ISSN 2350-1049

International Journal of Recent Research in Interdisciplinary Sciences (IJRRIS)
Vol. 9, Issue 3, pp: (70-77), Month: July - September 2022, Available at: www.paperpublications.org

Radiological Health Risk Assessment of Cassava (*Manihot Esculenta*) and Yam (*Dioscorea Alata*) Obtained From Farm Lands in Akwa Ibom State, Nigeria

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DOI: https://doi.org/10.5281/zenodo.7043377

Published Date: 02-September-2022

Abstract: **One of the major sources of human exposure to radionuclides could be from ingestion of food crops grown on contaminated soil. This work is aimed at assessing the level of health risk associated with the intake of^{238}U, ^{226}R, ^{232}Thand ^{40}K in yam and cassava cultivated in farm lands in Akwa Ibom State. The activity concentration of naturally occurring radionuclides in the samples, were measured using a High Purity Germanium (HPGe) Detector. The mean activity concentrations of radionuclides in yam were 2.81±0.42 Bq/kg, 1.02±0.36 Bq/kg, 0.82±0.15 Bq/kg and 335.23±17.20 Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K respectively. Mean activity concentrations of radionuclides in cassava were 3.29±0.46 Bq/kg, 1.15±0.29 Bq/kg, 1.38±0.18 Bq/kg and 272.65±14.40 Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K respectively. The estimated mean values of external hazard index (H_{ex}) and internal hazard index (H_{in}) were 0.08, 0.07 and 0.11, 0.08 respectively in cassava and yam respectively. The estimated mean values of gamma absorbed dose rate in yam and cassava were 15.71 nGy. y^{-1} and 13.66 nGy. y^{-1} respectively. The mean values of Annual effective dose (AED) due to consumption of cassava and yam were 0.070 µSv yr^{-1} and 0.186 µSv yr^{-1}, respectively. The mean estimated values of excess lifetime cancer risk due to consumption of cassava and yam were 0.00019 and 0.00022, respectively. The values obtained for the radiological doses for the yam and cassava samples were below the world recommended values. It is recommended that farmers should be educated to only apply the right types and quantities of fertilizers to soil in order to check further increases in concentration levels of these radionuclides in soil and plants.**

Keywords: **Activity Concentration, Radionuclides, Health Risk, Yam, Cassava.**

1. INTRODUCTION

Radioactive materials circulate through the biosphere and end up in the air, water, grasses and vegetables. Plants are therefore exposed to radioactive substances through environmental contamination and grazing on contaminated forage [1]. Most human activities include the introduction of heavy metals into a plant environment in the form of phosphate fertilizers applied on lands. Rock phosphates contain high levels of uranium, radium and thorium which can result in higher soil, outdoor air, and groundwater content of radon which is a decay product of Uranium. Radionuclides accumulated in arable soil can be incorporated metabolically into plants and eventually get transferred into the bodies of animals when contaminated forages are eaten [9]. Indirect sources of radiation can also result from the use of well or ground water that contains radon or any. Naturally occurring radionuclides of^{238}U, ^{226}Ra, ^{232}Th and ^{40}K have significant contributions in the ingestion dose and are present in the biotic system of plants, animals, soil, water and air. Distribution of radionuclides in different parts of the plant depends on the chemical characteristics and several parameters of the plants and soil [8]. Contamination of the food chain occurs as a result of direct deposition of radionuclides on the plant leaves, root uptake from contaminated soil or water, and animals ingesting contaminated plants, soil or water. Ingestion of food crops grown in contaminated soil can be a major source of human exposure to radionuclides since it can lead to internal radiation doses [2].

