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RADIOLOGICAL HEALTH RISK DUE TO CONSUMPTION OF CASSAVA FROM NIGERIAN GOVERNMENT FARMS

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ABSTRACT

Assessment of radionuclide contamination of food crops is of great importance for the protection of human health. The activity concentration of radionuclides in cassava food crop which is a dietary importance to the population that relies on the fertilized agricultural farm has been determined using gamma ray spectroscopy. The mean activity concentration of ^{226}Ra ranges from Bdl to 60.13 ±6.83 Bqkg^{-1}, ^{232}Th ranges from 576.13±2.85 to 955.46 ±2.33 Bqkg^{-1} and ^{40}K ranges from 403.91 ±18.00 to 795.53±9.96 Bqkg^{-1}. These values are above the average values of 8 (1-9) Bqkg^{-1} for ^{226}Ra, 3 (2-10) Bqkg^{-1} for ^{232}Th and 50 (25-75) Bqkg^{-1} for ^{40}K respectively. The study also revealed that the total effective dose for adult citizens from consumption of cassava is 1.93 Svy^{-1} which exceeds the annual limit of 1 mSv for the public. The cancer risk and hereditary cancer effect due to consumption of cassava from fertilized farms estimated shows that 1 out of 10,000000 population will probably develop cancer while 48 out of 10,000000 population might have the hereditary cancer effect. The lifetime cancer risk estimated value shows that only 0.27 out of 10,000000 population will develop lifetime cancer and hereditary effect. This is a potential health risk to the inhabitants and domestic animals which depend on cassava from fertilized farms for food in the area. The study therefore underlines the need for more research on the transfer ratio of the radionuclide and their reduction coefficient to gain more insight into the radiological risks.

***Keywords*: Radioactivity, Cassava, health risk, hereditary effect, Cancer risk, Effective dose.**

INTRODUCTION

Studies on the radioactivity of consumable parts of a vegetable have assumed importance as it is necessary in the estimation of the ingestion dose to the public (Addo *et al*., 2013; Shanti *et al*., 2009). The status of the soil on which food crops are grown determines the quality of foodstuff produced (Jibiri and Abiodun, 2012). Currently there is the need to increase food production to ensure food security for the growing world population. Due to this important need of man, chemical fertilizers are employed in agriculture not only to reclaim land but also to enhance crop yield (Alharbi, 2013) mostly in government owned farms. The application of phosphate fertilizer globally for increased crop production and land reclamation has risen to more than 30 million tons annually (El-

Tahor and Abbady, 2012).

The major raw materials for the production of chemical fertilizers are therefore such as would supply the essential nutrients necessary for plant growth. These nutrients are Nitrogen, Phosphorus and Potassium. ^{238}U, ^{232}Th and ^{40}K are three long-lived naturally occurring radionuclides present in the earth crust (Saleh *et al*., 2007). They are also present in fertilizers made from the phosphate ore, biotic system of plants, soil, water and air and have significant contributions in ingestion dose (Addo *et al.,* 2013). The uptake of radionuclide by plant varies from species to species and also from place to place. The intake of different food products therefore forms a secondary source of variability in radionuclide concentration ingestion. Distribution of radionuclides in different parts of the plant depends on the chemical characteristics and several parameters of the plants and soil (Shanti *et al.,* 2009).

The uptake of radionuclides by plant roots constitutes the main pathway for the migration of radionuclides from the soil to humans, via food chain. This edible root crop exhibits greater root absorption of radionuclide than through the trapping onto external plant surfaces though there is some level of atmospheric capture (Rezoanul *et al*., 2014). It varies significantly in size from 15 to 100 cm as well as in weight from 0.5 to 2.0 kg (Alsaffar *et al.,* 2015). Cassava (*Manihot esculenta*) represents about 50% of all calories consumed in sub-sahara Africa (Long *et al*., 2017) and is the third most important source of calories in the tropics (FAO, 2008).

The radioactivity level in soil can be used to show the magnitude of contamination in locally grown food crops, but it cannot describe the biological effects of radiation exposure to individuals who consume that food (Tawalbeh *et al.,* 2012). Therefore the estimation of doses is usually carried out for assessing health safety of an individual undergoing radiation exposure through ingestion of contaminated food. The intake of radionuclide within food is dependent on the concentration of radionuclides in various food crops and on the food consumption rates. The risks associated with an intake of radionuclides in the body are proportional to the total dose delivered by radionuclides while staying in various organs (Ononugbo Avwiri and Tutumeni, 2016).

