ISSN 2350-1030

International Journal of Recent Research in Physics and Chemical Sciences (IJRRPCS)
Vol. 9, Issue 1, pp: (26-37), Month: April 2022 – September 2022, Available at: www.paperpublications.org

An Evaluation of the Radiological Health Risk Associated with the consumption of Afang (*Gnetum Africanum*) and Fluted pumpkin (*Telfairia Occidentalis*) Obtained from farms Lands in Akwa Ibom State, Nigeria

I. M. Essen[1], O. P. Akpan, J. I. Ukpong, E. O. Isaac[2].

[1]Department of Science Technology, Akwa Ibom State Polytechnic, Ikot Osurua, Nigeria.

[2]Department of Physics, University of Uyo, Akwa Ibom State. Nigeria

DOI: https://doi.org/10.5281/zenodo.6957676

Published Date: 03-August-2022

Abstract: **The radionuclides present in the environment transfer to plants through uptake from soil through roots and direct absorption through aerial parts of the plants. This work is aimed at assessing the level of radiological health risk associated with the intake of ^{238}U, ^{226}R, ^{232}Th and ^{40}K present in afang and fluted pumpkin obtained from 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 concentration of radionuclides in fluted pumpkin were 26.34 ± 2.36 Bq/kg, 13.80 ± 1.22 Bq/kg, 26.44 ± 1.77 Bq/kg and 1349.58 ± 71.35 Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K, respectively. The mean activity concentration of radionuclides in afang were 13.29±1.28 Bq/kg, 4.85±0.79 Bq/kg, 6.80±0.45 Bq/kg and 459.65±25.64 Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K, respectively. The estimated mean values of absorbed dose in fluted pumpkin and afang were 79.05 nGy. y^{-1} and 28.97 nGy. y^{-1}, respectively. The mean estimated values of excess lifetime cancer risk due to consumption of fluted pumpkin leaves and afang leaves were 0.0024 and 0.00027, respectively. All the plants had ECLR values within permissible limit of 0.0029. Estimated mean values of external hazard index and internal hazard index were 0.45, 0.15 and 0.52 and 0.18 in fluted pumpkin and afang samples respectively, these were all within the world reference value of 1. The mean values of Annual effective dose due to consumption of fluted pumpkin leaves and afang leaves were 0.68 µSv yr^{-1} and 0.078 µSv yr^{-1}, respectively. These values are within and well below recommended reference value of 1000 µSv yr^{-1} or 1 mSv yr^{-1}. Continuous evaluation and monitoring of activities of farmers through agricultural extension workers in the state would go a long way in providing Information on radionuclide levels in soil in different areas.**

Keywords: **Radionuclides, Radiological Health Risk, Afang, Fluted pumpkin.**

1. INTRODUCTION

Natural radioactivity in the environment, originating from the naturally occurring radionuclides of ^{232}Th, ^{238}U, and ^{40}K radioactive series, largely contributes to the natural irradiation of man and other living organisms. This can occur externally or internally. A series of successive radioactive decays occur from parent radionuclides whose offspring are also unstable and is subject to decay in order to become stable. Ionizing radiations such as alpha(α), beta(β) and gamma(ɤ) are products of decay of these naturally occurring radionuclides. The continuous exposure of human beings to ionizing radiation from natural sources is thus an unavoidable feature of life on earth. This exposure to ionizing radiation also arises from other naturally occurring sources such as radiation from high-energy cosmic ray particles incident on the earth's atmosphere [1]. There are also sources with artificial origin such as medical diagnostic and therapeutic procedures, radioactive material resulting from nuclear weapons testing, energy generation by means of nuclear power, unplanned events such as the nuclear power plant accidents at Chernobyl in 1986 and that following the great East-Japan earthquake and Tsunami of March 201I [2].

The basic component of our life support system is considered to be in the soil, water, plants and air. These environmental components contain measurable amount of radioactivity. The specific metabolic character of the plant species may lead to accumulation of radionuclides in their organs which may further depend upon the physico-chemical characteristics of the soil. Therefore, there may be increased risk to human population via food chain. The interaction of plant with radionuclides occurs at two levels, either in the aerial or shoot portion of the plant or in the rhizosphere which is the soil-root zone of the plant [3].

The continuous increase in the levels of radionuclides in the environment especially soil and plants may be due to several factors such as successive application of phosphate fertilizers, mining and milling operations, burning of fossil fuels amongst others [4]. The addition of inorganic phosphate fertilizers to soils and crops to increase crop yield is a common practice in agriculture worldwide including the study area. Phosphate rock may be sedimentary, volcanic or biologic in origin. They are starting material for the production of phosphate fertilizers. Fertilizers are considered as products of technological enhancement of natural radiation, which increase the uranium and partially thorium concentrations in the environment [5]. The high value of radionuclide contents in the phosphate rocks and fertilizers were reported by several researchers [6] [4]. The long-continued application of phosphate fertilizers may elevate heavy metal, radionuclide contents and fluorine concentrations in soil profiles. This may cause the increase of availability of radionuclide in soil and subsequent transfer to the human food chain through plants [7] [8].

