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Radioactivity Concentration and Radionuclide Transfer Factor Assessment in Afang Leaves *(Gnetum africanum)* Cultivated in Akwa Ibom State, Nigeria

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ABSTRACT:

Activity concentration of radionuclides present in soil and transfer factor (TF) in plants are very useful parameters in accessing the level of radioactive contamination in farmlands and in plants cultivated in such farmlands. In this research work the activity concentration of naturally occurring radionuclides in farm soil and Afang leaves planted in the soil were measured using high purity Germanium (HPGe) detector. In soil the mean activity concentration of 238U was58.34±3.41Bq/kg,226Ra had mean value of 26.98±1.39Bq/kg, 232Th had 45.06±2.38Bq/kg, while that of 40K was30.91±1.71Bq/kg. The mean activity concentration of 238U, 226Ra, 232Th and 40Kin Afang leaves were 13.29±1.28Bq/kg, 4.85±0.79Bq/kg, 6.80±0.45Bq/kg and 459.65±25.64Bq/kg respectively.Transfer factors of 238U, 226Ra, 232Th and 40K were 0.22, 0.22, 0.17 and 31.21 respectively from soil to Afang leaves. In soil mean activity concentration of226Ra and 40K were within recommended limits while themean values obtained for activity concentration of 238U and 232Th in soil from most sampling locations were observed to be above world recommended values.Mean activity concentration of 238U, 226Ra and 232Th in afang leaves were within permissible values except for 40K.High values of TF were also obtained for 40K in all afang leaves samples, however 40K is known to be naturally abundant in soil and plants.Values of transfer factor obtained for 238U, 226Ra and 232Th in all afang samples were all below unity, which is within the recommended limits and therefore safe for consumption.

Keywords: Radionuclides, Soil, Activity Concentration, Afang, Transfer Factor.

1. INTRODUCTION

Naturally occurring radionuclides of^{238}U, ^{226}Ra, ^{232}Th and ^{40}K have significant contributions in the ingestion dose and are present in the biotic system of plants, animals, soil, water and air. Distribution of radionuclides in different parts of the plant depends on the chemical characteristics and several parameters of the plants and soil [18]. Inhalation and ingestion are the main pathways through which natural radionuclides enter into the human body. Dietary pathways become contaminated with radioactive materials from naturally enhanced radionuclides and man-made applications during routine operation, accidents, and migration of radionuclides from radioactive waste disposal repositories into the biosphere [19]. Contamination of the food chain occurs as a result of direct deposition of radionuclides on the plant leaves, root uptake from contaminated soil or water, and animals ingesting contaminated plants, soil or water. Ingestion of food crops grown in contaminated soil can be a major source of human exposure to radionuclides since it can lead to internal radiation doses. Considerable efforts are being made by authors in many parts of the world to measure the activity of radionuclides in the foodchain, the radiological burden and the estimated soil–plant transfer of radionuclides Uranium, radium, thorium, potassium and their decay products are among the most important radionuclides and they can be easily transferred from soil to plants through roots [19]. Phosphate rocks which are starting material for production of fertilizers contain high levels of uranium, thorium and other heavy metals. Due to reduction or loss of soil fertility in most Nigerian soils, inorganic fertilizers are used to boost crop yield. This consequently has a bearing on the chemical and radionuclide composition of the crops grown on such soil [3].

The extensive use of fertilizers can increase the amount of radionuclides in soil, plants, groundwater and consequential ingestion by humans through exposure routes such as drinking water and the food chain. Once deposited in bone tissue ^{226}Ra has a high potential for causingbiological damage because of the continuous irradiation of the human skeleton. Over many years,it can induce bone tumor [16].

Afang (*Gnetumafricanum*) also known as okaziis planted and consumed in large amounts in the study area. It is used to make afang soup which serves as a major delicacy within the study area.Since radionuclides are naturally available in soil and can also be enhanced by man throughactivities such as successive application of phosphate fertilizers and pesticides, mining and milling operations, burning of fossil fuels amongst others, it is therefore necessary to know the uptake of natural radionuclides by the plant from the soil. Although a lot has been done on measurement of radioactivity level in soil of the area, not much has been reported on radionuclide uptake by plant from soils in AkwaIbom State. This work is aimed at measuring the activity concentration of ^{238}U, ^{226}R, ^{232}Thand ^{40}K in soil, afanggrown on the soil of the study area and the estimation of soil - to –afangtransfer factor of these radionuclides.

2. MATERIALS AND METHOD

2.1. Study Area

The study area covered selected Local Government Areas (LGA) of AkwaIbom State. The Local Government Areas considered for sampling were IkotEkpene, Obot-Akara, EssienUdim, Abak, EtimEkpo, OrukAnam, Ikono and Uyo.AkwaIbom is a Statelocated in the southern coastal part of Nigeria and is within the South-South Geopolitical Zone. It lies between latitudes 4°32′N and 5°33′N, and longitudes 7°25′E and 8°25′E. The State is bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the south by the Atlantic Oceanand the southernmost tip of Cross River State.

2.2. Sample Collection and Preparation

Some factors considered in selection of sample sites include: farmlands where afang leaves were highly cultivated; and farmlands where the leaves were cultivated for both subsistence and small-scale commercial purposes. The type of pesticide used if any were noted, fertilizers used were also noted, whether organic or inorganic fertilizers. A total of 15afang leaf samples and their corresponding soil samples were collected. The farms were divided into evenly spaced sites with a distance of 20m between each site for larger coverage of the farm according to [8]. At each sampling location, the soil surface was cleared of stones, pebbles, vegetation and roots. Soil samples were collected around the root area of the sampled plants. Soil samples of about 2.0Kg (wet weight) were collected from each position with a shovel, and at a depth of about 15cm to 20cm. Samples of the corresponding edible part of the plant were collected. Each sample was put in a separate polythene bag and labeled carefully.

Afang samples collected were thoroughly washed with tap water, and then washed in distilled water to remove surface sand and debris [14]. The samples were then cut into small pieces and exposed to ambient air in a dust-free environment before being dried to a constant weight for 48 hours in a monitored oven maintained at I50^{o}C in the laboratory. The samples were then ground to powdery form, sieved and then weighed. The weight of the dry plant samples varied between 220g and 300g.

For soil sample preparation, the method used by [7] was adopted. The soil samples were also exposed to ambient air in a dust-free environment, dried, pulverized and then sieved. The weight of each soil sample was about 500g to 600g. Both plant and soil samples were then packed in properly sealed air tight polythene bags and labeled with appropriate sample codes. Thereafter, the samples were taken to National Institute of Radiation Protection and Research, Ibadan, for analysis.

2.3. Method for Sample Analysis

The prepared plant and soil samples were taken to National Institute of Radiation Protection and Research in University of Ibadan for analysis. The activity concentration of naturally occurring radionuclides in edible plants and their corresponding soil samples were measured using a High Purity Germanium (HPGe) