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Determination of Activity Concentrations and Soil to Cassava Transfer Factors of Natural Radionuclides in Ikot Ekpene Local Government Area, Akwa Ibom State, Nigeria

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Author's contribution

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Natural radioactivity exists in primordial formations such as rocks, soils, water and air where long lived radionuclides such as ^{238}U, ^{232}Th, ^{40}K and their affiliates are found. This work was done to determine the specific activity of radionuclides, soil to cassava transfer factor and the effective dose due to consumption of radionuclide in cassava products in Ikot Ekpene Local Government Area, Akwa Ibom State. The specific activity of ^{40}K, ^{238}U and ^{232}Th in soils and cassava in the study area was measured using gamma spectrometry. Mean specific activity in soils ranged from BDL to 153.46 ± 10. 99 Bq/Kg for ^{40}K; BDL to 31. 22 ± 7.49 Bq/Kg for ^{238}U and 1.03 ± 0.10 to 12.71 ± 1.24 Bq/Kg for ^{232}Th. Mean specific activity of the radionuclides in cassava in all locations ranged from 119.86 ± 8.61 to 601.28 ± 43.23 Bq//Kg for ^{40}K; below detectable limit (BDL) to 15. 89 ± 1.55 Bg/Kg for ^{238}U and BDL to 15. 89 ± 1.55 Bq/kg for ^{232}Th. Transfer factors ranged between 3.64 to 4.18 for ^{40}K; 1.30 to 1.82 for ^{238}U and 0.51 to 0.72 for ^{232}Th. Effective ingestion dose due to the consumption of cassava from the area ranged between 0.99 mSv/yr to 1.08 mSv/yr and 2.68 mSv/yr to 29.16 mSv/yr for children and adult respectively. Most of

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the TF and effective ingestion dose results for this study were above the recommended value of unity which suggests that consumption of cassava from the studied area may pose radiological health.

Keywords: Ikot ekpene; soil; cassava; radionuclides; transfer factors; effective ingestion dose; concentration.

1. INTRODUCTION

Natural radioactivity exists in primordial formations such as rocks, soils, water and air where long lived radionuclides such as ^{238}U, ^{232}Th, ^{40}K and their affiliates are found [1]. Cosmogenic radionuclides such as ^{14}C and ^{3}H, also contribute to the natural radioactivity level of our environment [2]. The activities of these radionuclides produce ionizing radiations which irradiate human beings and its environment with its attendant detrimental health effect.

Natural radioactivity concentrations have been measured in food materials like vegetables, fruits, medicinal plants [3]. Evidence also abound on the transfer of these NORMS from soil to food materials planted on it and this serving as a pathway to internal exposure when consumed [4-6].

Cassava (Manihot Esculenta), is a tuberous edible plant that can be used as food, confectionery and as industrial products such as starch, ethanol, etc. The amount of radionuclides that accumulates in the body of a person who consumes this contaminated food material can be determined by measuring the concentration of the radionuclides in the food material by estimating the soil to plant transfer of radionuclide.

It is reported that many factors, natural and physicochemical affect the accumulation of radionuclides in plant and are identified to include; concentration of radionuclides in the soil, soil PH, climate, speciation of radionuclide in soil solution, organic content of the soil, soil type and time [7]. This work is necessary because the information obtained will address the concern of the dearth of data from tropical and sub-tropical ecosystem on the effect of radionuclide in edible plant. However, there is information from some parts of Nigeria on TF for different plants including maize [8,9]. Cassava [7], palm oil and other crops [10].

This study was carried out to measure the specific activity of NORM deposit in the soil and estimation of TF of the radionuclides from soil to cassava in two farmlands in Ikot Ekpene Local Government Area, Akwa Ibom State.