The negative effect of phosphate fertilizers on agriculture is the contamination of cultivated lands by trace metals (cadmium, copper and zinc) and increase in radioactivity in the vegetation and food [8]. Phosphate rocks contain high concentration of ^{238}U, ^{226}Ra and ^{232}Th and their decay products due to accumulation of dissolved uranium during its formation [9].Continuous application of fertilizers can lead to accumulation of radionuclides in the soil and this can change soil properties and eventually cause environmental pollution [10]. Different types of crops are grown traditionally in the study area. Fluted pumpkin (*Telfairia occidentalis*) is one of the most consumed plants in the study area. It is a tropical vine grown in West Africa. It belongs to the species "Occidentalis" and a member of the Cucurbitaceae family. The fluted pumpkin is also called fluted gourd and is known in the local language of the area as ikong-ubong. It is also popularly called ugwu in other parts of the country. Afang (*Gnetum africanum*) also known as okazi is also equally planted and consumed in large amounts in the study area.

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 afang and fluted pumpkin obtained from different farm lands in Akwa Ibom State, Nigeria.

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.Figure 1 shows the map of Akwa Ibom State with the study area highlighted.

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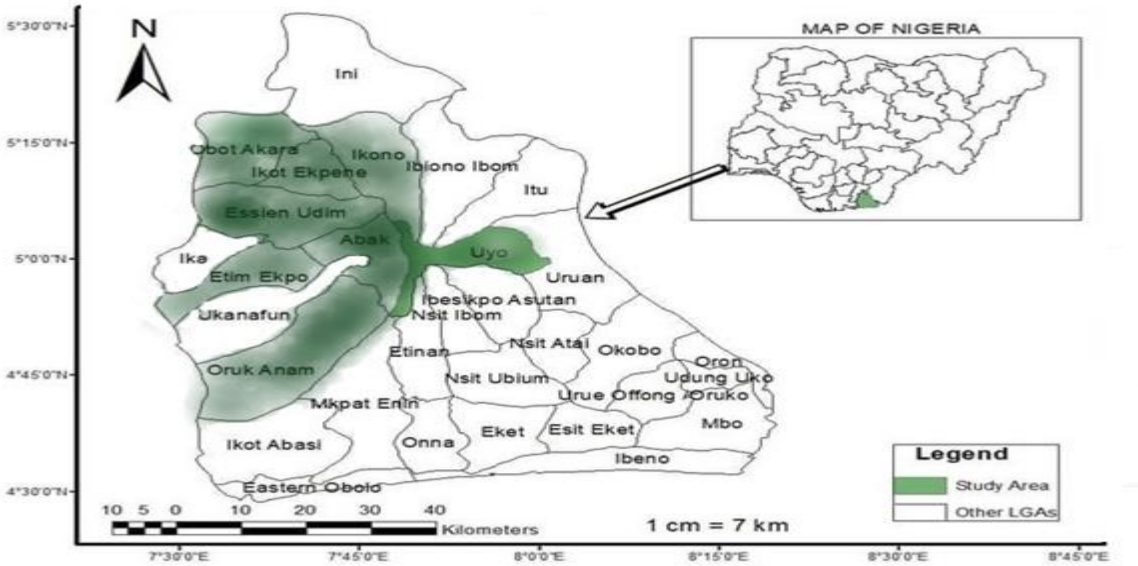

Figure 1: Map of Akwa Ibom State showing the study area

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.

The type of pesticide used if any were noted, fertilizers used were also noted, whether organic or inorganic fertilizers. A total of 33 samples were collected, consisting of 18 fluted pumpkin leaf samples and 15 afang leaf samples. The farms were divided into evenly spaced sites with a distance of 20M between each site for larger coverage of the farm according to [11]. At each sampling location, the soil surface was cleared of stones, pebbles, vegetation and roots. The plant samples collected were thoroughly washed in distilled water to remove surface sand and debris [12]. 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 all the plant samples varied between 250g and 350g.

2.3. Method for Sample Analysis

The prepared plant 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 afang and fluted pumpkin samples with detected photo peak at energy E, was calculated using Equation 2.1

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

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 [1] .

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2.5 Annual Effective Dose

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

Total AED = $\sum A_i \times DCf_i \times C_r$ 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}; 4.5×10^{-8}; 2.3×10^{-7} and 6.2×10^{-9} Sv/Bq for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K, respectively [1] [2].

2.6 Excess lifetime cancer risk (ELCR)

The excess lifetime cancer risk (ELCR) associated with the consumption of the radionuclies in the afang and pumpkin samples were calculated using Equation 2.3 [13]. This was to determine the potential carcinogenic effects of the long-termconsumption of these samples [14]

ELCR = AED ×RF×DL 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 [15]. The ELCR recommended world mean value is 0.0029 [15].

2.7. Gamma Absorbed Dose Rate (D)

The external terrestrial gamma absorbed dose rate in air associated with the afang and pumpkin sampleswas calculated by using Equation 2.4 [16] [17].

$D\ (nGy.y^{-1}) = (R_K \times A_K) + (R_U \times A_U) + (R_{Th} \times A_{Th})$ 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 [16]. 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 [16] [17]. These are hazard indicators that predict the external and internal detriment of natural radiation from ^{40}K, ^{238}U and ^{232}Th.

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

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

2.9 Correlation Studies

A correlation study was used to find the extent of the existence and relationship of the hazard indices together at a particular place [18]. Correlation is positive when the values of the two variables are in the same direction in such a way that an increase in the value of one variable also results to an increase in the value of the other variable. Correlation is said to be negative when the values of the two variables move in a reverse direction so that an increase in the values of one variable results in a decrease of the value of the other variable.