Yam (*Dioscorea alata*) is a tuber commodity which is largely consumed by people living in Akwa Ibom State. It is used to make different delicacies such as the common white soup and pounded yam within the study area. Cassava (*Manihot esculenta*) is a root crop that is commonly grown and it provides a major staple food in the study area. Cassava tubers in its raw for is processed into garri and other forms of delicacies which is a common food consumed by people living in Akwa Ibom State. Since radionuclides are naturally available in soil and can also be enhanced by man through activities such as successive application of phosphate fertilizers and pesticides, mining and milling operations, burning of fossil fuels amongst others, it is therefore necessary to know the uptake of natural radionuclides by the plant from the soil [6]. Some works have been done on the level of radionuclide concentration in some consumables, but not much has been done on radionuclide uptake by yam and cassava from soils in Akwa Ibom State. This work is aimed at assessing the level of health risk associated with the intake of^{238}U, ^{226}R, ^{232}Thand ^{40}K in yam and cassava obtained from farm lands in Akwa Ibom State.

2. MATERIALS AND METHOD

2.1. Study Area

The study area covered selected Local Government Areas (LGA) of AkwaIbom State. The Local Government Areas considered for sampling were IkotEkpene, Obot-Akara, EssienUdim, Abak, EtimEkpo, OrukAnam, Ikono and Uyo.AkwaIbom is a Statelocated in the southern coastal part of Nigeria and is within the South-South Geopolitical Zone. It lies between latitudes 4°32′N and 5°33′N, and longitudes 7°25′E and 8°25′E. The State is bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the south by the Atlantic Oceanand the southernmost tip of Cross River State.

2.2. Sample Collection and Preparation

Sample sites were selected from cultivated farmlands in the study area**.** Some factors considered in selection of sample sites include: farmlands where highly-consumed crops were cultivated; and farmlands cultivated for both subsistence and small-scale commercial purposes. The type of pesticide used if any were noted, fertilizers used were also noted, whether organic or inorganic fertilizers.

Plant samples collected were thoroughly washed with tap water, cassava and yam samples were peeled, and then all plant samples were washed in distilled water to remove surface sand and debris [7]. The samples were then cut into small pieces and exposed to ambient air in a dust-free environment before being dried to a constant weight for 48 hours in a monitored oven maintained at I50^{o}C in the laboratory. The samples were then ground to powdery form, sieved and then weighed. The weight of the plant samples varied between 220g and 300g.

2.3. Method for Sample Analysis

The prepared yam and cassava samples were taken to National Institute of Radiation Protection and Research in University of Ibadan for analysis. The activity concentration of naturally occurring radionuclides in the samples were measured using a High Purity Germanium (HPGe) Detector. The HPGe used was manufactured by Canberra, model GC 8023 with serial number 9744. It is coupled to a pre amplifier, model 2002CSL with serial number 13000742. The standard source used for calibration was Multi-Gamma Ray Standard (MGS6M315). The detector has a resolution (FWHM) of 2.3Kev, ^{60}Co at 1.33Mev with relative efficiency of 80%. The software used for analysis was Genie 2K.

2.4. Activity Concentration in Samples

The activity concentration (AC) in unit of Bq kg^{-1}, for the radionuclides present in the yam and cassava samples with detected photo peak at energy E, was calculated using Equation 2.1

$$C = \frac{N_t}{TP_y EM} \qquad \text{Equation 2.1}$$

ISSN 2350-1049

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Where C is the activity concentration of radionuclides in Bq kg^{-1}, N_t is the net count under corresponding photo peak, T is the counting time in seconds, P_r gamma intensity of specific gamma-ray, £ absolute efficiency, and M mass of sample in (kg), respectively. The world recommended value for AC in the samples for ^{238}U, ^{226}Ra,^{232}Th, and ^{40}K are 35 Bq/kg, 35 Bq/kg, 30 Bq/kg and 400 Bq/kg, respectively [11] [12].

2.5 Annual Effective Dose

The Annual effective dose received by the public from the consumption of the cassava and yam samples was estimated using Equation 2.2 [1].

$$\text{Total AED} = \sum A_i \times DCf_i \times C_r \qquad \text{Equation 2.2}$$

A_i(Bq/kg) is the specific activity of radionuclide i, DCf_i (mSv/Bq) is the dose conversion factor of radionuclide i, C_r ($kg.yr^{-1}$) is the annual consumption rate of the samples. The DCf values are 2.8×10^{-7}; $4.5 \text{ x } 10^{-8}$; 2.3×10^{-7} and 6.2×10^{-9} Sv/Bq for ^{226}Ra,^{238}U, ^{232}Th and ^{40}K, respectively [11] [3].

