the sample collected from farmland far from the quarry, the effective dose ranged between 0.301 ± 0.017 mSv – 3.159 ± 0.476mSv with mean value of 1.63 ± 1.02 mSv. finding show the committed effective dose due to ingestion of radionuclide in cassava for both farmlands were higher than 1 mSv recommended for public (ICRP, 2012)

Table 9: Committed effective dose (EDi) due to ingestion for all the Radionuclides in cassava for the Farmland around quarry (CFAQ)

Sample Name	K- 40 (mSv)	Ra-226 (mSv)	Th-232 (mSv)	Effective Dose of radionuclides (mSv)
1	0.075±0.004	BDL	0.191 ± 0.014	0.266 ± 0.015
2	0.144±0.003	BDL	0.068 ± 0.0036	0.212 ± 0.005
3	0.051±0.004	0.968±0.22	0.859 ± 0.075	2.09 ± 0.232
4	0.253±0.020	0.068±0.015	0.428 ± 0.037	0.749 ± 0.047
5	0.179±0.012	2.361±0.54	0.267 ± 0.024	2.807 ± 0.541
6	0.294±0.017	0.181±0.040	0.073 ± 0.006	0.548 ± 0.096
Range	0.075–0.294	BDL–2.361	0.314 ± 0.027	0.212 – 2.807
Mean± STD	0.166±0.09	0.89 ± 0.91		1.11 ± 0.98

BDL: Below detectable limits

Table 10: Committed effective dose (EDi) due to ingestion for all the Radionuclides in (CFFQ)

Sample Name	K- 40 (mSv)	Ra-226 (mSv)	Th-232 (mSv)	effective Dose of of radionuclides (mSv)
1	0.386 ± 0.021	BDL	BDL	0.386 ± 0.021
2	0.301 ± 0.017	BDL	BDL	0.301 ± 0.017
3	0.262 ± 0.017	1.77 ± 0.41	0.267± 0.024	2.299 ± 0.411
4	0.294 ± 0.018	0.836 ± 0.20	0.907± 0.076	2.037 ± 0.215
5	0.265 ± 0.015	1.306 ± 0.24	BDL	1.571 ± 0.240
6	0.217 ± 0.014	2.104 ± 0.47	0.838± 0.073	3.159 ± 0.476
Range	0.217–0.386	BDL–2.104	BDL–0.907	0.301 – 3.159
Mean±Std.Dev	0.29 ± 0.017	1.00 ± 1.50	0.67 ± 0.29	1.63 ± 1.02

BDL: Below detectable limits

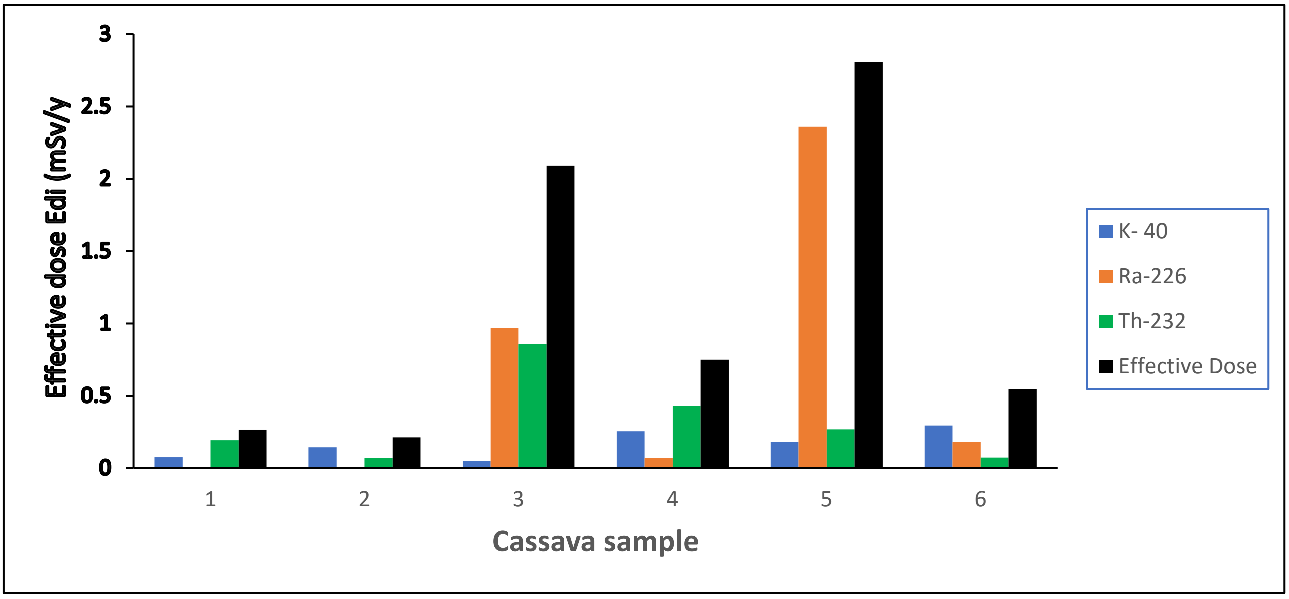

Figure 3. Graphical representation of committed effective dose (*Edi*)