The Pearson‘s correlation coefficientr, is a measure of the level of strength of a linear association between two variables. For linear correlation coefficient r^2 greater than 0.5, the values of the two quantities is considered to be linearly related. For values of r^2 less than 0.5, the quantities though related to one another, but the values of one is not very much influenced by the other [18]. Equation 2.7 shows the equation for the Pearson‘s correlation coefficient r [18].

$$r_{xy} = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$ Equation 2.7

Where x and y are the two variables involved and n is the number of pairs of observations.

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3. RESULTS AND DISCUSSION

3.1: Activity Concentration in Fluted Pumpkinand Afang Samples

The activity concentration of ^{238}U, ^{226}Ra,^{232}Th, and ^{40}K in the fluted pumpkin and afang 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 fluted pumpkin samples from the study areas.

LGA	SAMPLE CODES	^{238}U	^{226}Ra	^{232}Th	^{90}K
Abak	F1	43.16±3.75	6.91±1.63	11.43±0.94	1152.35±60.95
	F2	BDL	10.42±0.89	14.50±1.04	1694.24±89.01
	F3	16.50±1.99	8.85±0.61	9.02±0.61	1127.59±59.64
	F4	18.54±2.85	14.72±1.94	22.15±1.70	1409.71±74.57
	Mean	19.55±2.14	10.22±1.27	14.27±1.07	1345.97±71.04
Essien Udim	F5	50.47±4.08	28.23±2.03	24.10±4.08	1293.38±68.41
	F6	73.13±5.54	25.94±1.48	65.32±3.59	1499.98±79.33
	F7	50.47±4.23	21.67±1.24	49.27±2.71	1227.26±64.91
	F8	BDL	15.43±0.98	36.16±2.02	805.28±42.89
	Mean	43.52±3.46	22.82±1.43	43.71±3.10	1206.47±63.88
Etim Ekpo	F9	19.57±2.32	8.47±1.09	23.76±1.74	1605.07±84.89
	F10	9.08±1.51	6.90±0.81	28.04±1.56	1393.45±73.70
	F11	15.11±1.91	13.08±0.95	42.81±2.38	1363.62±72.12
	Mean	14.59±1.91	9.48±0.95	31.54±1.89	1454.05±76.90
Ikot Ekpene	F12	BDL	9.48±1.36	4.81±0.84	1582.93±83.72
	F13	25.27±2.23	7.17±0.83	27.94±1.59	1286.69±68.05
	Mean	12.64±1.12	8.33±1.09	16.37±1.21	1434.81±75.88
Ikono	F14	BDL	14.46±1.36	25.97±1.52	1538.42±81.37
Oruk Anam	F15	47.69±4.18	13.60±1.36	18.02±1.17	1260.88±66.69
	F16	18.17±2.21	13.15±1.03	17.10±1.17	1444.44±76.40
	F17	86.96±5.63	21.28±1.38	44.30±2.46	1361.34±72.00
	Mean	50.94±4.01	16.01±1.26	26.47±1.60	1355.55±71.70
Uyo	F18	BDL	8.67±1.08	11.35±0.74	1245.91±65.70

BDL = BELOW DETECTION LIMIT

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

LGA	SAMPLE CODES	^{238}U	^{226}Ra	^{232}Th	^{90}K
Abak	A1	10.53±1.45	12.45±1.22	4.18±0.50	74.58±35.69
	A2	BDL	ND	0.54±0.14	271.89±14.41
	Mean	5.26±0.72	6.22±0.61	2.36±0.32	173.23±25.05
Essien Udim	A3	ND	BDL	BDL	397.68±21.04
	A4	BDL	ND	2.18±0.21	332.13±17.57
	A5	BDL	ND	6.59±0.69	838.84±44.37
	A6	64.55±5.94	10.74±2.15	6.20±0.71	714.46±37.85
	Mean	16.14±1.48	2.68±0.54	3.74±0.40	570.78±30.21
Etim Ekpo	A7	29.62±2.66	6.49±1.12	2.76±0.40	536.78±28.40
	A8	BDL	BDL	BDL	564.85±35.69
	Mean	14.81±1.33	3.24±0.56	1.38±0.20	550.82±32.04
Ikot Ekpene	A9	ND	ND	4.65±0.67	512.52±27.17
Ikono	A10	61.27±5.07	7.77±1.01	4.19±0.77	605.30±32.03
Obot Akara	A11	15.65±2.07	4.91±1.25	5.02±0.55	460.69±24.37
	A12	12.69±1.33	2.47±0.56	7.01±0.56	151.95±8.04
	Mean	14.17±1.70	3.69±0.91	6.01±0.55	306.32±16.20
Oruk Anam	A13	BDL	ND	7.39±0.99	536.39±28.40
Uyo	A14	4.45±0.71	ND	7.55±0.75	468.65±24.80
	A15	BDL	25.59±2.46	36.60±0.71	428.02±22.84
	Mean	2.22±0.35	12.80±1.23	22.07±0.73	448.33±23.82

ND: NOT DETECTED

ISSN 2350-1030

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Table 3: Average annual consumption rates of different plant samples from the study areas.

Samples	Daily Consumption (g)	Frequency per week	F (frequency/7)	Annual Rate ($kg.yr^{-1}$)
Fluted Pumpkin	120	5	0.71	31.20
Afang	100	3	0.43	15.60

3.2. Health Risk Assessment of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in the fluted pumpkin and afang Samples.