2.6 Excess lifetime cancer risk (ELCR)

The excess lifetime cancer risk (ELCR) associated with the consumption of the radionuclies in the cassava and yam samples were calculated using Equation 2.3 [10]. This was to determine the potential carcinogenic effects of the long-term consumption of these samples [13]

$$ELCR = AED \times RF \times DL \qquad \text{Equation 2.3}$$

Where AED is the annual effective dose, DL is the duration of life (55 years) and RF is the fatal cancer risk factor which is 0.05 for the public [11]. The ELCR recommended world mean value is 0.0029 [11].

2.7. Gamma Absorbed Dose Rate (D)

The external terrestrial gamma absorbed dose rate in air was calculated by using Equation 2.4 [4] [5].

$$D\ (nGy.y^{-1}) = (R_K \times A_K) + (R_U \times A_U) + (R_{Th} \times A_{Th}) \qquad \text{Equation 2.4}$$

Were R_K (0.0414), R_U (0.462) and R_{Th} (0.604) are the conversion factors for ^{40}K, ^{238}U and ^{232}Th, respectively [4]. A_K, A_U and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th, respectively, in $Bq.kg^{-1}$.

2.8 External (H_{ex}) and Internal (H_{in}) Hazard Indices

The external hazard index (H_{ex}) and internal hazard index (H_{in}) values were calculated using Equations 2.5 and 2.6 [4] [5]. These are hazard indicators that predict the external and internal detriment of natural radiation from ^{40}K, ^{238}U and ^{232}Th.

$$H_{ex} = 0.0027A_U + 0.00386\ A_{Th} + 0.000208\ A_K \qquad \text{Equation 2.5}$$

$$H_{in} = 0.0054\ A_U + 0.00386\ A_{Th} + 0.000208\ A_K \qquad \text{Equation2.6}$$

Where A_U, A_{Th} and A_K are the activity concentrations of^{238}U, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ respectively.

3. RESULTS AND DISCUSSION

3.1 Activity Concentration in yam and cassava samples

The activity concentration of ^{238}U, ^{226}Ra,^{232}Th, and ^{40}K in the yam and cassava samples is presented in Tables 1 and 2 while the average annual consumption rates is presented in Table 3

Table 1: Activity concentration of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in $Bq.kg^{-1}$ for the yam samples from the study areas.

LGA	SAMPLE CODES	^{238}U	^{226}Ra	^{232}Th	^{90}K
Abak	Y1	BDL	BDL	BDL	261.20±13.82
	Y2	BDL	BDL	0.66±0.07	175.23±9.27
	Mean	BDL	BDL	0.33±0.03	218.21±11.54
Essien Udim	Y3	7.42±1.53	BDL	1.00±0.19	566.30±29.96
	Y4	4.10±0.60	2.47±1.06	BDL	473.56±25.05

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	Y5	11.44±1.25	3.95±0.73	0.33±0.13	355.77±18.82
	Y6	BDL	2.44±1.08	1.16±0.30	371.86±19.67
	Mean	5.74±0.84	2.21±2.87	0.62±4.86	441.87±23.37
Etim Ekpo	Y7	BDL	ND	3.40±0.50	381.92±20.21
Uyo	Y8	BDL	BDL	BDL	95.97±5.08

Table 2: Activity concentration of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in Bq.kg^{-1} for the cassava samples from the study areas.

