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

Ime Essien¹, Akaninyene Akankpo¹*, Alice Nyong¹ and Etido Inyang¹

¹Department of Physics, University of Uyo, Nigeria.

ABSTRACT

Natural radioactivity exists in primordial formations such as rocks, soils, water and air where long lived radionuclides such as $^{238}U$, $^{232}Th$ and $^{40}K$ 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 below detectable limit (BDL) to 119.86 ± 8.61 to 601.28 ± 43.23 Bq/Kg for $^{40}K$; below detectable limit (BDL) to 15.89 ± 1.55 Bq/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

*Corresponding author: E-mail: akankpo@gmail.com;
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 $^{238}\text{U}$, $^{232}\text{Th}$, $^{40}\text{K}$ and their affiliates are found [1]. Cosmogenic radionuclides such as $^{14}\text{C}$ and $^{3}\text{H}$, 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°–5.140° N and longitudes 7.390°–7.458° 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$^\circ$ - 6.5$^\circ$C. The maximum daily temperature lies between 28$^\circ$ and 30$^\circ$C during March and the minimum daily mean temperature lies between 23$^\circ$ and 24$^\circ$C 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, ground 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°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 226Ra 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 Y11 to Y55 and Cassava Y1 to Y5 while in Obot Ndua farm codes as Z11 to Z55 and Z1 to Z5 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 238U, 232Th and 40K 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].

\[
c = \frac{N}{\xi \gamma M}
\]

Where M is the mass of the samples measured in Kg, \(\xi\) the detector energy dependent efficiency, \(t\) is the counting time 36,000 s (10 hrs), \(\gamma\) 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 40K, the 1.760 MeV photopeak was used for the measurement of 236U, while the 2.614 MeV photopeak was used for the measurement of 232Th.

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].

\[
TF = \frac{A_p}{A_s}
\]

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/year) due to intake of radionuclide contaminated material is calculated using equation 3 [6].

\[
E = C \sum A_i DCF_i
\]

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 the 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 \(2.8 \times 10^{-4}\), \(6.9 \times 10^{-4}\) and \(6.2 \times 10^{-6}\) mSv/Bq for 238U, 232Th and 40K 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 ± 10.72 (99.11 ± 7.12) Bq/kg dry weight (DW) for 40K; between BDL to 0.92 ± 0.21 (3.60 ± 0.99) Bq/Kg (DW) for 238U; between 7.62 ± 0.74 to 12.71 ± 1.24 (8.64 ± 0.84) Bq/Kg (DW) for 232Th. In Obot Ndua farm (Table 2), the measured specific activity for the area ranged from BDL to 153.46 ± 10.99 (93.60 ± 6.72) Bq/Kg (DW); for 238U, 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 232Th.

3.2 Specific Activity of Measure Radionuclides in Cassava in Studied Areas

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

| Sample code | 40K (Bq/Kg) | 238U (Bq/Kg) | 232Th (Bq/Kg) |
|-------------|-------------|--------------|---------------|
| Y_11        | 21.41 ± 1.54| BDL          | 12.71 ± 1.24  |
| Y_22        | 149.46 ± 7.22| 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 Ndua farm

| Sample code | 40K (Bq/Kg) | 238U (Bq/Kg) | 232Th (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   |

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 40K. 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 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 (40K) ranged between 119.89 ± 8.61 to 407.35 ± 29.15 (360.40 ± 25.63) Bq/Kg (DW); 238U ranged between BDL to 26.30 ± 6.78 with mean value of 6.56 ± 1.65 Bq/Kg (DW), while 232Th 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 40K ranged between 289.54 ± 20.81 to 601.28 ± 43.13 (391.13 ± 28.07) Bq/Kg (DW); for 238U, 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 232Th.
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\textsuperscript{U} and 232\textsuperscript{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\textsuperscript{K}, 238\textsuperscript{U} and 232\textsuperscript{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\textsuperscript{K}; 1.30 to 1.82 for 238\textsuperscript{U} and 0.51 to 0.75 for 232\textsuperscript{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\textsuperscript{K} and 238\textsuperscript{U}) were higher than unity which may be due to the continuous accumulation of 40\textsuperscript{K} through the root uptake over a period of time. This higher uptake of 40\textsuperscript{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 3. Specific activity of radionuclides in cassava in Ufam farm

| Sample code | 40\textsuperscript{K} (Bq/Kg) | 238\textsuperscript{U} (Bq/Kg) | 232\textsuperscript{Th} (Bq/Kg) |
|-------------|-------------------------------|-------------------------------|-------------------------------|
| Y\textsubscript{1}     | 407.35 ± 29.45                | 2.92 ± 0.66                   | 1.36 ± 0.13                   |
| Y\textsubscript{2}     | 331.51 ± 23.76                | 3.56 ± 0.80                   | 15.89 ± 1.55                  |
| Y\textsubscript{3}     | 538.73 ± 38.53                | BDL                           | 8.59 ± 0.89                   |
| Y\textsubscript{4}     | 119.86 ± 8.61                 | BDL                           | 5.22 ± 0.51                   |
| Y\textsubscript{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 | 40\textsuperscript{K} (Bq/Kg) | 238\textsuperscript{U} (Bq/Kg) | 232\textsuperscript{Th} (Bq/Kg) |
|-------------|-------------------------------|-------------------------------|-------------------------------|
| Z\textsubscript{1}   | 601.28 ± 43.23                | 32.14 ± 8.66                  | BDL                           |
| Z\textsubscript{2}   | 312.92 ± 22.46                | 1.54 ± 0.34                   | 0.75 ± 0.07                   |
| Z\textsubscript{3}   | 400.96 ± 28.69                | 6.63 ± 1.49                   | 6.84 ± 0.67                   |
| Z\textsubscript{4}   | 350.96 ± 25.17                | 6.15 ± 1.40                   | 7.58 ± 0.77                   |
| Z\textsubscript{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                   |

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

| Farm     | 40\textsuperscript{K} | 238\textsuperscript{U} | 232\textsuperscript{Th} |
|----------|------------------------|------------------------|------------------------|
| Ufam     | 3.64                   | 1.82                   | 0.72                   |
| Obot Ndua| 4.18                   | 1.30                   | 0.51                   |
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

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

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