3.3 Estimation of the annual gonadal equivalent dose (AGED)

The annual gonadal equivalent dose (AGED) equivalent due to specific activities of ^{226}Ra, ^{232}Th, and ^{40}K determined and the mean AGED for (SFAQ) samples was 0.38 mSv/yr, while for (SFFQ), it was 0.45 mSv/yr. Both values were above the UNSCEAR World average values of 0.3 mSv/yr. (UNSCEAR 2000) In the case of the cassava samples, the mean AGED values were 0.19 mSv/yr for the CFAQ samples while those from the CFFQ samples averaged 0.33 mSv/yr, indicating only the cassava samples from CFAQ had AGED below world average.

3.4 Estimation of the Excess lifetime cancer risk (ELCR)

(ELCR) is defined in this study as an estimation of the risk to a member of a population dying from cancer as a result of the intake of a radionuclide in food from the study area. The ELCR associated with the intake of food crops (Alausa 2020). The mean total ELCR values from soil exposure in this study was 1.16 x 10^{-3} with (SFAQ) an outdoor ELCR average value of 0.23 x 10^{-3} and indoor of 0.93 x 10^{-3}. while (SFFQ) estimates of total, indoor and outdoor ELCR values of 1.39 x 10^{-3}, 0.28 x 10^{-3} and 1.11 x 10^{-3} respectively. In the case of cassava around quarry site, this study estimates the total, indoor and outdoor ELCR values of 0.56 x 10^{-3}, 0.11 x 10^{-3} and 0.45 x 10^{-3} respectively. All values estimates were also below World averages indicating low cancer risk potential for those who live or work indoors near the quarry sites. The excess lifetime cancer risk is calculated using:

$$ELCR = AEDE\,(mSv/yr) \times DL(yr) \times RF(Sv^{-1}) \times 10^{-3} \quad (5)$$

where *AEDE* is the annual effective dose equivalent, *DL* is the average duration of life (estimated to be 70 years), *RF* is the Risk Factor (Sv^{-1}) which is given as 0.05 for stochastic as stated by ICRP. (UNSCEAR 2000)

4.0 Conclusion

The activity concentrations of natural radionuclides [K-40, Ra-226, and Th-232] in the farm soil and food crops (cassava) grown in Moniya, Ibadan, Oyo State Nigeria, have been measured and the radiological health effects were evaluated in this study, all estimated mean activity concentration, radium equivalent (Ra_{eq}), external and Internal hazard indices, gamma indices, annual effective dose (AED), Indoor ELCR were found to be lower than the world average values.

The mean activity concentration of K-40 in the farmland soils around and far from the quarry site were lower than the world average values therefore posing less risks to workers and farmers around and far from the quarry sites. The case of Ra-226 concentration in soil is different as both farmlands (far and around the quarry sites) are higher than world average value. Th-232 activity concentration value in soil from farmlands around the quarry site is lower than the world average, the value from the soil in farmlands far from quarry is higher. This could be as a result of radionuclides in farmland around quarry been washed away by rainfall or blown away by wind. Also, the high radionuclides content in Moniya general may be due to the parent rock which is rich in migmatite–gneiss. The average absorbed dose rate from soil in farmland around the quarry site estimated in this study 54.02 nGy/h. The average absorbed dose rate from soil in farmland far from the quarry site was estimated at 64.68 nGy/h. The average absorbed dose rate from cassava in farmland around the quarry site estimated in this study 26 nGy/h. The average absorbed dose rate from soil in farmland far from the quarry site was estimated at 47 nGy/h against the 55nGy/h world average.

The mean total ELCR values from soil exposure in this study was 1.16 x 10^{-3} with an outdoor ELCR average value of 0.23 x 10^{-3} and indoor ELCR average value of 0.93 x 10^{-3}. All the ELCR values were below the global average outdoor ELCR, indicating low cancer risk potential for those who live or work around the quarry sites, while those far away from the quarry estimates of total, indoor and outdoor ELCR values of 1.39 x 10^{-3}, 0.28 x 10^{-3} and 1.11 x 10^{-3} respectively. All values estimates were also below global averages indicating low cancer risk potential for those who live or work indoors near the quarry sites. In the case of cassava crops around the quarry site, this study estimates the total, indoor and outdoor ELCR values of 0.56 x 10^{-3}, 0.11 x 10^{-3} and 0.45 x 10^{-3} respectively, against the world average. Crop planted for consumption in the area need to be monitored to prevent stochastic effects in the future and also for further radiological concern. Also, more toxicity analysis may be carried out in future to evaluate other radionuclides present within the same locations to have a more robust assessment of the potential hazards the quarry site might pose to farmers or workers within the area.

Received: 02/08/2025; Revised: 18/08/2025; Accepted: 31/08/2025; Published: 22/09/2025

References

[1] Tawfic, A.F., Omar, A., Abed, N.S. and Tantawy, H.R., 2021. Investigation of natural radioactivity in wadi el reddah stream sediments and its radiological implications. *Radiochemistry*, *63*(2), pp.243-250.