LGA	SAMPLE CODES	^{238}U	^{226}Ra	^{232}Th	^{90}K
Abak	C1	BDL	2.02±0.66	2.16±0.28	256.57±13.57
	C2	5.72±0.98	ND	0.32±0.09	137.55±7.32
	Mean	2.86±0.49	1.01±0.33	1.24±0.18	197.06±10.44
Essien Udim	C3	BDL	BDL	BDL	59.70±3.16
	C4	ND	ND	2.76±0.33	583.64±30.87
	Mean	BDL	BDL	1.38±0.16	321.67±17.01
Etim Ekpo	C5	10.12±1.24	ND	0.96±0.21	228.88±12.11
	C6	BDL	3.21±0.93	2.70±0.33	426.37±22.55
	Mean	5.06±0.62	1.60±0.46	1.83±0.27	327.62±17.33
Ikot Ekpene	C7	9.61±1.55	2.89±0.91	2.23±0.36	232.12±12.28
	C8	10.76±1.31	4.54±0.79	2.70±20.06	379.18±20.06
	Mean	10.18±1.43	3.71±0.85	2.46±10.21	305.65±16.17
Obot Akara	C9	BDL	BDL	0.90±0.10	163.34±8.65
	C10	BDL	ND	0.74±0.20	352.60±18.65
	Mean	BDL	BDL	0.82±0.15	257.97±13.65
Uyo	C11	BDL	ND	BDL	179.27±9.48

BDL = Below Detection Limit, ND= not detected

Table 3: Average annual consumption rates of yam and cassava samples from the study areas.

Samples	Daily Consumption (g)	Frequency per week	F (frequency/7)	Annual Rate (kg.yr^{-1})
Yam	250	2	0.28	26.00
Cassava	300	5	0.71	78.00

3.2. Radiological Health Risk Assessment of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in the yam and cassava Samples.

The health risk was assessed based on the estimated values of D, ELCR, H_{ex} , H_{in} and Total AED for the yam and cassava samples as presented in Tables 4 and 5 respectively. Figures 1 through 8, shows the level of distribution of the various radiological doses in the yam and cassava samples.

Table 4: Estimated values of D, ELCR, H_{ex} , $H_{in}$and Total AED for the yam samples from the study areas.

SAMPLE CODES	D (nGy. y^{-1})	ELCR	H_{ex}	H_{in}	Total AED (μSv.yr^{-1})
Y1	10.84	0.00012	0.05	0.23	0.042
Y2	7.66	0.00009	0.04	0.05	0.032
Y3	27.48	0.00029	0.14	0.04	0.106
Y4	21.52	0.00027	0.11	0.16	0.099
Y5	20.21	0.00028	0.10	0.12	0.101
Y6	16.10	0.00023	0.08	0.13	0.085
Y7	17.87	0.00024	0.09	0.08	0.082
Y8	3.99	0.00004	0.02	0.09	0.016
Mean	15.71	0.00019	0.08	0.11	0.070

Table 5: Estimated values of D, ELCR, H_{ex}, H_{in} and Total AED for the cassava samples from the study areas.

SAMPLE CODES	D (nGy. y^{-1})	ELCR	H_{ex}	H_{in}	Total AED ($\mu Sv.yr^{-1}$)
C1	11.93	0.00057	0.06	0.02	0.207
C2	8.53	0.00026	0.04	0.06	0.093
C3	2.49	0.00008	0.01	0.06	0.030
C4	25.83	0.00091	0.13	0.01	0.332
C5	14.73	0.00045	0.08	0.13	0.164
C6	19.29	0.00089	0.10	0.10	0.325
C7	15.40	0.00068	0.08	0.10	0.249
C8	22.30	0.00101	0.12	0.11	0.369
C9	7.31	0.00026	0.04	0.15	0.096
C10	15.05	0.00051	0.08	0.04	0.184
C11	7.45	0.00024	0.04	0.08	0.088
Mean	13.66	0.00022	0.07	0.08	0.186