The estimated values of D, ELCR, H_{ex}, H_{in} and Total AED for the fluted pumpkin and afang samples as presented in Tables 4 and 5 respectively, was used to assess the health risk. Figure 2 through 9, shows the level of distribution of the various radiological doses in the plants samples.

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

SAMPLE CODES	D (**nGy.** y^{-1})	ELCR	H_{ex}	H_{in}	Total AED ($\mu Sv.yr^{-1}$)
F1	74.55	0.0012	0.40	0.52	0.426
F2	78.91	0.0014	0.41	0.41	0.523
F3	59.75	0.0010	0.31	0.36	0.383
F4	80.31	0.0016	0.43	0.48	0.586
F5	91.42	0.0020	0.50	0.63	0.741
F6	135.34	0.0029	0.76	0.96	1.080
F7	103.88	0.0023	0.58	0.72	0.851
F8	55.17	0.0015	0.31	0.31	0.550
F9	89.84	0.0016	0.48	0.53	0.582
F10	78.82	0.0015	0.42	0.45	0.544
F11	89.29	0.0019	0.49	0.53	0.706
F12	68.44	0.0012	0.35	0.34	0.424
F13	81.82	0.0015	0.44	0.51	0.548
F14	79.38	0.0017	0.42	0.42	0.610
F15	85.12	0.0015	0.46	0.59	0.559
F16	78.52	0.0015	0.41	0.46	0.543
F17	123.29	0.0024	0.69	0.92	0.889
F18	58.44	0.0011	0.30	0.30	0.398
Mean	79.05	0.0024	0.45	0.52	0.608

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

SAMPLE CODES	D (**nGy.** y^{-1})	ELCR	H_{ex}	H_{in}	Total AED ($\mu Sv.yr^{-1}$)
A1	10.47	0.00023	0.06	0.09	0.084
A2	11.59	0.00008	0.05	0.06	0.028
A3	16.48	0.00012	0.08	0.05	0.039
A4	15.07	0.00011	0.07	0.08	0.040
A5	38.71	0.00029	0.20	0.07	0.105
A6	63.14	0.00051	0.34	0.20	0.184
A7	37.57	0.00031	0.20	0.52	0.111
A8	23.41	0.00015	0.12	0.28	0.055
A9	24.03	0.00018	0.13	0.11	0.066
A10	55.89	0.00042	0.31	0.12	0.151
A11	29.33	0.00026	0.16	0.47	0.095
A12	16.38	0.00016	0.09	0.20	0.069
A13	26.68	0.00022	0.14	0.12	0.078
A14	26.02	0.00021	0.13	0.14	0.076
A15	39.83	0.00078	0.23	0.15	0.285
Mean	28.97	0.00027	0.15	0.18	0.098

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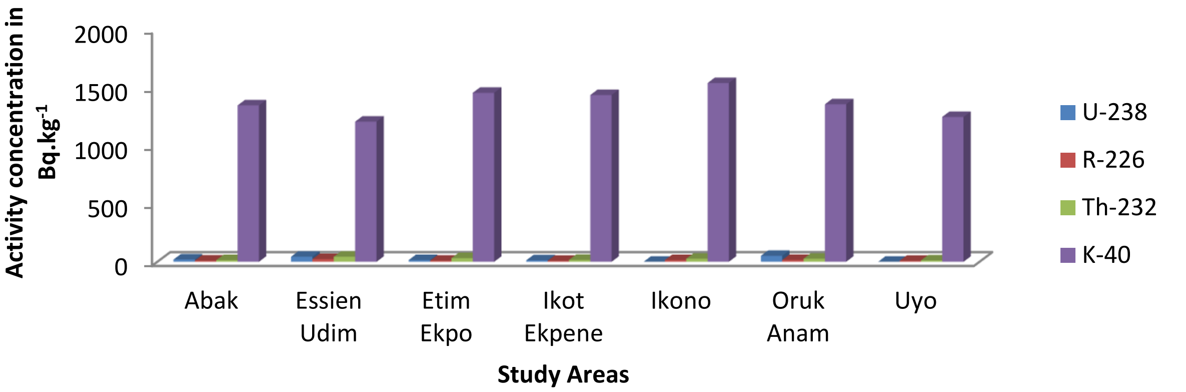

Figure 2: Distribution of the mean activity concentration in Bq.kg^{-1} of the fluted pumpkin samplesfrom the study areas.

