



# Assessment of Soil to Cassava Transfer Factor of Radionuclides in Ughelli North Local Government Area, Delta State, Nigeria

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## ABSTRACT

### Background:

This research was conducted to estimate the activity concentration level of <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th in soil and cassava and determine the transfer factor from soil to cassava in Ughelli North, Delta State, Nigeria.

### Materials and Methods:

These were examined using gamma spectrometry and considering a lead-shielded 3 x 3inch coaxial type Sodium Iodide Thallium doped detector.

### Results:

The mean activity concentrations of <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th are  $45.49 \pm 4.28$  BqKg<sup>-1</sup>,  $3.15 \pm 0.77$  BqKg<sup>-1</sup> and  $0.56 \pm 0.06$  BqKg<sup>-1</sup> respectively in soil samples and  $134.08 \pm 11.59$  BqKg<sup>-1</sup>,  $3.89 \pm 0.93$  BqKg<sup>-1</sup> and  $0.81 \pm 0.09$  BqKg<sup>-1</sup> correspondingly in cassava samples. The mean transfer factor of <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th from soil to cassava are  $3.44 \pm 0.75$ ,  $1.94 \pm 0.32$  and  $1.34 \pm 0.54$  respectively. Peak values of the TF were noted as 8.52 for <sup>40</sup>K at U18, D18, 25.58 for <sup>238</sup>U at U12, D12 and 5.71 for <sup>232</sup>Th at U11, D11.

### Conclusion:

The activity concentration of <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th in the area are lower than the world average values. Consequently, it will not pose any radiological hazard if consumed. The high value of Transfer factor is attributed to the richness of the organic matter in the soil and may indicate high ability to transfer radionuclides in the soil to food crops but from the concentration information, these radionuclides present in the soil are low as well as annual effective doses. There is no radiological risk of ingestion.

**Keywords:** Transfer factor, Cassava, Activity concentration, Radionuclides, Gamma spectrometry, Soil.



## 1. INTRODUCTION

Transfer factor is defined as the ratio of radionuclide concentration in plant to soil per unit mass. This parameter is essential for environmental transfer models, which are beneficial in the estimate of radionuclide concentration in agricultural crops for the estimation of dose impact to human beings [1]. Many factors, both natural and physicochemical, affect the build-up of radionuclides in plant and they 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 [2]. Natural radionuclides found in terrestrial and aquatic food chains can be transferred to humans through ingestion of food. For this reason, international efforts were brought together collectively to apply adequate procedures in investigating radionuclides in food [3], and to set crucial guidelines to protect against high levels of internal exposure that may be caused by food consumption [4]. Radionuclides are introduced in the soil (which is significant in the yield of our planet ecosystems [5] through application of inorganic fertilizers, chemical sprays, pesticides and erosion of NORM (Natural Occurring Radionuclide Materials) emit radiations that pose danger to human beings. The transportation of radionuclides from soil to plants is possible through root uptake and deposition of dust on plant leaves and to humans through inhalation, breathing, and ingestion. Soil–plant–human route is a major pathway for the transfer of radionuclides to human beings.

Radionuclides found in our environs are unstable form of nuclides [6] that break spontaneously into different daughter nuclides so as to reach stable nuclide [7]. The radionuclides present in the environment are usually in very low activity concentrations. Their sources are natural as well as man-made. Natural radionuclides are present in every human environment and Human health status is a function of his environment [8]; earth material, water, air, foods and even our own body contain naturally occurring radioactive materials (NORM) [9]. The valuations of natural environments are of high importance because every living organism is exposed to ionizing radiation [1]. When radionuclides that occur naturally in ores, soils, water, or other natural materials are concentrated or exposed to the environment by industrial activities, technologically enhanced naturally occurring radioactive materials (TENORM) are produced [10]. [11] stated that the artificial sources of radionuclides are largely due to medical and industrial activities. The uses of radioactive materials in the industry springs across numerous operations like pipeline leakages, drilling operations, well-logging, automated ionizing radiation gauge, radiography and application of radiotracers in oil well management [12]. Nevertheless, activities associated with utilizing geological resources that impacts the concentration of natural radionuclides can also be realized in cases of minerals, oil and gas explorations, and the production of phosphate fertilizer. Due to these processes, the concentrations of naturally occurring radioactive isotopes in the environment have increased to a large extent. Also, the redistribution of radioactive isotopes in the environment by both physical and biogeochemical processes has been enhanced [12].

The aim is to estimate the activity concentration level and determine the transfer factor of radionuclide from soil to cassava in Ughelli North Local Government Area, Delta State, Nigeria. The uptake of radionuclides from soil to plant is characterized by a transfer factor (TF). The presence of radioactivity in the edible parts of crops causes human internal exposure to  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  which are radiotoxic elements, whereas  $^{40}\text{K}$  is both radiotoxic and nutritionally important [13]. In the case of  $^{40}\text{K}$  (potassium), it helps cells, nerves and muscles discharge their tasks perfectly [14], and supports the body to regulate blood pressure, heart rhythm and volume of water in cells as well as digestion [14]. It is therefore necessary to determine and estimate the concentration of primordial radionuclides and their TF to plant, in order to assess the radiation doses to man and animal, and for economic sustainable development.