2. MATERIALS AND METHODS

2.1 Location and Geology of the Study Area

Ikot Ekpene lies between latitudes 5.072^0–5.140^0 N and longitudes 7.390^0 –7.458^0 E in Akwa Ibom State, Southeastern Nigeria. It spreads over an area of about 116 km^2. The maximum elevation in the area is of the order of 40 m (amsl) in the north whereas the minimum elevation is of the order of 10 m (amsl) in the south. Vegetation in the study area is of the rain forest type. It is sustained by the tropical climate characterized by high temperature with annual mean of 5.5^0 - 6.5^0C. The maximum daily temperature lies between 28^0 and 30^0C during March and the minimum daily mean temperature lies between 23^0 and 24^0C during July and August [11]. High relative humidity (annual mean of 83%) and high precipitation (250 mm per annum) are prevalent in the area. The area is geologically characterised by coarse-grained sand, gravelly sands with minor intercalation of clays and shales from top to bottom, respectively.

2.2 Sample Collection, Preparation and Analysis

Two cassava farms were selected for this study. Interaction with the farm owners to find out their knowledge of ionizing radiation and its biological effects was conducted. Also, permission to use their farms for this study was obtained. The farms were divided into evenly spaced sites with a distance of 20 m between each site for larger coverage of the farm [12]. At each sampling location, the soil surface was cleared of stones, pebbles, vegetation and roots. A soil sample of 2.0 kg (wet weight) was collected from each position with shovel at a depth of 0.3 m and corresponding cassava samples were collected in three different directions. At each sampling site, about 2 kg cassava (fresh weight) samples were collected. The samples were thoroughly washed with tap water and then in distilled water to remove surface soil. The two sets of samples were each placed into separate polyethylene bags [13].

The collected soil samples were dried, crushed, grounded and passed through a sieve of 1.0mm mesh size. The fine-grained powder of each sample obtained was dried in an oven at a temperature of 110^0 C for 3 days to ensure total removal of moisture. 300g of each dried prepared sample was sealed in a cylindrical plastic container and properly labeled for easy identification. The prepared samples were stored for a period of 30 days to ensure secular radioactivity equilibrium between ^{226}Ra and its short lived daughters. The cuticles of the cassava were removed with a stainless steel knife and the edible parts were cut into pieces and put in polyethylene materials for refrigeration. The cassava samples were freeze-dried for three days and crushed into powder form (flour) using a blender and kept separately in their respective containers. The samples were further screened in 110µm mesh sieve to obtain fine grained powder -sized particles before they were subjected to radioactivity measurement. Samples codification was done for easy identification. Soils in Ufam farms were coded Y_{11} to Y_{55} and Cassava Y_1 to Y_5 while in Obot Ndua farm codes as Z_{11} to Z_{55} and Z_1 to Z_5 were given to soils and cassava samples respectively.

These samples were sent to National institute of radiation protection and research (NIRPR) an affiliate of Nigerian nuclear regulatory authority (NNRA). In the laboratory, the specific activity of ^{238}U, ^{232}Th and ^{40}K were measured using gamma spectrometry system (NaI(Tl)) scintillation detector [13].

2.3 Specific Activity in the Soil Sample

Specific activity of the radionuclides in the analyzed sample is being estimated using equation 1 below [13].

$$c = \frac{N}{\xi t \gamma M} \qquad 1$$

Where M is the mass of the samples measured in Kg, ξ the detector energy dependent efficiency, t is the counting time 36,000 s (10 hrs), γ is the gamma ray yield per disintegration of the nuclides and N is the net peak area of the nuclide. The 1.460 MeV photopeak was used for the measurement of ^{40}K, the 1.760 MeV photopeak was used for the measurement of ^{238}U, while the 2.614 MeV photopeak was used for the measurement of ^{232}Th.

2.4 Transfer Factor (TF)

The soil to plant transfer factor depends on the activity concentration of the radionuclides in soil and plant and is calculated according to equation 2 [10].

$$TF = \frac{A_p}{A_s} \qquad 2$$

where A_p is the activity concentration of radionuclides in plant (Bq/Kg dry weight) and A_s is the activity concentration of radionuclides in soil (Bq/Kg dry weight).

2.5 Effective dose Due to Consumption of Radionuclide in Food Stuff

Effective dose E(Sv/y) due to intake of radionuclide contaminated material is calculated using equation 3 [6].

$$E(Sv/year) = C\sum A_i DCF_i \qquad 3$$

Where C (Kg/year) is the mean annual consumption of the contaminated food stuff, A_i (Bq/ Kg) is the activity concentration of radionuclide (i) in the ingested material and DCF (Sv/Bq) is the dose coefficient for radionuclide i while the summation is for all the radionuclide considered in the sample material under study. Evaluation of the ingested dose estimates the radiation induced deleterious health effects associated with consumption of radionuclides. This is because the ingested dose in the body is proportional to the total dose delivered by the radionuclides into the body. This effective radiation doses from the consumption of contaminated food are obtained by measuring radionuclide activities concentration in the material and multiplying the activities by dose conversion factors and the mean annual consumption of food stuffs. The dose conversion coefficients for the respective radionuclides are given as 2.8 × 10^{-4}, 6.9 ×10^{-4} and 6.2× 10^{-6} mSv/Bq for ^{238}U, ^{232}Th and ^{40}K respectively.

3. RESULTS AND DISCUSSION

3.1 Specific Activity of Radionuclides in Soil in the Area

Results for specific activity of the radionuclides determined in Soils in the respective farms are presented in Tables 1 and 2. Specific activity in soils in Ufam farm (Table 1) shows the concentration was below detection level (BDL) in some soils. The specific activity ranged (mean) from BDL to 149. 46 ± 0.72 (99.11 ± 7.12) Bq/kg dry weight (DW) for ^{40}K; between BDL to 0.92 ± 0.21 (3.60 ± 0.99) Bq/Kg (DW) for ^{238}U; between 7.62 ± 0.74 to 12.71 ± 1.24 (8.64 ± 0.84) Bq/Kg (DW) for ^{232}Th. In Obot Ndua farm (Table 2), the measured specific activity for the area ranged from BDL to 153.13 ± 10.99 (93 60 ± 6.72) Bq/Kg (DW) for ^{40}K; ^{238}U ranged between BDL to 31.22 ± 7.49 (8.96 ± 2.13) Bq/kg (DW), while ^{232}Th ranged between 1.03 ± 0.10 to 8.72 ± 0.85 (6.12 ± 0.60) Bq/Kg (DW).

3.2 Specific Activity of Measure Radionuclides in Cassava in Studied Areas

There exist a transfer of radionuclides into plant from the soil due to the uptake of nutrients. Results for specific activity of the radionuclides in cassava determined in the farms are presented in Tables 3 and 4. The specific activity of radionuclides in Cassava in Ufam farm is presented in Table 3, where concentration of potassium (^{40}K) ranged between 119.89 ± 8.61 to 407.35 ± 29.15 (360.40 ± 25.63) Bq/Kg (DW); ^{238}U ranged between BDL to 26.30 ± 6.78 with mean value of 6.56 ± 1.65 Bq/Kg (DW), while ^{232}Th ranged between BDL to 15.89 ± 1.55 with mean of 6.21 ± 0.61 Bq/Kg (DW). In Obot Ndua farm the concentration of radionuclides in cassava as presented in Table 4. The result shows that ^{40}K ranged between 289. 54 ± 20.81 to 601. 28 ± 43.13 (391.13 ± 28.07) Bq/Kg (DW); for ^{238}U, it ranged between 1.54 ± 0.34 to 32.14 ± 8.66 (11.64 ± 2.94) Bq/Kg (DW) and ranged between BDL to 7.88 ± 0.77 (3.09 ± 0.30) Bq/Kg (DW) for ^{232}Th.

Results presented show a high deposition of potassium in the cassava tubers while absorption of other radionuclides is low. The mean values of the specific activity of potassium obtained for this study are slightly below the world mean of 400 Bq/Kg for ^{40}K. This high value of potassium could be as a result of the fact that potassium is an essential element required for proper plant growth [14,9]. Furthermore [15] reported that the presence of potassium and calcium in the soil affect the transfer of other radionuclides into the

Table 1. Specific activity of radionuclides in soils in Ufam farm

Sample code	Radionuclides in soil		
	^{40}K (Bq/Kg)	**^{238}U (Bq/Kg)**	**^{232}Th (Bq/Kg)**
Y_{11}	21.41 ± 1.54	BDL	12.71 ± 1.24
Y_{22}	149.46 ± 10.72	BDL	7.62 ± 0.74
Y_{33}	142. 55 ± 10. 23	0.81 ± 0.18	4.11 ± 0.40
Y_{44}	BDL	16.25 ± 4.57	11.11 ± 1.08
Y_{55}	182. 13 ± 13.08	0.92 ± 0.21	7.64 ± 0.74
Min	0.00	0.00	4.11 ± 0.40
Max	149.46 ± 10.72	16.25 ± 4.57	12.71 ± 1.24
Mean	99.11 ± 7.12	3.60 ± 0.99	8.64 ± 0.84

Table 2. Specific activity of radionuclides in soils in Obot Nduo farm

Sample code	Radionuclides in soil		
	^{40}K (Bq/Kg)	**^{238}U (Bq/Kg)**	**^{232}Th (Bq/Kg)**
Z_{11}	BDL	8.98± 2.13	8.72 ± 0.85
Z_{22}	78.91 ± 5.67	BDL	1.03 ± 0.10
Z_{33}	153.13 ± 10. 23	31.22 ± 7.49	6.57 ± 0.64
Z_{44}	123.02 ± 8.85	BDL	8.13 ± 0.79
Z_{55}	112.95 ± 8.11	4.61 ± 1.04	6.15 ± 0. 06
Min	0.00	0.00	1.03 ± 0.10
Max	153.46 ± 10. 99	31. 22 ± 7.49	8.72 ± 0.85
Mean	93.60 ± 6.72	8.96 ± 2. 13	6.12 0. 60

Table 3. Specific activity of radionuclides in cassava in Ufam farm

Sample code	Radionuclides		
	^{40}K (Bq/Kg)	**^{238}U (Bq/Kg)**	**^{232}Th (Bq/Kg)**
Y_1	407. 35 ± 29.45	2.92 ±0.66	1.36 ± 0.13
Y_2	331.51 ± 23.76	3.56 ± 0.80	15.89±1.55
Y_3	538.73 ± 38. 53	BDL	8.59 ±0.89
Y_4	119. 86 ± 8.61	BDL	5.22 ± 0.51
Y_5	404.54 ± 28.10	26.30 ± 6.78	BDL
Min	119.86 ± 8.61	0.00	0.00
Max	538.73 ± 38.53	26.30 ± 6.78	15. 89 ±1.55
Mean	360.40 ±25. 63	6.56 ± 1.65	6.21 ± 0.61

Table 4. Specific activity of radionuclides in cassava in Obot Ndua farm

Sample code	Radionuclides		
	^{40}K (Bq/Kg)	**^{238}U (Bq/Kg)**	**^{232}Th (Bq/Kg)**
Z_1	601.28 ± 43.23	32.14 ± 8.66	BDL
Z_2	312. 92 ± 22.46	1.54 ± 0.34	0.75 ± 0.07
Z_3	400.96 ± 28. 69	6. 63 ± 1.49	6.84 ± 0.67
Z_4	350.96 ± 25.17	6.15 ± 1.40	7.58 ± 0.77
Z_5	289. 54 ± 20.81	11.72 ± 2.81	BDL
Min	289.54 ± 20.81	1.54 ± 0.34	0.00
Max	601.28± 43.23	32.14 ± 8.66	7.88 ± 0.77
Mean	391.13 ± 28.07	11.64± 2.94	3.09 ± 0.30

plants which could also be responsible for the lower value of activity concentration of uranium and thorium presented. It is also observed that the mean specific activity values obtained for ^{238}U and ^{232}Th are lower than the world mean of 35 Bq/Kg and 30 Bq/Kg respectively.