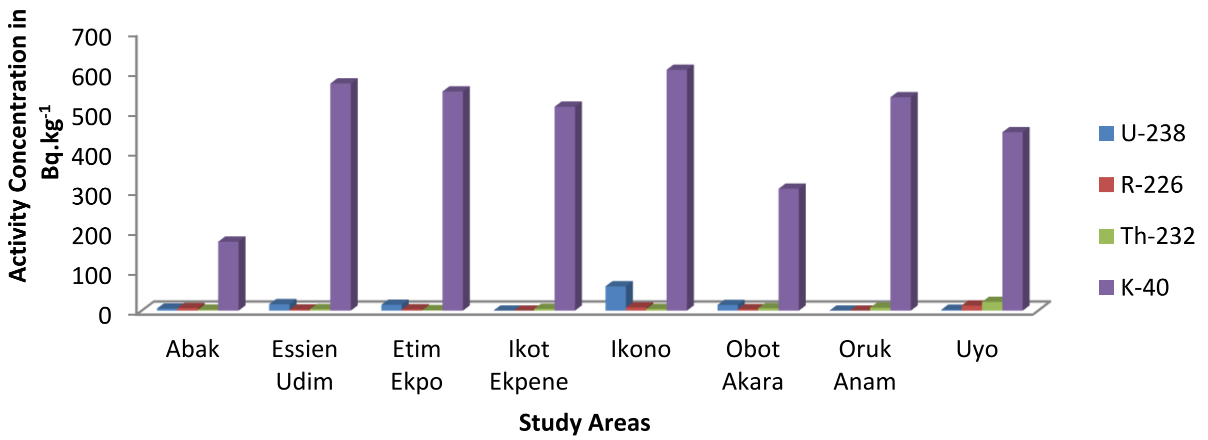

Figure 3: Distribution of the mean activity concentration in Bq.kg^{-1} of the Afang samplesfrom the study areas.

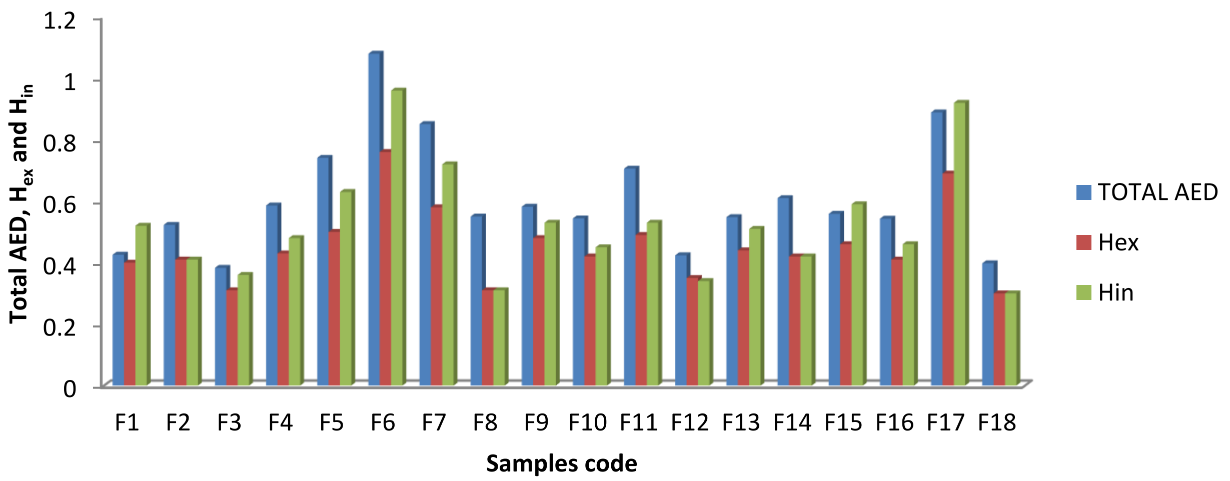

Figure 4: Distribution of the total AED (μSv.yr^{-1}), H_{ex} and H_{in} of the fluted pumpkin samplesfrom the study areas.

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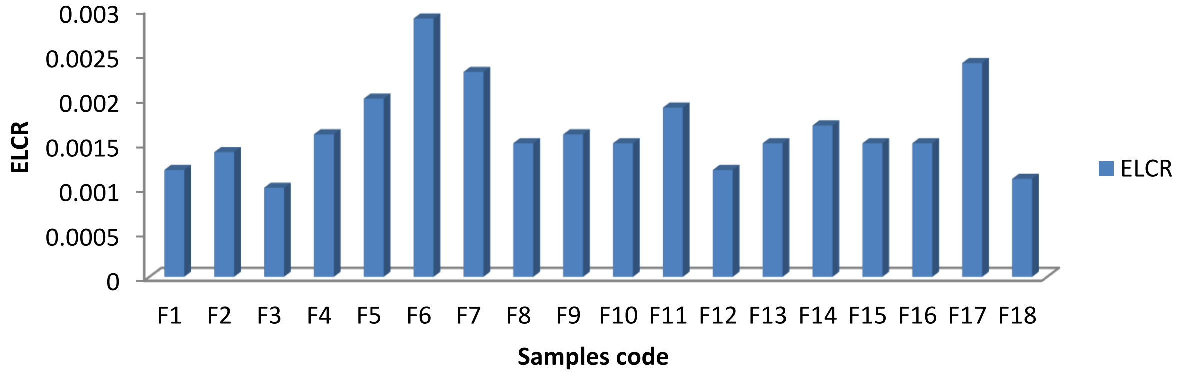

Figure 5: Distribution of the excessive life time cancer (ELCR) risk of the fluted Pumpkin samplesfrom the study areas.