## 2. MATERIALS AND METHOD

### 2.1 Study Area

Delta state is one of the oil producing state in the Niger Delta region, Nigeria. It is located about latitude  $5.7040^{\circ}\text{N}$  and longitude  $5.9339^{\circ}\text{E}$  (Fig. 1). Ughelli North is one of the Local Government Areas in Delta State whose headquarter is at Ughelli. The people in the area are predominantly farmers. Cassava, Yam, Okra, Maize and oil palm are cultivated in the area. The study area lies within the Niger Delta sedimentary basin which is characterized by both Marine and mixed continental quaternary sediments that are composed of abandoned beach ridges and mangrove swamps. The samples were collected during the rainy season from some farmlands in Ughelli LGA of Delta state. The studied area is situated in the Niger Delta region where two distinct seasons are experienced: the dry and the rainy (wet) seasons [15-21]. The 10 locations are listed with codes as U11 to U20 (where soil samples were taken); also, as D11 to D20 (where cassava samples were obtained).

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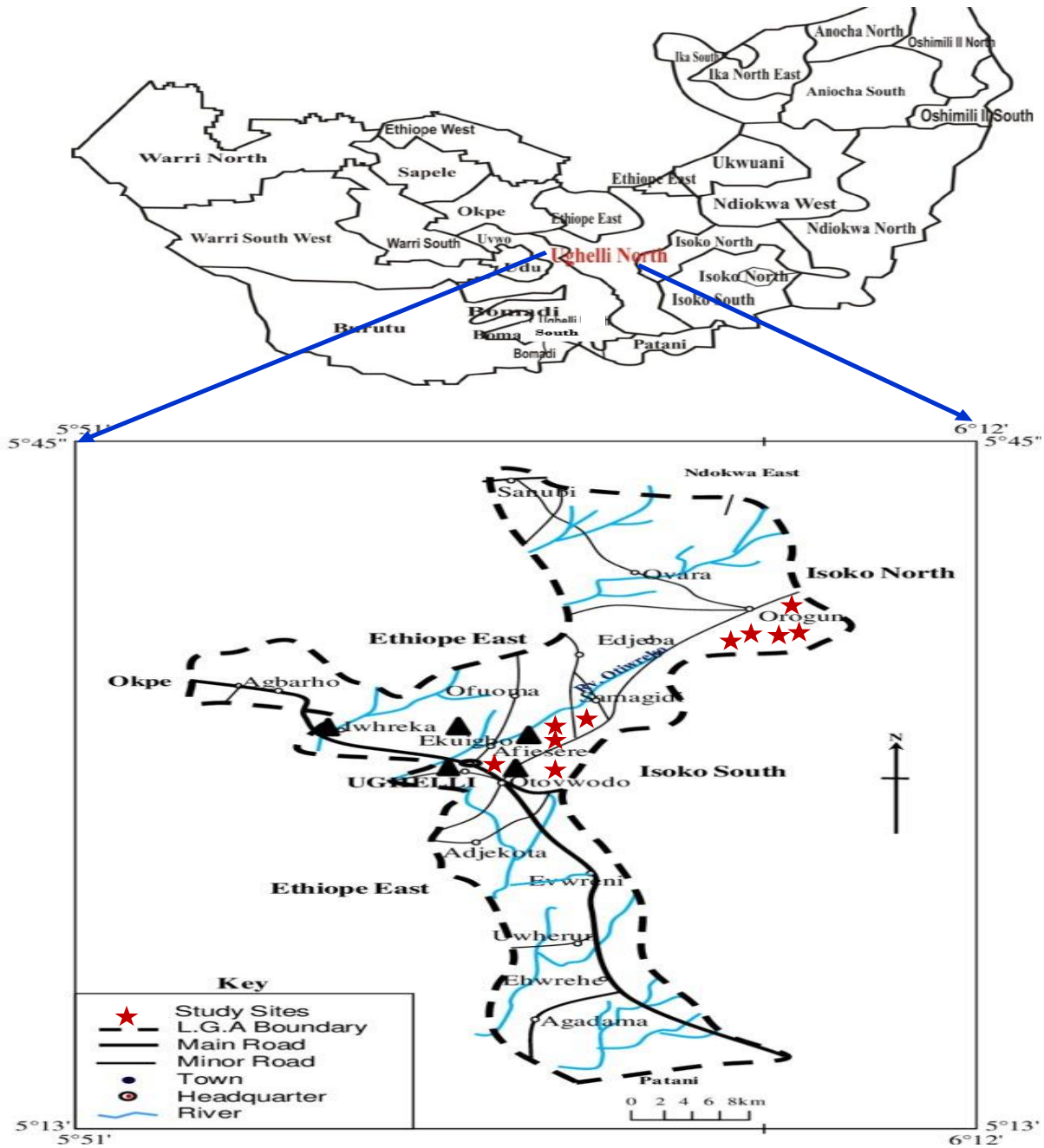


Fig. (1) Map showing the study area

### Sample Collection and Preparation

10 (ten) samples of soil and 10 (ten) samples of cassava were collected from cultivated farmlands in Ughelli North. Only farms where cassava was cultivated were used for the study. Soil samples of about 2.0 kg (wet weight) was collected around the root area of the cassava plants from each position, and corresponding edible part of cassava tuber samples was also collected. The cassava samples collected were thoroughly washed with tap water and then in distilled water to remove surface sand and they were placed into separate polyethylene bags and labelled. The samples were grated into small pieces using a grater, sun dried to a constant weight, ground to powdery form, and sieved to attain homogeneity. The weight of each soil

sample was about 600g; the meshed soil samples were stored in a black polythene bag to allow for secular equilibrium [22]. Thereafter, the samples were taken to the National Institute of Radiation Protection and Research, University of Ibadan, Oyo State, Nigeria, for analysis.