The internal exposure is always preceded by incorporation of radionuclides into the human body. This can occur mainly by inhalation of contaminated air or ingestion of contaminated water and food. Effective dose in food stuffs is a useful concept that enables the radiation doses from different radionuclides and from different types and sources of radioactivity to be added (Addo *et al*., 2013). This is based on the risks of radiation induced health effects and the use of the International Commission on Radiological Protection (ICRP) metabolic model that provides relevant conversion factors to calculate effective doses from the total activity concentrations of radionuclides measured in foods (ICRP, 1996). Estimates of the radiation induced health effects associated with intake of radionuclides in the body are proportional to the total dose delivered by the radionuclides while resident in various organs. Radionuclide intake is activity concentration of radionuclides multiplied by dietary intake (masses of food consumed over a period of time (Akinloye et al., 1999). The mean annual consumption of cassava per capita is 102 kg in Nigeria (FAO,

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2012).

Ingestion and inhalation are the main pathways through which natural radionuclides enter into human body. According to Tawalbeh et al. (2012) ingested radionuclide could be concentrated in certain parts of the body, for example, chemical uranium toxicity primarily affects the kidney, causing damage to the proximal tubule. This metal has also been identified as a potential reproductive toxicant (Ononugbo and Anyalebechi, 2017). Internal human exposure to radionuclides can lead to radiological health risk to the individual such as weakening of the immune system, induction of cancers and other various radiation related sicknesses which increases the mortality rate (Tawalbeh *et al.,* 2012). Hence the need for this study which aimed at determining the radiological health risks due to consumption of edible cassava crop from government farms in the area.

MATERIALS AND METHODS

Study area

The study area includes the cities of Agbor, Ogwashi-Uku, Ibusa and Igbodo, of Delta state, Nigeria. Agbor lies between Longitudes 6°25'N and Longitude 6°19'E. Ogwashi-Uku lies between Latitude 6 °18'N and Longitude 6°52'E, Ibusa lies within latitude 6°10'N and 6°37' while Igbodo is between 6°18'N and 6°22'E as shown in Figure 1. Delta State is under the Niger Delta Structural Basin, it has three major sedimentary cycles which have occurred since the early Cretaceous. The sub-surface stratigraphic units associated with the cycles are, the Benin, the Agbada and the Akata Formations. The surface rock throughout the state consists of the Ogwashi-Ukwu formation. The Benin formation is about 1800m and has free, unconsolidated sands. Agbor and Igbodo lie within this formation, previously known as the Coastal Plain sands. It spans over a considerable portion of the coastal region of Nigeria, adjacent to the Deltaic Plain Sediments. The formation generally consists of unconsolidated sandy beds and clay-lenses (Ononugbo 2019). The Agbada Formation which consists of sandstone and shales has an abundance of hydrocarbons. It is about 3000m and is underlain by the Akata Formation. The Ogwashi-Asaba formation that underlies the north-east consists of a transposition of lignite seams and clay. The vegetation of the area is under the savannah vegetation.

Sample Collection and Preparation

Twelve samples of cassava tubers were collected from government farms (fertilized farms) and individual cassava farms using plastic trowel in Delta State. All samples were washed and sliced into bits, sun dried and then oven dried at 80 °C until a constant weight is reached. Each sample was crushed and sieved using mortar and sieve mesh (2mm) and kept in marinelli container that has been washed, rinsed with dilute Hcl and dried previously. The crushing and sieving was crucial for achieving homogeneous state of the sample (Jwanbot et al., 2012). The marineli containers and its contents were hermetically sealed for 28 days to allow a sufficient time for ^{238}U and ^{232}Th to attain a state of secular equilibrium with their corresponding progenies before gamma spectroscopy.

Gamma Spectrometric Analysis

The specific activity concentration of radionuclide (^{226}Ra, ^{232}Th and ^{40}K) was measured using gamma ray spectroscopy method. The measuring system consists of a scintillation detector sealed with a photo-multiplier tube and connected through a preamplifier base to a Canberra series 10 and multi -channel analyzer (MCA). The detector is a 2″ x 2″ NaI(TI) model. The detector has a resolution of about 8% at 0.662 MeV of ^{137}Cs. The detection energy calibration of the system was carried out using reference standard source (IAEA-444) prepared from the Radiochemicals centre, Amersham, England. The digiBase is connected to a computer where data collection and analysis are carried out using ORTEC MAESTRO -32 software(IAEA, 2003).