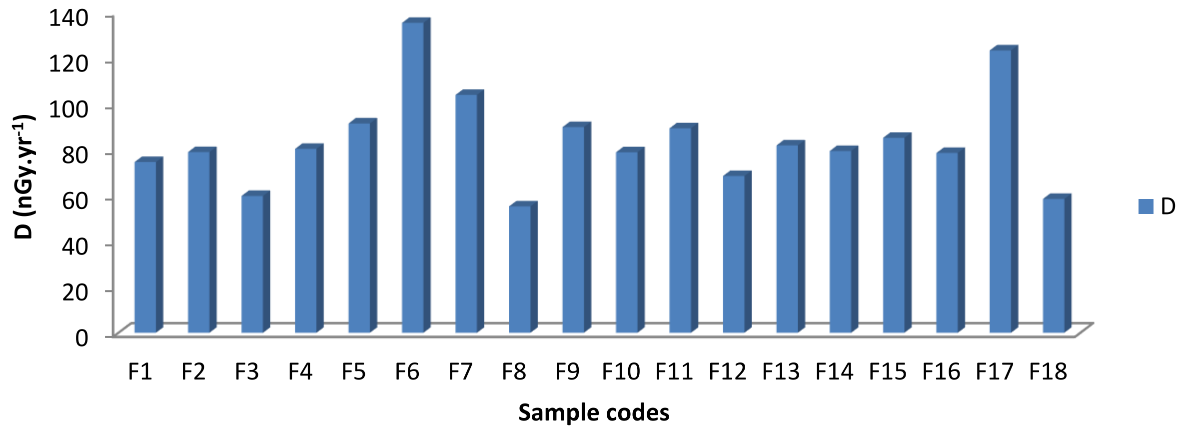

Figure 6: Distribution of the gamma dose rate (nGy.yr^{-1}) of the fluted Pumpkin samples from the study areas.

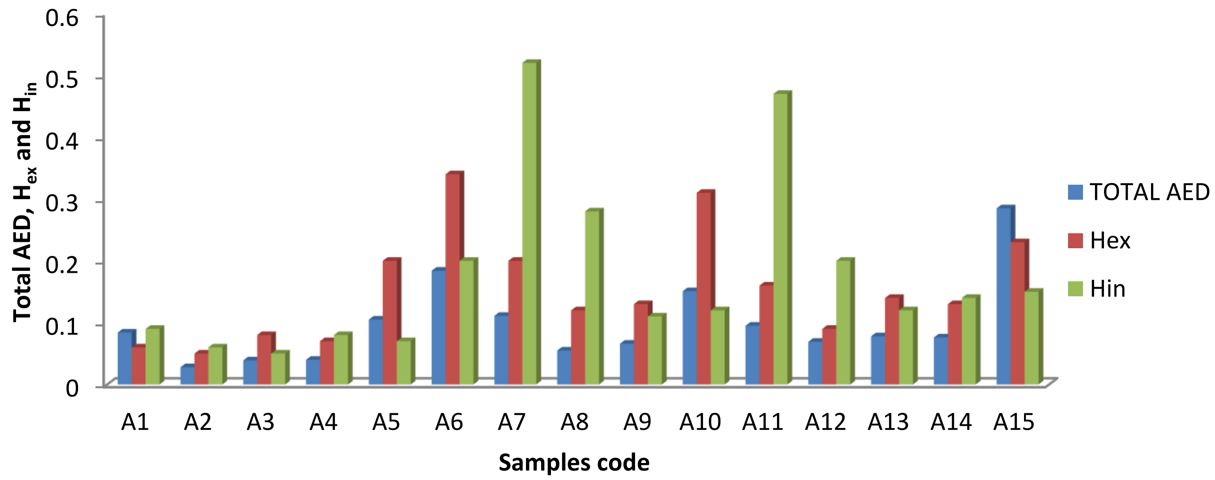

Figure 7: Distribution of the total AED (μSv.yr^{-1}), H_{ex} and H_{in} of the afang samples from the study areas.

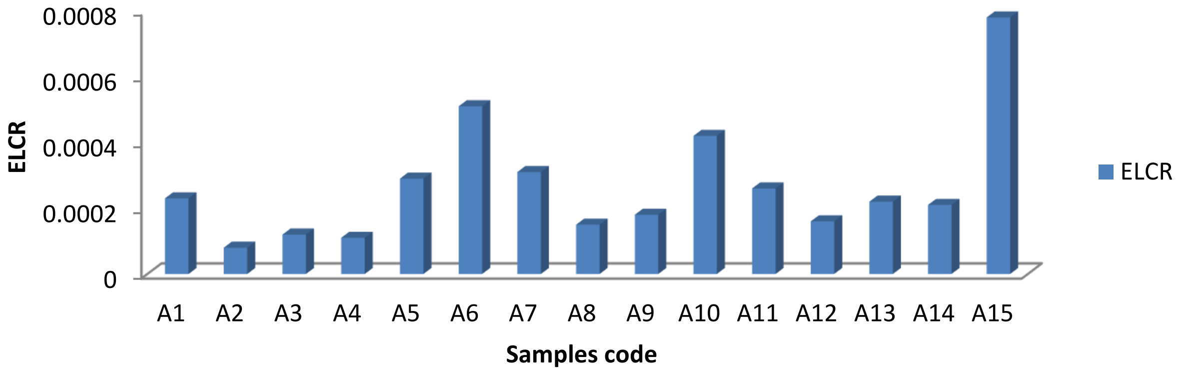

Figure 8: Distribution of the excessive life time cancer (ELCR) risk of the afang samplesfrom the study areas.