### 2.3 Sample Analysis

Gamma ray spectroscopy was employed for the measurement of the activity concentration in the samples. A lead-shielded 3 x 3inch coaxial type Sodium Iodide Thallium [NaI (TI)] doped detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra series multichannel Analyzer (MCA) (Model N0.1104) through a preamplifier was used. It has a resolution full width at half maximum (FWHM) of about 8% at energy of 0.662 Mev.

### 2.4 Transfer factor

The transfer factor is defined as stated in Equation 1 [23]. Considering different environmental conditions, plant contamination is calculated on the basis of dry weight [22]. Soil to plant transfer is influenced by factors such as the physicochemical characteristics of the radionuclides, the form of the fallout or the waste, the time after fallout, soil properties, the type of crop, and the soil management practices [24].

$$TF = \frac{A_{cp}}{A_{cs}} \quad (1)$$

Where  $A_{cp}$  is the activity concentration of radionuclide in plant measured in ( $Bqkg^{-1}$ ),  $A_{cs}$  is the activity concentration of radionuclide in soil in ( $Bqkg^{-1}$ ) and  $TF$  is the Transfer Factor.

### 2.5 Radium Equivalent Concentration ( $Ra_{eq}$ )

In order to describe the gamma output from the mixture of Uranium (that is,  $^{226}Ra$ ),  $^{232}Th$ , and  $^{40}K$  in a material, an index: radium equivalent is adequate to compare the radionuclides present in any material. The radium equivalent was computed using Equation 2.

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.077C_K \quad (2)$$

Where  $C_U$ ,  $C_{Th}$  and  $C_K$  are the radioactivity concentrations in  $Bqkg^{-1}$  of  $^{238}U$ ,  $^{232}Th$  and  $^{40}K$  respectively.  $^{238}U$  will be used in place of  $^{226}Ra$  in the calculations, although there may be disequilibrium between these radionuclides. This disequilibrium is stated as 1.03 by [4]. Equation 2 is based on the assumption that 370  $Bqkg^{-1}$  of  $^{238}U$ , 259  $Bqkg^{-1}$  of  $^{232}Th$  and 4810  $Bqkg^{-1}$  of  $^{40}K$  produce the same gamma radiation dose rate. To minimize radiation hazards, samples whose  $Ra_{eq}$  are greater than 370  $Bqkg^{-1}$  should not be ingested into the body [25,26].

### 2.6 Annual Effective Dose

The effective dose (AEDE) permits the addition of all radiations engrossed in the body. It can be evaluated by the use of Equation 3 [27].

$$E(Svyr^{-1}) = C \sum A_i DCF_i \quad (3)$$

Where,  $E(Svyr^{-1})$  is the annual effective dose due to ingestion,  $C$  ( $Kgyr^{-1}$ ) is the mean annual consumption of food stuff,  $A_i$  ( $Bqkg^{-1}$ ) is the activity concentration of radionuclide  $i$ , in the ingested food and  $DCF_i$  ( $SvBq^{-1}$ ) is the dose coefficient for radionuclide  $i$ . The summation is for all the radionuclides considered in the sample material under study.





[28] values of ingestion coefficient for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  radionuclides for age groups above 17 years are  $2.8 \times 10^{-7}$ ,  $6.2 \times 10^{-7}$  and  $6.2 \times 10^{-9} \text{ SvBq}^{-1}$  respectively. The mean annual consumption rate of cassava staple food in Nigerian per capita value of  $102.0 \text{ kg yr}^{-1}$  was used for calculating the effective dose due to ingestion of food stuff [27].

**2.7 Excess Lifetime Cancer Risk (ELCR)**

This is may be noted as an assessment of the danger to a person dying from cancer due to the consumption of a radionuclide in food. ELCR will be evaluated by means of Equation 4 [23].

$$ELCR = \sum r_i I_i \tag{4}$$

Where *ELCR* is the lifetime cancer risk due to ingestion of food crop, *r<sub>i</sub>* denotes the cancer risk coefficient for *i<sup>th</sup>* radionuclide, and *I<sub>i</sub>* is ACT, signifies the per capital activity intake of the radionuclide. A is the activity concentration of the *i<sup>th</sup>* radionuclide, C is food consumption rate, and T is the average life expectancy. The risk coefficients, r for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  considered are  $9.56 \times 10^{-9} \text{ Bq}^{-1}$ ,  $2.45 \times 10^{-9} \text{ Bq}^{-1}$ , and  $5.89 \times 10^{-10} \text{ Bq}^{-1}$  correspondingly. At birth, the mean life expectancy is  $455 \times 10^{-1}$  years in Nigeria [23]. The food intake data considered in this research is the mean annual consumption rate of cassava in Nigerian per capita value of  $102.0 \text{ kg yr}^{-1}$  [27].