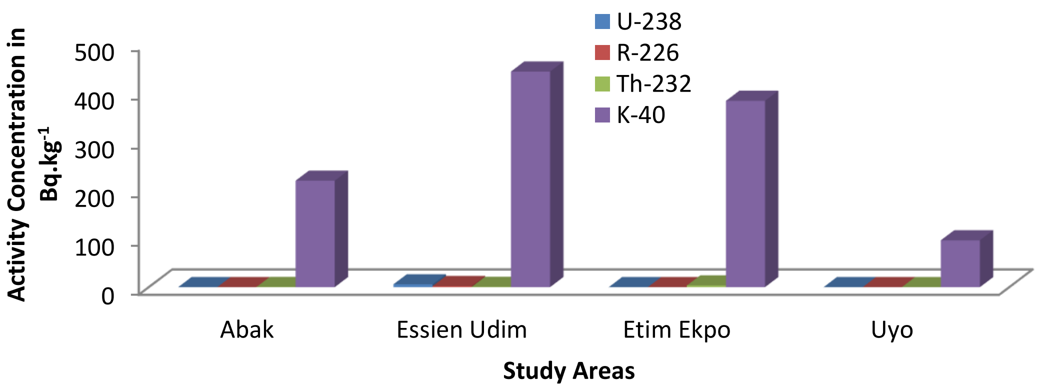

Figure 1: Distribution of the mean activity concentration in $Bq.kg^{-1}$ of the yam Samples from the study areas.

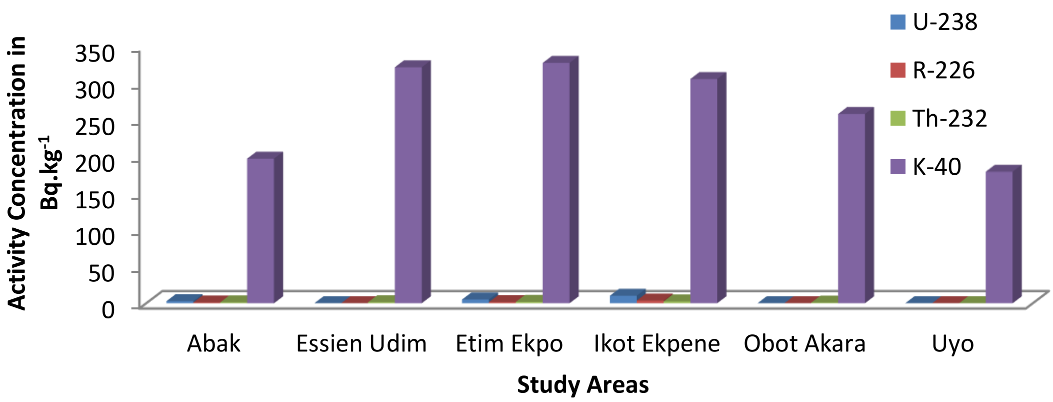

Figure 2: Distribution of the mean activity concentration in $Bq.kg^{-1}$ of the cassava Samples from the study areas.

ISSN 2350-1049

International Journal of Recent Research in Interdisciplinary Sciences (IJRRIS)
Vol. 9, Issue 3, pp: (70-77), Month: July - September 2022, Available at: www.paperpublications.org

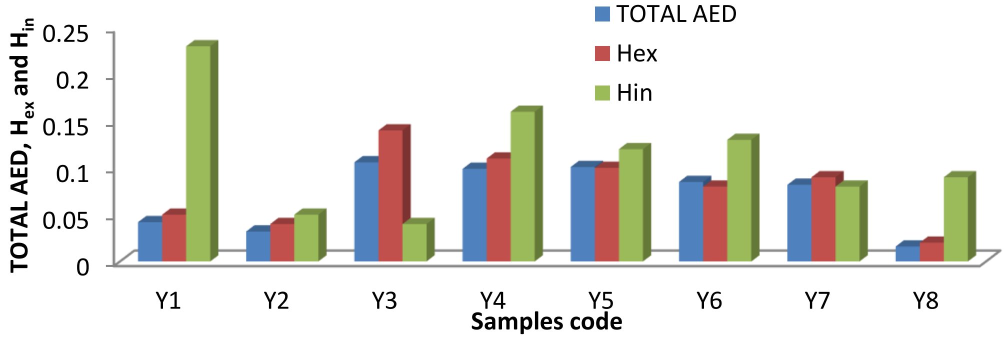

Figure 3: Distribution of the total AED (µSv.yr^{-1}), H_{ex} and H_{in} of the yam samples from the study areas.