3.3 Transfer Factors of Radionuclides from Soil to Cassava Tubers

Transfer factor of radionuclides in plant measures the contamination level of the plant by the radionuclides and this is useful in evaluating radiological risk to humans and animals when the plant is consumed. Transfer factor of ^{40}K, ^{238}U and ^{232}Th were determined and presented in Table 5 and Fig. 1. Transfer factors obtained in this area ranged between 3.64 to 4.18 for ^{40}K; 1.30 to 1. 82 for ^{238}U and 0.51 to 0.75 for ^{232}Th. The TF value for potassium obtained for this work is higher while TF for Thorium is lower than those obtained elsewhere [7,16,17]. Most TF values obtained for this work (^{40}K and ^{238}U) were higher than unity which may be due to the continuous accumulation of ^{40}K through the root uptake over a period of time. This higher uptake of ^{40}K may be due to the essential nutrient property of potassium to the plant. This shows that the level of contamination of the food chain is high and this suggests that consumption of the cassava tuber in this area might pose a high potential hazard to its consumers. However, the radiological health effect of the contaminated food could be reduced by cooking the food stuff before consumption [18].

3.4 Effective dose Due to Consumption of Radionuclide in Food Stuff

In calculating the effective dose, it is assumed that the mean annual consumption of cassava in Akwa Ibom State, Nigeria is 127.20 Kg/yr and 343.10 Kg/yr for children and adult respectively [19]. Effective ingestion dose ranged from 0.99 mSv/yr to 1.08 mSv/yr for children while the ingestion dose for adult ranged from 2.68 mSv/yr

Table 5. Transfer factors from soil to cassava in the studied areas

Farm	Radionuclides		
	^{40}K	**^{238}U**	**^{232}Th**
Ufam	3.64	1.82	0.72
Obot Ndua	4.18	1.30	0.51

^{40}K ^{238}U ^{232}Th

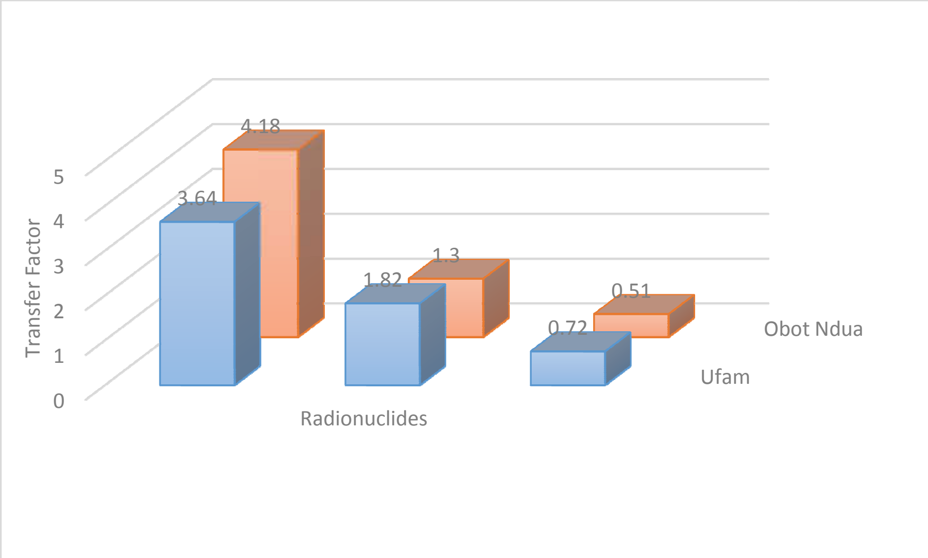

Fig. 1. Transfer factors from soil to cassava in the studied areas

Table 6. Ingestion dose for children and adult due to consumption of cassava

Farm	Effective dose for children and adult	
	Children (mSv/yr)	Adult (mSv/yr)
Ufam	1.08	29.16
Obot Ndua	0.99	2.68