**3. RESULTS AND DISCUSSION**

**3.1 Results**

The results of the activity concentration and transfer factor from Soil to Cassava in Ughelli North are as summarized. Table 1 presents the information concerning the sample codes with their corresponding locations of certain farmlands. The results of the activity concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  in soil samples are seen in Table 2. Table 3 has the results of the activity concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$ , AEDE and ELCR in cassava samples. Charts (Fig. 2 and Fig. 3) have been used to represent the variation of activity concentrations with corresponding location. There exists a transfer of radionuclides from soil to plant due to the uptake of nutrients; Fig. 4 is adequate for the variation of Transfer Factor results from soil to cassava. The pie chart has the percentage of transfer factor for each radionuclide in a concise form.

The 10 locations are listed with codes as U11 to U20 (where soil samples were taken); also, as D11 to D20 (where cassava samples were obtained).

**Table (1) GPS Location**

| LGA           | Sample Location | Sample Code        | Latitude (N) | Longitude (E) |
|---------------|-----------------|--------------------|--------------|---------------|
| Ughelli North | Orogun          | U11, D11 – U15,D15 | 05°38.649'   | 006°05.503'   |
| Ughelli North | Afisiere        | U16,D16 – U20,D20  | 05°32.658'   | 006°01.173'   |

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**Table (2) Radionuclide Activity Concentration in Soil Samples**

| Sample Code | Surface Dose Rate (mR.hr <sup>-1</sup> ) | <sup>40</sup> K(BqKg <sup>-1</sup> ) | <sup>238</sup> U(BqKg <sup>-1</sup> ) | <sup>232</sup> Th(BqKg <sup>-1</sup> ) | R <sub>aeq</sub> (BqKg <sup>-1</sup> ) |
|-------------|--|--------------------------------------|---------------------------------------|--|--|
| U11         | 0.001                                    | 60.65 ± 5.55                         | 3.21 ± 0.81                           | 0.35 ± 0.04                            | 8.38                                   |
| U12         | 0.007                                    | 60.80 ± 4.64                         | 0.12 ± 0.03                           | 0.64 ± 0.06                            | 5.72                                   |
| U13         | 0.013                                    | 42.91 ± 4.39                         | 3.24 ± 0.76                           | 0.32 ± 0.04                            | 7.00                                   |
| U14         | 0.009                                    | 38.80 ± 3.85                         | 2.73 ± 0.72                           | 0.51 ± 0.06                            | 6.45                                   |
| U15         | 0.027                                    | 46.32 ± 4.26                         | 2.85 ± 0.72                           | 0.49 ± 0.06                            | 7.12                                   |
| U16         | 0.005                                    | 36.98 ± 3.78                         | 4.24 ± 0.98                           | 1.45 ± 0.16                            | 9.16                                   |
| U17         | 0.020                                    | 64.45 ± 5.88                         | 3.18 ± 0.83                           | 0.71 ± 0.08                            | 9.16                                   |
| U18         | 0.197                                    | 18.53 ± 2.03                         | 3.96 ± 0.94                           | 0.32 ± 0.04                            | 5.84                                   |
| U19         | 0.016                                    | 46.4 ± 4.52                          | 3.77 ± 0.86                           | 0.30 ± 0.04                            | 7.77                                   |
| U20         | 0.009                                    | 39.04 ± 3.87                         | 4.20 ± 1.06                           | 0.51 ± 0.06                            | 7.94                                   |
| Range       | 0.001 – 0.197                            | 18.53 – 64.45                        | 0.12 – 4.24                           | 0.30 – 1.45                            | 5.72 – 9.16                            |
| Mean        | 0.03 ± 0.02                              | 45.49 ± 4.28                         | 3.15 ± 0.77                           | 0.56 ± 0.06                            | 7.45 ± 0.34                            |