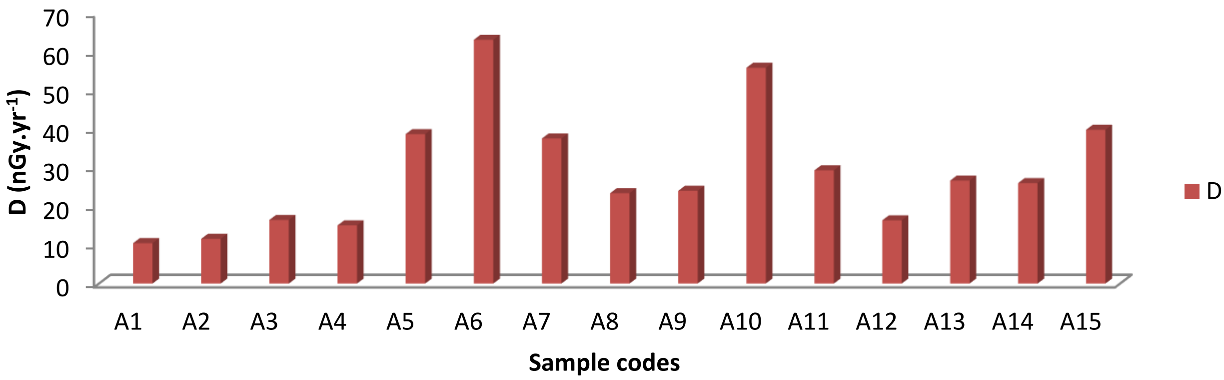

Figure 9: Distribution of the gamma dose rate (nGy.yr^{-1}) of the afang samples from the study areas.

3.3 Correlation Studies

Figures 10 and 11 show the correlation between H_{ex} and H_{in} of fluted pumpkin and afang samples respectively from study areas.

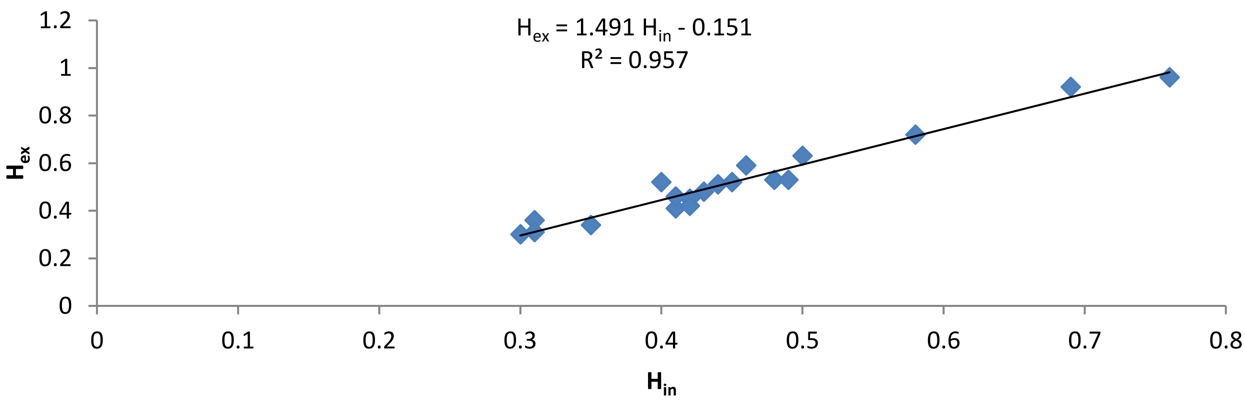

Figure 10: Correlation between H_{ex} and H_{in} of fluted pumpkin samples from study areas

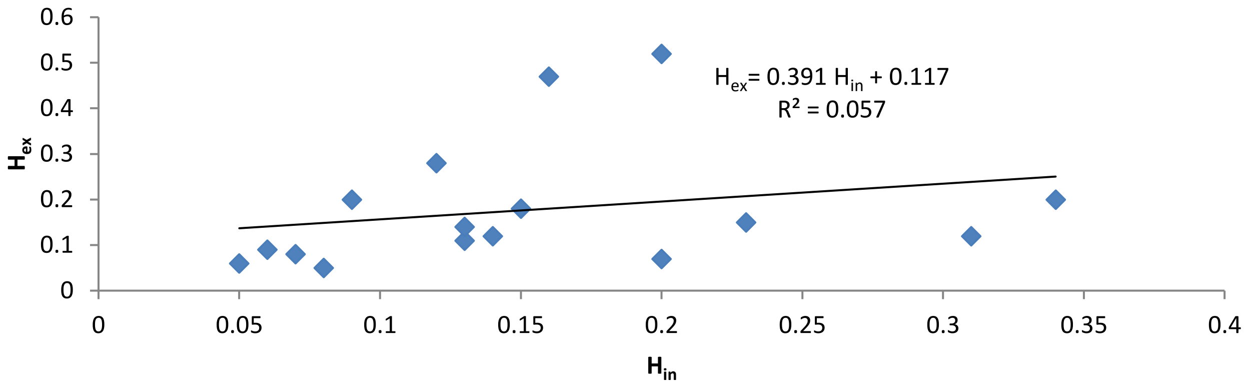

Figure 11: Correlation between H_{ex} and H_{in} of afang samples from study areas