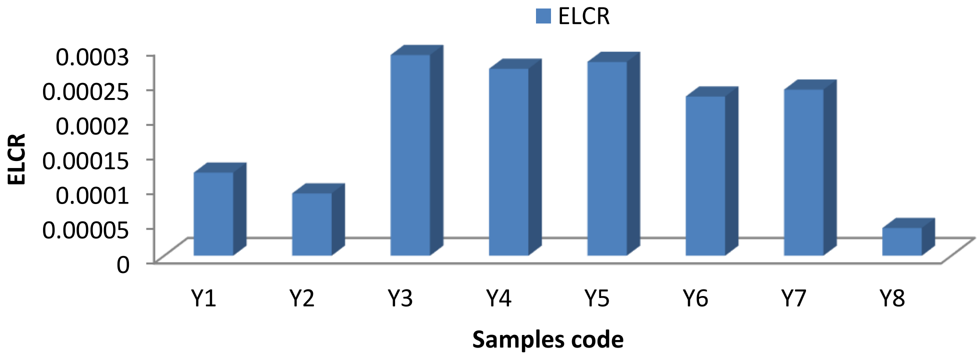

Figure 4: Distribution of the excessive life time cancer (ELCR) risk of the yam samples from the study areas.

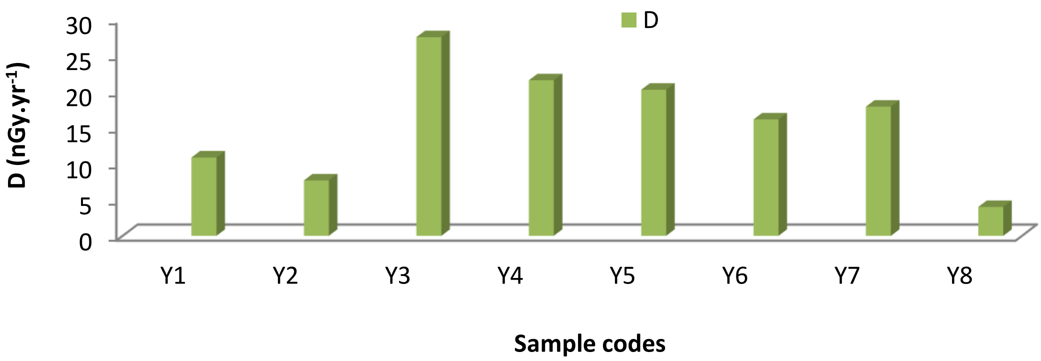

Figure 5: Distribution of the gamma dose rate (nGy.yr^{-1}) of the yam samples from the study areas.