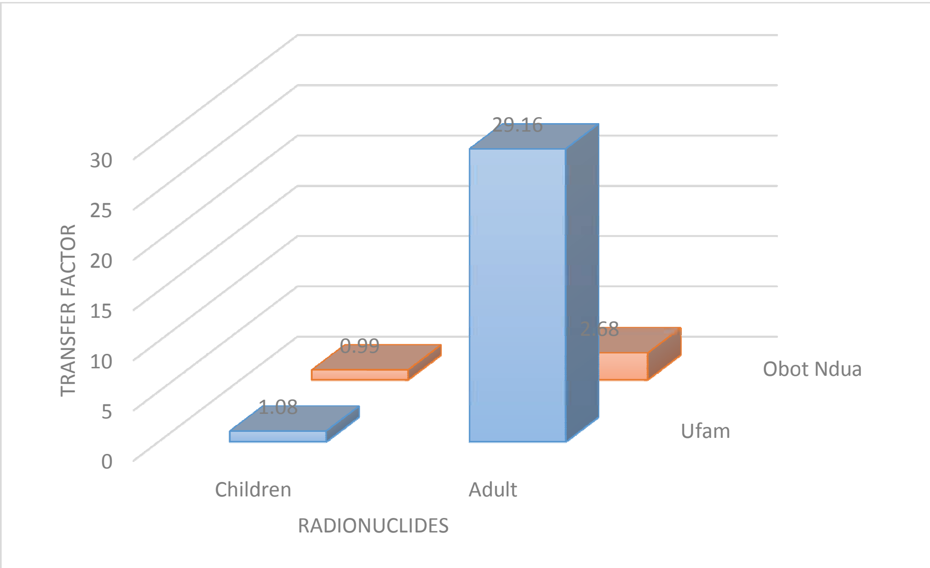

Fig. 2. Ingestion dose for children and adult due to consumption of cassava

to 29.16 mSv/yr (Table 6 and Fig. 2). Most of these values are higher than 1 mSv/yr which is the annual dose limit recommended for safety of the general public. This could pose a serious radiological health hazard to the consumers [6].

4. CONCLUSION

This study was conducted to provide baseline data for transfer factors of radionuclides from soil to cassava for Ikot Ekpene Local Government