**Table (3) Radionuclide Activity Concentration in Cassava Samples**

| Sample Code | <sup>40</sup> K(BqKg <sup>-1</sup> ) | <sup>238</sup> U(BqKg <sup>-1</sup> ) | <sup>232</sup> Th(BqKg <sup>-1</sup> ) | R <sub>aeq</sub> (BqKg <sup>-1</sup> ) | AEDE (mSvBq <sup>-1</sup> ) | ELCR (×10 <sup>-3</sup> ) (Bqkg <sup>-1</sup> ) |
|-------------|--------------------------------------|---------------------------------------|--|--|-----------------------------|---|
| D11         | 164.85 ± 14.11                       | 5.50 ± 1.45                           | 2.00 ± 0.21                            | 21.05                                  | 0.39                        | 0.45  |
| D12         | 64.43 ± 6.12                         | 3.07 ± 0.83                           | 0.87 ± 0.09                            | 9.28                                   | 0.18                        | 0.18  |
| D13         | 112.09 ± 8.37                        | 1.29 ± 0.29                           | 0.10 ± 0.01                            | 10.06                                  | 0.11                        | 0.31  |
| D14         | 121.73 ± 10.87                       | 8.09 ± 1.90                           | 0.81 ± 0.09                            | 18.62                                  | 0.36                        | 0.33  |
| D15         | 125.15 ± 11.72                       | 5.23 ± 1.32                           | 0.48 ± 0.06                            | 15.55                                  | 0.26                        | 0.34  |
| D16         | 157.88 ± 14.11                       | 9.57 ± 2.10                           | 0.55 ± 0.06                            | 22.51                                  | 0.41                        | 0.43  |
| D17         | 130.31 ± 12.39                       | 9.30 ± 2.08                           | 0.65 ± 0.07                            | 20.26                                  | 0.39                        | 0.36  |
| D18         | 157.82 ± 11.76                       | 0.14 ± 0.03                           | 0.12 ± 0.01                            | 12.46                                  | 0.11                        | 0.43  |
| D19         | 123.07 ± 11.14                       | 7.33 ± 1.83                           | 0.35 ± 0.04                            | 17.31                                  | 0.31                        | 0.34  |
| D20         | 183.50 ± 15.28                       | 6.47 ± 1.58                           | 0.31 ± 0.04                            | 21.04                                  | 0.32                        | 0.50  |
| Range       | 64.43 – 183.50                       | 0.14 – 9.57                           | 0.10 – 2.00                            | 9.28–<br>22.51                         | 0.11–0.41                   | 0.18–<br>0.45                                   |
| Mean        | 134.08 ± 11.59                       | 5.60 ± 1.34                           | 0.62 ± 0.07                            | 16.81 ±<br>1.32                        | 0.28 ± 0.03                 | 0.37 ±<br>0.03                                  |

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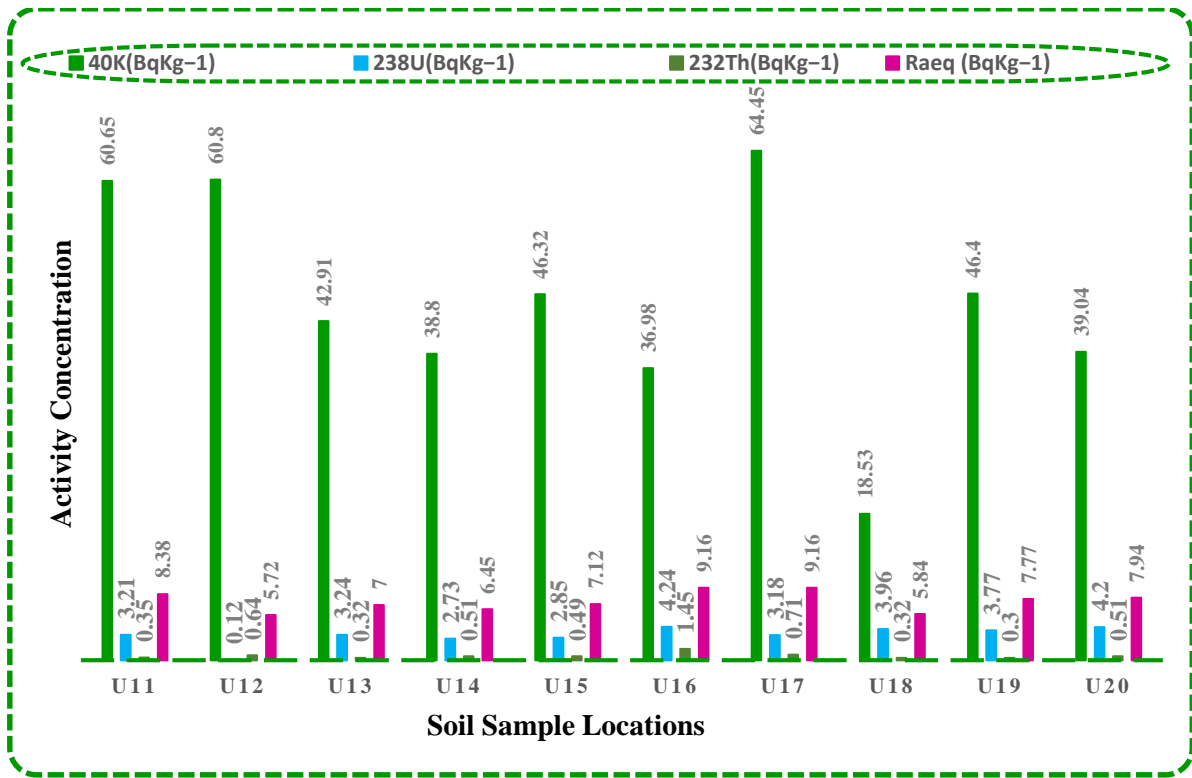