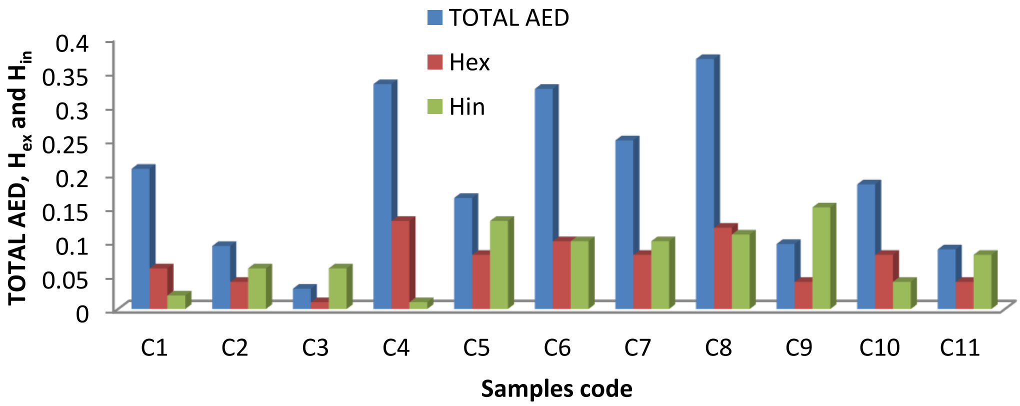

Figure 6: Distribution of the total AED (µSv.yr^{-1}), H_{ex} and H_{in} of the cassava samples from the study areas.

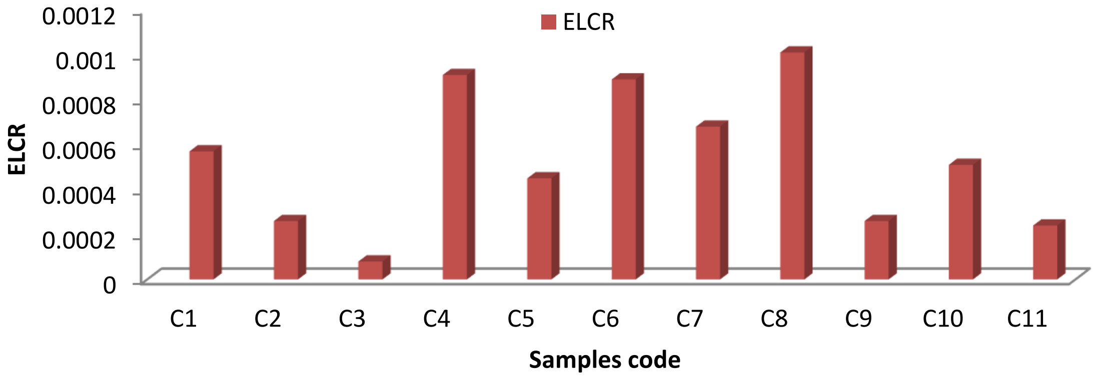

Figure 7: Distribution of the excessive life time cancer (ELCR) risk of the cassava samples from the study areas.

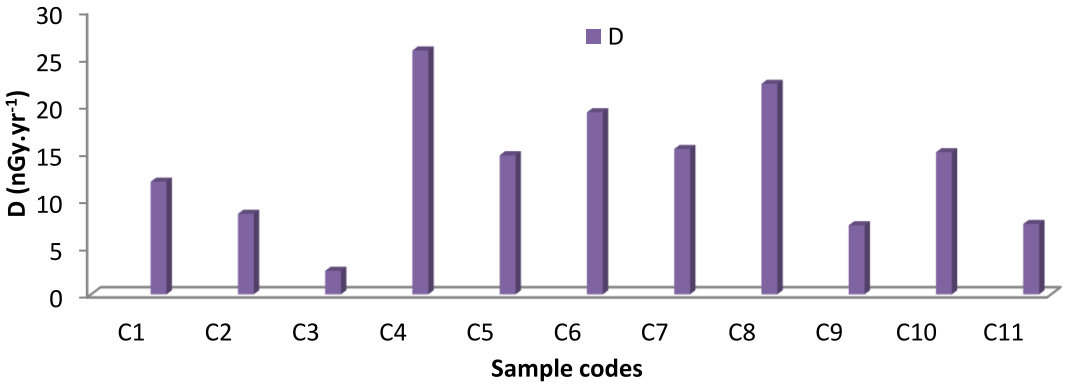

Figure 8: Distribution of the gamma dose rate (nGy.yr^{-1}) of the cassava samples from the study areas.

3.3. Discussion

The mean activity concentrations of radionuclides in yam were 2.81±0.42Bq/kg, 1.02±0.36 Bq/kg, 0.82±0.15 Bq/kg and 335.23±17.20 Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K respectively. Mean activity concentrations of radionuclides in cassava were 3.29±0.46 Bq/kg, 1.15±0.29 Bq/kg, 1.38±0.18 Bq/kg and 272.65±14.40 Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K respectively. Activity concentration of ^{238}U, ^{226}Ra and ^{232}Th in yam and cassava were within the permissible maximum values [11] [13].