[2] N.N. Jibiri, M.O. Isinkaye, & H.A. Momoh.: *Assessment of radiation exposure levels at Alaba e-waste dumpsite in comparison with municipal waste dumpsites in southwest Nigeria.* Journal of Radiation Research and Applied Sciences. Volume 7(4),2014. pp536-541.

[3] A.K. Ademola, A.K. Bello, & A.C Adejumobi.: *Determination of natural radioactivity and hazard in soil samples in and around gold mining area in Itagunmodi, south-western, Nigeria.* Journal of Radiation research and applied sciences. Volume *7*(3),2014, pp.249-255.

[4] B. C Eke, I. R. Akomolafe, U.M Ukewuihe & C.P Onyenegecha.: *Assessment of radiation hazard indices due to natural radionuclides in soil samples from Imo State University, Owerri, Nigeria.* Environmental Health Insights, Volume 18(3). 2024. pp.11786302231224581.

[5] D. O. Jegede, T.A Afolabi, F.O Agunbiade, T.A Afolabi, O.O Ogundiran, M. R. Gbadamosi, S.O Sojinu, O.Z. Ojekunle, & P. Varanusupakul.: *Spatial distribution and radiological hazards assessment of naturally occurring radionuclide materials in soil from quarry sites in Ogun State*, Nigeria. Environmental Monitoring and Assessment Volume 197(5), 2025. pp.575.

[6] R.M. Hazen, R.C. Ewing & D.A. Sverjensky.: *Evolution of uranium and thorium minerals. American Mineralogist,* Volume 94(10), 2022. pp.1293-1311.

[7] IAEA *Safety standards for protecting people and the environment. Radiation protection and safety in medical use of ionizing radiation,* 2018 specific safety guide No.SSG-46. Available online: https://wwwpub.iaea.org.

[8] K. T Osman.:*Soil resources and soil degradation. In Soils: principles, properties and management.* Dordrecht: Springer Netherlands. 2024.pp. 175-213.

[9] N. A Mlwilo, N.K. Mohammed & N. M Spyrou.: *Radioactivity levels of staple foodstuffs and dose estimate for most of the Tanzanian population.* Journal of radiological Protection, Volume *27*(4), 2007. pp.471.

[10] R. Nieder, D.K. Benbi, & F. X. Reichl.: *Health risks associated with radionuclides in soil materials. In Soil components and human health 2018.* Dordrecht: Springer Netherlands.Volume5(1) pp. 451-501.

[11] Angela Akanwa O., Faustina Onwuemesi E., Gladys Chukwurah O., Maurice Officha (2016) Effects of Open Cast Quarrying Technique on Vegetation Cover and the Environment in South-Eastern Nigeria, *American Scientific Research Journal for Engineering, Technology, and Science, Vol.21, 1: 227-240*

[12] D.O Jegede, T.A. Afolabi, F.O. Agunbiade, O.S. Oladeji, M.R. Gbadamosi, S.O Sojinu. O.Z Ojekunle & P. Varanusupakul.:*Fuzzy logic modelling of the pollution pattern of potentially toxic elements and naturally occurring radionuclide materials in quarry sites in Ogun State, Nigeria.* Environmental geochemistry and health, 2025. *47*(2), pp.59

[13] J. M Gebicki, & T. Nauser.: *Initiation and prevention of biological damage by radiation-generated protein radicals.* International journal of molecular sciences, 2021.Volume *23*(1), pp.396.

[14] C.E Ihejirika, E.C Ndubuisi, J.D. Njoku, E.I. Emereibeole, T.E. Ebe, R.F. Njoku-Tony, O.C Ihejirika, E.O. Imo, I.N. Nwachukwu, E.C. Chinakwe, & C.N. Uyo.: *Heavy metal contamination of cassava (Manihot esculentum) grown on quarry soils in Umunneochi Abia state and its health implications.* EQA-International Journal of Environmental Quality, Volume 45.2021, pp.1-9.

[15] Sengar, R. S. (2022). Cassava processing and its food application: A review. *Pharma Innov. J*, *2*, 415-422.

[16] International Atomic Energy Agency (IAEA). *Understanding radioactivity and radiation in everyday life*, 2019.Available online: http// www.iaea.org/Publications/radlife

[17] International Atomic Energy Agency (IAEA)*Exposure Due to Radionuclides in Food Other Than During a Nuclear or Radiological Emergency, 2011, IAEA TECDOC-201*

[18] Food and Agriculture Organization of The United Nations (FAO). *The State of Food and Agriculture* 2006, Available online: http//www.fao.org/4/a0800e/a0800e00.htm.

[19] Alausa, S. K. (2020). *Radiometric Assessment of farm soils and food crops grown in Kuru-Jos, Nigeria.* Iran J. Med. Phys, *17*(5), 2020, 289-297.

[20] UNSCEAR 2000 Report – "Sources and Effects of Ionizing Radiation", Vol. I, Annex B (Exposure from Natural Radiation Sources).