The 1460 keV gamma radiation of ^{40}K was used to determine the concentration of ^{40}K in the sample. The gamma transition energy of 1764.5 keV of ^{214}Bi was used to determine the concentration of $^{226}Ra(^{238}U)$ while the gamma transition energy of 2614 keV of ^{208}TI was used to determine the concentration of ^{232}Th. The efficiency calibration was done using standard reference source (IAEA-375) whose energies and activities are known (Alexander Nwankpa, 2017). The same geometry was used to determine peak area of samples and references. Each sample was measured during an accumulation time of 36,000s. The activity concentrations were calculated based on the weighted mean value of their respective decay products in equilibrium. The background counts were determined by counting an empty container of the same dimension as those containing the samples. The activity content of the samples was evaluated by the net area under the photo peaks using 1.

$$A_c = \frac{C_n}{P\gamma\, M\, \varepsilon} \qquad 1$$

Where A_c is the activity concentration in $Bqkg^{-1}$, C_n is the net count rate under the corresponding peak which can be written as ($C_n = C_T - C_B$; C_T = gross count rate for the specific γ peak and C_B= count rate for the corresponding γ peak), Pγ is the absolute transition probability of the γ -ray. M is the mass of the sample (kg) and ε is the detector efficiency at the specific γ-ray energy.

The maestro software program automatically searches for the peak, evaluates the peak position in energy, identifies the radionuclide by the use of nuclide library. It calculates the net peak areas, subtracts the background count and displays the activity concentration in selected units.

Annual effective dose due to ingestion of cassava

The effective dose E (Svy^{-1}) due to intake of a radionuclide with the ingested material is calculated using the following expression (Addo *et al.*, 2013; Hamideen and Sharaf , 2012):

$$E\ (Svy^{-1}) = C \sum A_i \times DCF_i \qquad 2$$

Where C (kgy^{-1}) = mean annual consumption of food stuff, Ai ($Bqkg^{-1}$) = activity concentration of radionuclide I in the ingested food and DCFi ($SvBq^{-1}$) = dose coefficients for radionuclide i.

Ideally the summation over i should include all the radionuclides present in the ingested material, so the three most important radionuclide which was identified in the samples are considered in thecalculation. The ICRP (2012) values of ingestion coefficient for ^{226}Ra, ^{232}Th and ^{40}K radionuclides for age groups above 17 years are 2.8 E-07, 6,2E-07 and 6.2 E-09 $SvBq^{-1}$ respectively.

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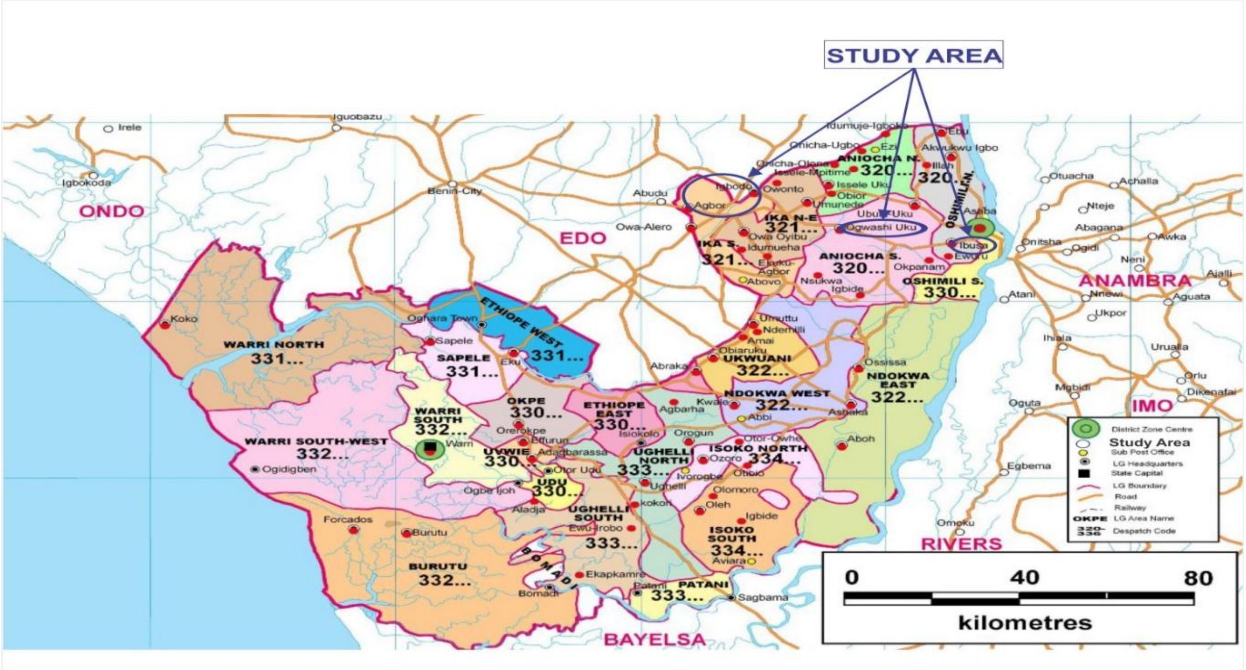