Area, Akwa Ibom State. The activity concentration of the radionuclides considered for this study were below the recommended mean world value of 400 Bq/Kg for ^{40}K, 35 Bq/Kg for ^{238}U and 30 Bq/Kg for ^{232}Th. Most of the TF and effective ingestion dose results for this study were above the recommended value of unity which suggests that consumption of cassava from the studied area may pose radiological health risk, hence to minimize these effect it is recommended that the food stuff be cooked even though it is reported that there is no low dose of radiation exposure that does not have radiological effect on human.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Malanca A, Pessina V, Dallara G. Assessment of the natural radioactivity in the brazillian state of rio grende do norte. Journal of Health Physics. 1996;65:298–302.
2. Saeed MA, Yusof SS, Hossain I, Ahmed R, Abdullah HY, Shahid M, Ramli AT. Soil to rice transfer factor of the natural radionuclides in Malaysia, Rom Journal of Physics. 2012;57(9-10):1417-1424.
3. Harb SA, El-Kamel AH, Zahran EM, Abbady A, Ahmed A. Assessment of Agriculture Soil Primordial Radionuclide Concentration in Aden Govenorate South of Yemen region. International Journal of New Horizon in Physics. 2015;2(2):81-86.
4. Gautam YP, Avinash K, Sharma AK, Ravi PM, Tripathi RM. Evaluation of internal dose, due to the ingestion of primordial radionuclide 40k around Narora site, India. Ambit Journal of Research in Environmental Studies. 2015;1(1):1-12.
5. Alamoudi ZM. Assessment of natural radionuclides in powdered milk consumed in Saudi Arabia and estimates of the corresponding annual effective dose. Journal of American Science. 2013;9(6): 267-273.
6. Addo MA, Darko EO, Gordon C, Nyarko BJ. A preliminary study of natural radioactivity ingestion from cassava grown and consumed by inhabitants around a cement production facility in the Volta region, Ghana. International Journal of Environmental Sciences. 2013;3(6):2312-2320.
7. Amakom CM, Orji CE, Eke BC, Okoli UA, Ndudi CS. The influence of selected soil physicochemical properties on radionuclide transfer in cassava crops. International Journal of Plant and Soil Science. 2017; 14(1):1-7.
8. Alausa SK, Odunaike K, Adeniji IA. Transfer factor of radionuclides from soil-to palm oil produced from Elere palm tree plantation near Ibadan, Oyo State, Nigeria. Nigeria Journal of Pure and Applied Physics. 2017;7(1):7-12.
9. Adesiji NE, Ademola JA. Soil – to – maize transfer factor of natural radionuclides in a tropical ecosystem of Nigeria. Nigeria Journal of Pure and Applied Physics. 2019;9(1):6-10.
10. Ocheje JA, Tyovenda AA. Determination of the transfer factor and dose rate of radionuclides in some selected Crops in Kogi State, Nigeria. IOSR Journal of Applied Physics. 2020;12(3):7-12.
11. George NJ, Akpan AE, Obot IB. Resistivity study of shallow aquifers in the parts of Southern Ukanafun Local Government Area, Akwa Ibom State, Nigeria. E-Journal of Chemistry. 2010;7(3):693–700.
12. Essien IE, Essiett AA, Ani OB, Peter IG, Udofia AE. Estimation of radiological hazard indices due to radioactivity in soils in Ibiono Ibom, Akwa Ibom State, Nigeria. International Journal of Scientific and Research Publications. 2017;7(5):245-250.
13. Essien IE, Akpan EN. Evaluation of radiological hazards indices due to radioactivity in quarry sites in Itu, Akwa Ibom State, Nigeria. International Journal of Scientific Research in Environmental Sciences. 2016;4(3):71-77.
14. Golmakani S, Moghaddam MV, Hosseini T. Factors affecting the transfer of radionuclides from the environment to plants. Radiation Protection Dosimetry; 2008.
DOI: 10.1093/rpd/ncn063

15. Chen SB, Zhu YG, Hu QH. Soil to plant transfer of ^{238}U, ^{226}Ra and ^{232}Th on uranium mining-impacted soil from southeastern China. J. Environ Radioactivity. 2005;82:213-216.
16. Ononugbo CP, Azikiwe O, Awiri GO. Uptake and distribution of natural radionuclides in cassava crops from Nigerian Government farms. Journal of Scientific Research and Reports. 2019; 23(5):1-15.
17. Ademola AK. Natural radionuclide transfer from soil to plants in high background areas in Oyo state, Nigeria. Radiat Prot Environ. 2019;42:112-118.
18. Jibiri NN, Alausa SK, Farai IP. Assessment of external and internal doses due to farming in high background radiation areas in old tin mining localities in Jos-Plateau, Nigeria. Radioprotection. 2009;44(2):139 – 151.
19. Fabiana F, Moura D, Moursi M, Lubowa A, Barbara H, Erick B, Oguntona B, Sanusi R, Dixon M. Cassava Intake and vitamins: A Status among Women and Preschool Children in Akwa Ibom State, Nigeria. Plos One. 2015;10(6): 0129436.

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