The results for radiological health risk assessment of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K due to consumption of yam are presented in Table 4. The parameters presented are estimated values of gamma absorbed dose D, Excess lifetime cancer risk ELCR, External hazard index H_{ex},Internal hazard index H_{in}, Annual effective dose (AED) due to consumption of yam. In yam the absorbed dose ranges from 3.99 nGy.yr^{-1} to 27.48 nGy.yr^{-1}with mean of 15.71 nGy.yr^{-1} the values are within permissible limits. Estimated values of ELCR due to consumption of yam ranged from 0.00004 to 0.00029 with a mean of 0.00019, these values are within the recommended limit of 0.0029 [11] [12]. The distribution of the excessive life time cancer (ELCR) risk due to consumption of yam from the study area is shown in Figure 4. The estimated annual effective doses due to consumption of yam ranged from 0.016 µSv.y^{-1} to 0.106 µSv.y^{-1} with mean of 0.070 µSv.y^{-1} these values are well below the recommended reference limit. For the yam samples, H_{ex} ranged from 0.02 to 0.14 with a mean of 0.08 while H_{in} ranged from 0.04 to 0.23 with mean of 0.11 these values are all within the world reference limit of 1 [11].

The results for radiological health risk assessment of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K due to consumption of cassava are presented in Table 5. The parameters presented are estimated values of gamma absorbed dose D, Excess lifetime cancer risk ELCR, External hazard index H_{ex},Internal hazard index H_{in}, Annual effective dose (AED) due to consumption of cassava.The estimated annual effective doses due to consumption of cassava ranged from 0.030 µSv.y^{-1} to 0.369 µSv.y^{-1} with a mean of 0.186 µSv.y^{-1}. These values are well below the recommended reference limit. The H_{ex} ranged from 0.01 to 0.13 with a mean of 0.08 while the H_{in} ranged from 0.01 to 0.15 with mean of 0.08 these values are all within the world reference limit of 1.

In cassava samples, the absorbed dose ranged from 2.49 $nGy.yr^{-1}$ to 25.83 $nGy.yr^{-1}$ with mean of 13.66 $nGy.yr^{-1}$ the values are within permissible limits. Estimated values of ELCR due to consumption of cassava ranged from 0.00008 to 0.00091 with a mean of 0.00022, these values are within the recommended limit of 0.0029 [11].

4. CONCLUSION

In conclusion, the estimated values of the gamma absorbed dose rate (D), Excess lifetime cancer risk (ELCR), External hazard index (H_{ex}), Internal hazard index (H_{in}) , Annual effective dose (AED) due to consumption of yam and cassava are presented in Tables 4 and 5 respectively. The estimated mean values of absorbed dose in yam and cassava were 15.71 $nGy.y^{-1}$ and 13.66 $nGy.y^{-1}$ respectively. It was observed that in this study that the yam and cassava samples had absorbed dose rate lower than the world reference limit of 55 $nGy.y^{1}$. Mean estimated values of excess lifetime cancer risk due to consumption of cassava and yam were 0.00019 and 0.00022, respectively. All the samples had ECLR values within permissible limit of 0.0029 [11].

Estimated mean values of external hazard index were 0.08 and 0.07 in the cassava and yam samples respectively, these were all within the world reference value of 1. Internal hazard index estimated mean values were 0.11 and 0.08 in cassava and yam respectively, these were all also within permissible limit of 1. The mean values of Annual effective dose (AED) due to consumption of cassava and yam were 0.070 and 0.186 $\mu Sv\ yr^{-1}$, respectively. These values are within and well below recommended reference value of 1000 $\mu Sv\ yr^{-1}$ or 1 $mSv\ yr^{-1}$ [11]

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