Figure 1: Map showing the study Area (Source: Delta State Medium Term Development Plan (DSMTDP; 2016-2019)

Cancer Risk and Hereditary Effects

The cancer risk and hereditary effect due to low dose without any threshold doses known as stochastic effect were estimated using ICRP, (2012) cancer risk assessment method:

Cancer Risk = Total Annual Effective Dose (Sv) X Cancer Risk Factor ($0.05Sv^{-1}$)3

Hereditary Effect =Total Annual Effective Dose (Sv) X Hereditary Effect Factor 4

Severe hereditary effect in adult per year = Total effective dose X $0.2 \times 10^{-2} s\upsilon^{-1}$

Estimated lifetime hereditary effect in adult is = Total effective dose x 70 x 0.002

Radium Equivalent Dose (Raeq)

The radium equivalent (Ra_{eq}) activity represents a weighted sum of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in sediment samples which allows comparison with their individual ^{226}Ra, ^{232}Th and ^{40}K activity concentration(Suregandhi *et al.,* 2014) . It is based on the estimation that 1 Bq kg^{-1} of ^{226}Ra, 0.7 Bq kg^{-1} of ^{232}Th and 13 Bq kg^{-1} of ^{40}K produce the same radiation dose rates. The radium equivalent activity index was estimated using the relation (Avwiri *et al*., 2013).

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad 5$$

Where C_u, C_{Th} and C_K are the activity concentration in $Bqkg^{-1}$ or Bql^{-1} of ^{226}Ra, ^{232}Th and ^{40}K.

RESULTS

The activity concentration of radionuclides in cassava crop from selected fertilized government farms are presented in Table 1 with calculated radium equivalent doses. Table 2 presents that estimated effective doses due to ingestion of cassava crops and its associated cancer risks and hereditary effects.

Table 1: Specific Activity Concentration of ^{40}K, ^{226}Ra and ^{232}Th in cassava crop Samples from

S/N	Sample crop location	Sample code	GPS Position	Activity concentrations ($Bqkg^{-1}$)			Raeq $Bqkg^{-1}$
				^{40}K	^{226}Ra	^{232}Th	
1	Ministry of Agriculture, Agbor	CMOA 1	N: 6˚15□37□□.0075 E:6˚11□16□□.29683	455.89 ± 14.72	60.13± 6.83	792.61 ± 2.53	1228.67
2	Ministry of Agriculture, Agbor	CMOA 2	N:6˚15□34.48112 E: 6˚11□16□□.57248	654.11 ± 11.07	6.33±2.99	819.91 ± 2.60	1229.17
3	Ministry of Agriculture, Agbor	CMOA-3	N:6˚15□29.38142 E: 6˚11□15.45835	443.80 ± 12.32	12.10 ± 8.67	776.03 ± 2.53	1156.00
4	Ministry of Agriculture, Agbor	CMOA 4	N: 6˚15□ 40.235 E: 6˚11□16□□.39362	534.45 ± 13.19	33.71± 6.66	833.56 ± 2.63	1266.85
5	Ministry of Agriculture, Agbor	CMOA-5	N:6˚15□ 29.334 E:6˚11□16□□.46425	544.11± 11.79	26.99 ± 6.72	930.10 ± 2.40	1398.93