Fig. (2) Mean activity concentration in soil from sample areas

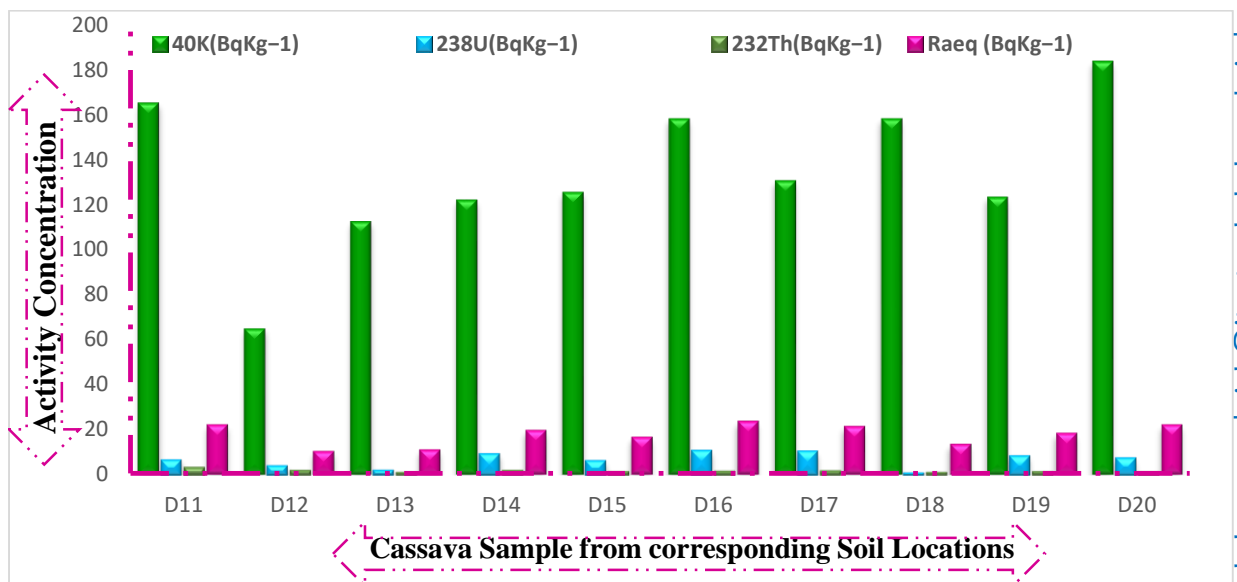


Fig. (3) Mean activity concentration in cassava



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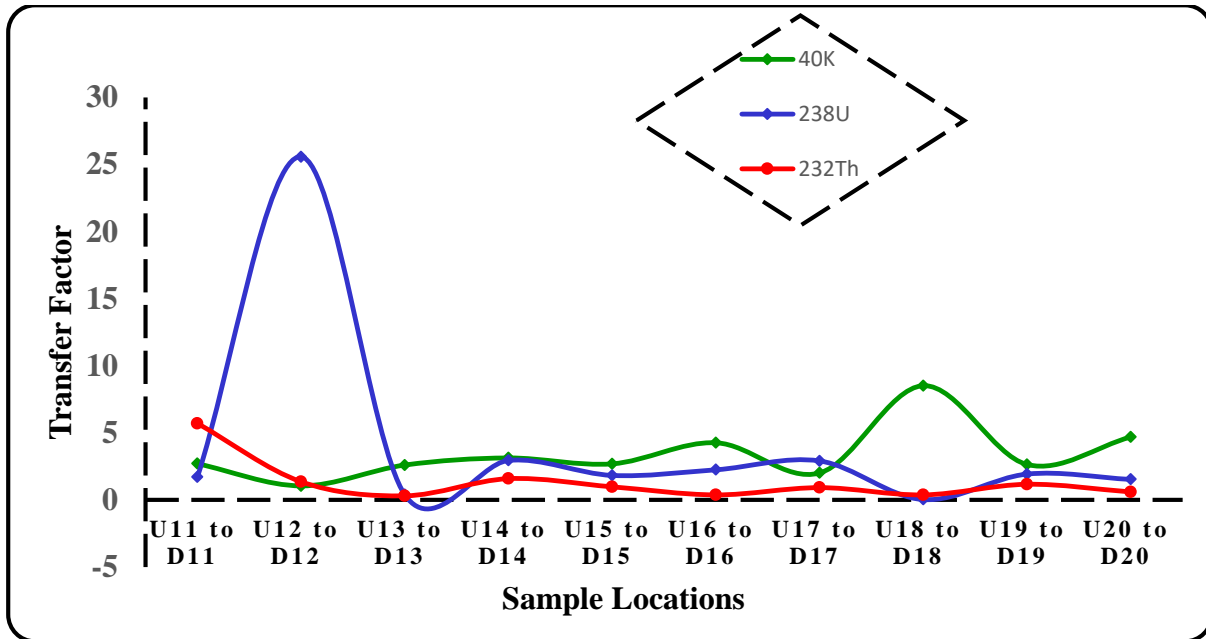