3.4 Discussion

Results for activity concentration (AC) of radionuclides in fluted pumpkin leaves are presented in Table 1 according to locations sampled in each LGA. Activity concentration of potassium (^{40}K) ranged from 805.28 ± 42.89 Bq/Kgto 1582.93 ± 83.72Bq/Kg. The range of AC for ^{238}U was between BDL to 86.96 ± 5.63Bq/Kg, while AC of ^{232}Th ranged from 4.81 ± 0.84 Bq/Kgand 65.32±3.59Bq/Kg. Activity concentration of ^{226}Ra ranged between 6. 90±0.81Bq/Kgand 28.23± 2.03Bq/Kg. Mean AC values were 26.34 ± 2.36Bq/Kg, 13.80 ± 1.22Bq/Kg, 26.44 ± 1.77Bq/Kg and 1349.58 ± 71.35Bq/Kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K, respectively. These results show a relatively higher rate of deposition of potassium in fluted pumpkin leaves compared with absorption of other radionuclides. Occasional use of pesticides to control pests by farmers, as was admitted to by farmers in some of the sample locations could also add to the radionuclide levels in the pumpkin leaves. It is an established fact however, that potassium is an essential elemental requirement for plant growth that is abundantly available in the environment[20] [21].

Results for AC in afang leaves are presented in Table 2. The AC of radionuclides in afang leaves ranged from BDL to 64.55±5.94Bq/Kg, BDL to 25.59±2.46Bq/Kg, BDL to 36.6±0.71Bq/Kg and 74.58±35.69Bq/Kg to 838.84±37.83Bq/Kg for ^{238}U,^{226}Ra, ^{232}Th and ^{40}Krespectively with mean values of 13.29±1.28Bq/kg, 4.85±0.79Bq/kg, 6.80±0.45Bq/kg and 459.65±25.64Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. Whereas ^{40}K was detected in all of the 15 afang leaf samples collected, ^{238}U was below detection level (BDL) in about 6 samples and not detected (ND) in 2 samples, ^{226}Ra was BDL in 2 samples and ND in 5 samples, while ^{232}Th was BDL in 2 samples. Values of AC of radionuclides in afang leaf samples were lower compared to values obtained for fluted pumpkin leaves, even with AC of the radionuclides in the corresponding soil being comparatively lower than in the leaf samples. This suggests that the quantity of transferred radionuclide to plant may not be directly proportional to the quantity of the radionuclide present in the soil[20] [21]..

The estimated values of Absorbed dose D, Excess lifetime cancer riskELCR, External hazard index H_{ex},Internal hazard index H_{in}, Annual effective dose (AED) due to consumption of fluted pumpkin are presented in Table 4 for each individual sample of fluted pumpkin. The absorbed dose of fluted pumpkin samples from various farms ranges between 55.17nGy.y^{-1}and 135.34nGy.y^{-1}with a mean of 79.05nGy.y^{-1}. It is observed that individual fluted pumpkin sample and the mean had values that exceeded the recommended reference limit of 55nGy.y^{-1} [1].Values for ELCR which is the risk that one might develop cancer in a lifetime due to consumption of fluted pumpkin leaves ranged between 0.0011 and 0.0029, with a mean of 0.0024.These are within the world reference limit of 0.0029 [1]. The estimated annual effective doses due to consumption or ingestion of fluted pumpkin ranged from 0.398μSv.y^{-1} to 0.851μSv.y^{-1} with mean of 0.608μSv.y^{-1}, these values are well below the recommended reference level of 1000μSv.y^{-1}or 1mSv.y^{-1} (UNSCEAR, 2000; IAEA Report, 1994). H_{ex} ranged from 0.30 to 0.76 with a mean of 0.45 while H_{in} ranged from 0.398 to 0.851 with mean of 0.608 these are within the world reference limit of 1 [1].

The estimated values of 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 afang are presented in Table 5 for each individual sample of afang leaves. The absorbed dose in afang leaf samples from various farms ranges between 10.44nGy.yr^{-1}and 63.14nGy.yr^{-1} with a mean of 28.97nGy.yr^{-1}. It was observed that only one afang sample A6 from Essien Udim LGA had value of absorbed dose above the reference value this could be attributed to the amount radionuclide present in the sample. All other afang samples and their mean had values of D within the world reference limit.Estimated values of ELCR due to consumption of afang leaves ranged between 0.00008 and 0.00079 with a mean of 0.00027, these values are within the recommended limit.The estimated annual effective doses due to consumption of afang leaves ranged from 0.028µSv.y^{-1} to 0.285µSv.y^{-1} with mean of 0.098µSv.y^{-1} these values are well below the recommended reference limit. $H_{ex}$for the afang samples ranged from 0.05 to 0.34 with a mean of 0.15 while H_{in} ranged from 0.020 to 0.52 with mean of 0.18 these values are all within the world reference limit [1].

4. CONCLUSION

The mean activity concentration of ^{238}U, ^{226}Ra and ^{232}Th in afang were within permissible maximum values except for fluted pumpkin which had mean AC of ^{238}U and ^{232}Th slightly above their reference limits, with highest concentration from farmlands in Ikono, Ikot Ekpene and Etim Ekpo LGAs. Fluted pumpkin had value of absorbed dose above permissible limit while that of afang were within permissible limits. Excess lifetime cancer risk (ELCR), External hazard index (H_{ex}), Internal hazard index (H_{in}), Annual effective dose (AED) due to consumption of fluted pumpkin leaves and afang leaves were all within permissible maximum values.

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ISSN 2350-1030

International Journal of Recent Research in Physics and Chemical Sciences (IJRRPCS)
Vol. 9, Issue 1, pp: (26-37), Month: April 2022 – September 2022, Available at: www.paperpublications.org

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