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6	Ministry of Agriculture, Agbor	CMOA 6	N: 6˚15□ 35.434 E:6˚11□16□□.5 4682	753.22 ± 10.12	BDL	576.13 ± 2.85	887.05
7	ADP Illoh	C- Illoh 1	N: 6˚6□ 4.90612 E: 6˚31□56.33285	505.44± 15.59	10.66± 7.62	848.19±2.47	238.60
8	ADP Illoh	C-Illoh 2	N: 6˚6□ 5.07892 E: 6˚31□56.46072	795.53± 9.96	13.54± 6.23	826.74±2.39	1262.49
9	ADP Ibusa	C-Ibusa 1	N: 6˚11□ 1.58359 E: 6˚39□ 7□.85948	403.91 ± 18.00	26.99 ± 7.46	814.06 ± 2.48	1257.03
10	ADP Ibusa	C-Ibusa 2	N: 6˚11□ 1□□.59473 E:6˚39□ 7□.73865	564.67 ± 14.93	28.43 ± 6.23	955.46 ±2.33	1222.20
11	ADP Igbodo	M-Idumu1	N: 6˚18□4.99745 E: 6˚23□5.24733	472.81± 10.26	24.59 ±10.87	918.40 ± 2.46	1438.22
12	ADP Igbodo	M-Idumu2	N 6180.94656 E 6230.43534	546.54±10.77	25.07±10.87	800.41±2.47	1211.74
		Average		746.08±0.48	24.83±10.87	859.41±2.47	1324.98
13	Control		N 6.2541 E6.20570	300.12±2.35	16.04±4.07	378.21±3.10	579.99
14	Control		N.264092	220.30±0.21	10.48± 2.11	312.15± 5.23	473.82

BDL = Below detectable limit E6.201883

Table 2: The Mean Specific Activities, Effective Doses and Cancer Risks for Cassava Ingestion

s/n	Activity conc. ($Bqkg^{-1}$)			Effective dose (Svy^{-1})			Total	Cancer Risk and Hereditary Effect		
	^{40}K	^{226}Ra	^{232}Th	E_K	E_{Ra}	E_{Th}	E	CR	HE	LHE
1	455.89	60.13	792.61	0.0034	4.545	0.229	4.78	0.238927	119.4636	0.668996
2	654.11	6.33	819.91	0.0049	0.478	0.237	0.72	0.036046	18.02311	0.100929
3	443.8	12.1	776.03	0.0033	0.914	0.225	1.14	0.057141	28.57036	0.159994
4	534.45	33.71	833.56	0.0040	2.548	0.241	2.79	0.139689	69.8443	0.391128
5	544.11	26.99	930.1	0.0041	2.040	0.269	2.31	0.11569	57.84518	0.323933
6	753.22	0	576.13	0.0056	0	0.166	0.17	0.008627	4.313641	0.024156
7	505.44	10.66	848.19	0.0038	0.805	0.246	1.06	0.052766	26.38306	0.147745
8	795.53	13.54	826.74	0.0059	1.023	0.239	1.27	0.06345	31.72524	0.177661
9	403.91	26.99	814.06	0.0030	2.040	0.236	2.28	0.113957	56.97852	0.31908
10	564.67	28.43	955.46	0.0042	2.149	0.276	2.43	0.121508	60.75411	0.340223
11	472.81	24.59	918.4	0.0035	1.858	0.266	2.12	0.106423	53.21132	0.297983
12	546.54	25.07	800.41	0.0041	1.895	0.231	2.13	0.106556	53.27798	0.298357
AV.							**1.93**	**1.1512748**	**48.3658684**	**0.2708488**

CR = cancer Risk, HE = Hereditary cancer Effect, LHE = Lifetime Hereditary cancer Effect

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DISCUSSION

Specific Activity Concentration in Cassava crop

The activity concentration of radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in Cassava crop as presented in Table1 show that activity concentration of ^{226}Ra ranges from BDL to 60.13±6.83 $Bqkg^{-1}$ with a mean value of 24.83±10.87 $Bqkg^{-1}$ and activity concentration of ^{232}Th ranges from 576.13±2.85 to 955.46 ±2.33 $Bqkg^{-1}$ with mean value of 859.41 ±2.47 $Bqkg^{-1}$ while activity concentration of ^{40}K ranges from 403.91 ±18.00 to 795.53±9.96 $Bqkg^{-1}$ with mean value of 746.08±0.48 $Bqkg^{-1}$. These mean values were higher than the average values of 8(1-9) $Bqkg^{-1}$ for ^{226}Ra, 3(2-10) $Bqkg^{-1}$ for ^{232}Th and 50(25-75) $Bqkg^{-1}$ for ^{40}K respectively (UNSCEAR,2000; Alexander Nwankpa, 2017).