Fig. (4) Variation of transfer factor according to location

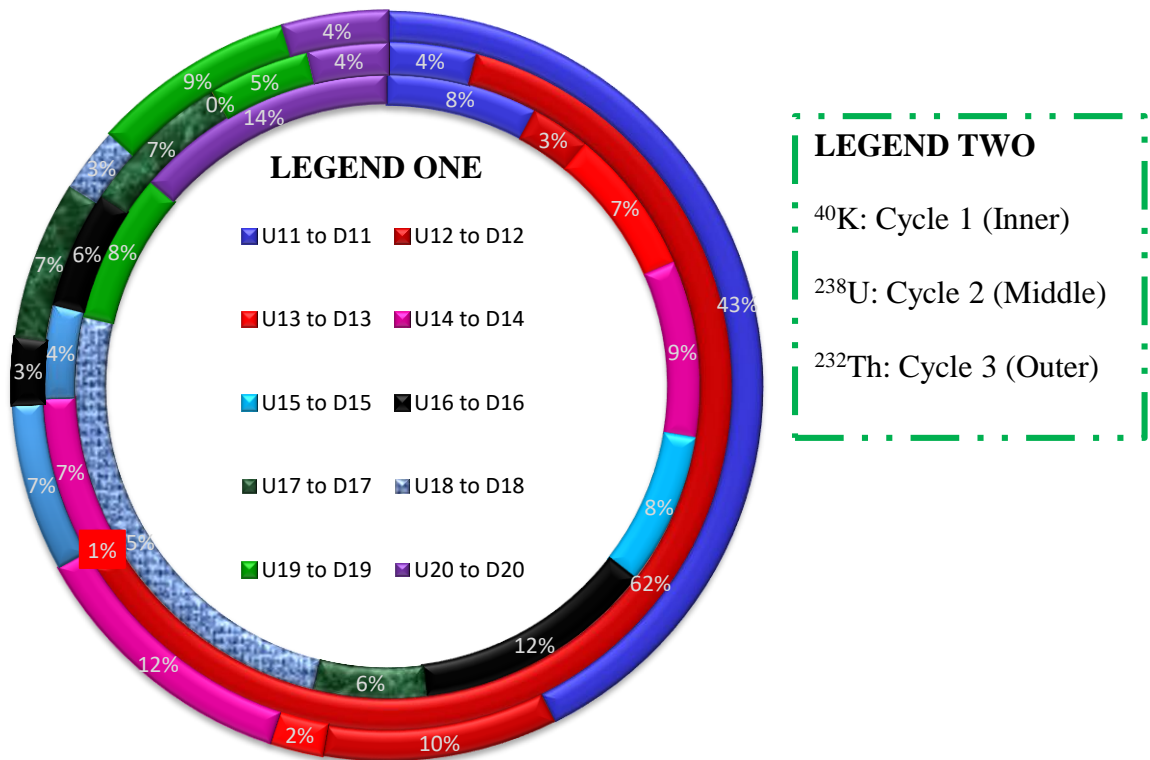


Fig. (5) Percentage of Transfer factor of each radionuclide in studied location



## 3.2 DISCUSSION

### 3.2.1 Activity Concentration in Soil

The activity concentration was determined using Equation 5 [29].

$$A_r \left( \frac{\text{Bq}}{\text{kg}} \right) = \frac{N - N_0}{I\gamma \xi mt} \quad (5)$$

Where  $A_r$  is the activity concentration of the radionuclide in the sample,  $N$  is the net counts of a given peak for a sample,  $N_0$  is the background of the given peak,  $I\gamma$  is the number of gamma photons per disintegration,  $\xi$  is the detector efficiency at the specific gamma-ray energy,  $m$  is the mass of the measured sample (fresh weight in kg); and  $t$  is the measuring time for the sample.

From Table 2,  $^{40}\text{K}$  has the highest mean activity concentration ( $(45.49 \pm 4.28) \text{ BqKg}^{-1}$ ) with the highest value ( $(64.45 \pm 5.88) \text{ BqKg}^{-1}$ ) recorded at U17. The mean activity concentrations of  $^{238}\text{U}$  and  $^{232}\text{Th}$  are  $3.15 \pm 0.77 \text{ BqKg}^{-1}$  and  $0.56 \pm 0.06 \text{ BqKg}^{-1}$  respectively. The peak values of  $^{238}\text{U}$  and  $^{232}\text{Th}$  are  $4.24 \pm 0.98 \text{ BqKg}^{-1}$  and  $1.45 \pm 0.16 \text{ BqKg}^{-1}$ . This is from the soil samples.

The mean activity concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  in soil from cultivated farmlands in the study area are below the world average of 420, 33 and 45  $\text{BqKg}^{-1}$  respectively [30]. The activity concentrations of  $^{40}\text{K}$  are lower in soil samples than in cassava samples, while in  $^{238}\text{U}$  and  $^{232}\text{Th}$ , the difference in activity concentration is relatively small. This is not in line with the conclusion drawn by [23] where the radionuclides in soil were higher than those of food crops. The low activity concentration of radionuclides may be due to the non use of fertilizers on the farmlands. The accumulation of radioisotopes may be affected by difference in properties of soil and weather conditions. The accumulation of  $^{40}\text{K}$  may be affected by several determinants such as cation exchange capacity (CEC), type and pH of the soil. Potassium is one of the basic cations and so the ability of the soil to hold cations increases its presence [31].

The mean concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  in soil was found to be lower than those reported by [1], [23], [25], [31-33]. The results were also compared with those reported in studies conducted in other countries. The mean concentrations were lower than those obtained in Saudi Arabia [34], North of Malaysia [35], Iraq [36] and South Africa [37].

Radium equivalent was determined using Equation 2 (Tables 2 and 3). To minimize radiation hazards, samples whose  $\text{Ra}_{\text{eq}}$  are greater than  $370 \text{ Bqkg}^{-1}$  should not be ingested into the body [25]. The result is below this standard. The radium equivalent in soil ranged from 5.72  $\text{BqKg}^{-1}$  to 9.16  $\text{BqKg}^{-1}$  with an average of  $7.45 \pm 0.34 \text{ BqKg}^{-1}$  which is over 98% less than the world average of  $370 \text{ BqKg}^{-1}$  [4]. This means that the soil from the study area will pose no health risk at all to inhabitants if used as components of building materials.

### 3.2.2 Activity concentration in cassava

Cassava tubers are usually big and long penetrating into the soil with increased ability to absorb more radionuclides. This may be the reason for the high concentration of radionuclides in cassava samples as compared to those of soil [15]. Tables 3 shows the activity concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  in cassava samples from the study area. Considering Equation 5 again, the result of activity concentration was achieved in Table 3 from cassava samples.  $^{40}\text{K}$  varies from 64.43 to 183.50  $\text{BqKg}^{-1}$  with the highest mean activity concentration



of  $134.08 \pm 11.59 \text{ BqKg}^{-1}$  and  $183.50 \pm 15.28 \text{ BqKg}^{-1}$  as the highest value noted at D20. The mean activity concentrations of  $^{238}\text{U}$  and  $^{232}\text{Th}$  are  $3.89 \pm 0.93 \text{ BqKg}^{-1}$  and  $0.81 \pm 0.09 \text{ BqKg}^{-1}$  respectively. The maximum values of  $^{238}\text{U}$  and  $^{232}\text{Th}$  determined from the computation from cassava samples are  $5.60 \pm 1.34 \text{ BqKg}^{-1}$  and  $0.62 \pm 0.07 \text{ BqKg}^{-1}$ . Figures 2 and 3 present these results in chart forms for easy understanding. More information is given in subsection 3.2.

The mean activity concentrations of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  in cassava samples was found to be less than those reported by [31], [23], [32, 33].

The radium equivalent obtained from cassava samples ranged from  $9.28 \text{ BqKg}^{-1}$  to  $22.51 \text{ BqKg}^{-1}$  with an average of  $16.81 \pm 1.32 \text{ BqKg}^{-1}$  which is over 95% less than the world average of  $370 \text{ BqKg}^{-1}$  [4]. This means that the cassava from the study area will pose no health risk at all to inhabitants if ingested.

Equation 3 was adequate for the determination of the annual effective dose due to ingestion of cassava grown in the sample area ranged from  $0.11 \text{ mSvBq}^{-1}$  to  $0.41 \text{ mSvBq}^{-1}$  (Table 3) with an average of  $0.28 \pm 0.03 \text{ mSvBq}^{-1}$ . The values obtained are less than the world average of unity and lower than  $0.45$  and  $0.31 \text{ mSvBq}^{-1}$  reported in other areas of Delta State by [15].

Equation 4 satisfies the result of excess lifetime cancer risk due to ingestion calculated (Table 3) ranged from  $0.18 \times 10^{-3} \text{ BqKg}^{-1}$  to  $0.45 \times 10^{-3} \text{ BqKg}^{-1}$  with an average of  $(0.37 \pm 0.03) \times 10^{-3} \text{ BqKg}^{-1}$ . This value is lower than the recommended world average of  $1.0 \times 10^{-3} \text{ BqKg}^{-1}$ .

### 3.2.3 Transfer Factor (TF)

Equation 1 was employed to determine the transfer factor; Fig. 3 shows the graphical representation of these results. The mean transfer factor of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  from soil to cassava are  $3.44 \pm 0.75$ ,  $1.94 \pm 0.32$  excluding the result at U12 to D12 [or  $4.12 \pm 2.55$  including U12 to D12 result of investigation which is much pronounced) and  $1.34 \pm 0.54$  respectively. The range of values of  $^{40}\text{K}$ ,  $^{238}\text{U}$  and  $^{232}\text{Th}$  varied as  $1.06$  to  $8.52$ ,  $0.04$  to  $25.55$  and  $0.31$  to  $5.71$  correspondingly. Peak values of the TF were noted as  $8.52$  for  $^{40}\text{K}$  at U18, D18,  $25.58$  for  $^{238}\text{U}$  at U12, D12 and  $5.71$  for  $^{232}\text{Th}$  at U11, D11. The value of TR is accredited to the richness of the organic matter in the soil. The mean values obtained for TF of  $^{40}\text{K}$  in the study areas are higher than the recommended ratio of  $2.7$  [24], [1].

## 4. CONCLUSION

The levels of activity concentrations of natural radionuclides in some selected soil and cassava grown in Ughelli North, Delta State, Nigeria, have been assessed, and the radiological health effects have been noted. The activity concentrations of the radionuclides determined from both sources are lower than the world average standards and facts stated in some other works. The radium equivalent in soil is insignificant due to the extremely low values obtained if likened to the world average. The high transfer factor may indicate high ability to transfer radionuclides in the soil to food crops but from the concentration information, these radionuclides present in the soil are low as well as annual effective doses. The lifetime cancer risks due to the ingestion were also lower than that of the world average limit of  $1.0 \times 10^{-3} \text{ BqKg}^{-1}$ . Therefore, there is no radiological risk of ingestion in the study area. However, other researchers should re-evaluate the result of activity concentration and transfer factor at location U12 linking D12 as it yields a higher factor of  $25.58$  for  $^{238}\text{U}$ .



### Conflict of interests.

There are non-conflicts of interest.

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