The higher activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K observed in all the samples may be attributed to the heavy use of NPK fertilizer by the ministry of agriculture to improve crop yield of the soil as a result of several decades of farming which has reduced soil fertility (Addo *et al.,* 2013). This could also be due to poor retention of radionuclide in the soil where this cassava was harvested. Cassava, a root crop exhibits greater root absorption of radionuclide than through the trapping onto external plant surfaces as well as atmospheric capture (Jwanbot *et al.*, 2012).

It can be observed from Table 1 that radionuclides show varying concentrations in the three different government farms studied. The lowest activity concentration of ^{226}Ra of below detectable limit (BDL) was observed in the sample collected from sloppy part of ministry of agricultural farm in Agbor which might be linked to the topography of the area. Fertilizer application might not favor sloppy area due to run-offs during rain falls. The activity concentration of ^{232}Th in the samples was too high to be compared with the standard value and control values. The highest activity concentration of 955.46±2.33 $Bqkg^{-1}$ was recorded in a sample from ADP Ibusa. Literature has shown that there are higher concentrations of ^{232}Th in the roots than other parts. Roots generally acts as a natural barrier to radionuclide transport in upper plant parts (Chen *et al.*,2005). It also shows that the geological component of the area is rich in thorium as indicated in the control sample from private farm in the area.

The concentration of ^{40}K in all the samples was found to be very high compared with ^{226}Ra and an indication of the poor migration characteristics of ^{226}Ra from the substrate to the cassava crops. Potassium is a macronutrient, so the concentration may be very high. It may be expected that the soil characteristics favour the immobilization of potassium and thorium and their subsequent migration into the plant (Shanti *et al.*, 2009). The concentration values of the radionuclides were higher than what Jwanbot *et al*. (2012), Jibiri and Abiodun, (2012) and Addo *et al.* (2013) observed for cassava crops at Jos-Plateau, Abeokuta and Osun which is regarded as high radiation areas in Nigeria respectively and Ghana. The trend in radionuclide concentration shows similar trend as in the soil samples from three different fertilized government farms. This could mean similar uptake of the radionuclide from soil by the cassava roots having the same topography, chemical constituent and other physical conditions.

The radium activity concentration as shown in Table 1 ranges from 238.60 to 1438.22 $Bqkg^{-1}$ with a mean value of 1324.98 $Bqkg^{-1}$. These values are higher than the value recorded in the control samples which range from 473.82 to 579.90 $Bqkg^{-1}$.

Annual Intake of Radionuclide and Effective Doses for Cassava Ingestio

In this study the calculation of individual doses and risks from ingestion pathways carried out were based on the assumption that all food is consumed at the point of production and that the required amount of food is produced in the given location (Addo *et al*., 2013). On the whole the effective dose due to ingestion of cassava in the soil at various government farms was higher than the values in the control samples. The average total annual effective dose from ingestion of cassava from the fertilized government farms was 1.93 Svy^{-1} (Table 2). It can be seen that the dose estimated from cassava ingestion are all higher than the annual dose limit of 1.0 $mSvy^{-1}$ for the general public. These higher doses could be attributed to fertilizer application in those studied farms that has enhanced the concentration of radionuclide in the soil of the study area and also higher transfer ratio of these radionuclides as shown in Ononugbo *et al*., (2019). The higher concentration of radionuclide in the soil which has translated to higher doses observed in this study could also be from the geological constituent of the farms under study. The total mean effective dose obtained in this work is far higher than the values of 0.66 μSvy^{-1} obtained in cassava in Osun by Alexander Nwankpa, (2017) and 1.23 $mSvy^{-1}$ obtained in cassava from Ghana by Addo *et al*. (2013). The higher values of effective dose obtained in this study could mean a potential health risk to both rural dwellers and urban dwellers that depend on such cassava crops.

The cancer risk and hereditary cancer effect due to consumption of cassava from fertilized farms estimated shows that 1 out of 10,000000 population will probably develop cancer while 48 out of 10,000000 population might have the hereditary cancer effect. The lifetime cancer risk estimated shows that only 0.27 out of 10,000000 population will develop lifetime cancer and hereditary effect.

This is a potential health risk to the inhabitants and domestic animals which depend on cassava for food in the area.

The study therefore underlines the need for more research on the transfer ratio of the radionuclide and their reduction coefficient to gain more insight into the radiological hazards risks. Stake holders and other government agency should educate the inhabitant on the best farm practices basically on the use of organic manure instead of fertilizer in order to reduce radiological health risk to as low as reasonably practicable.

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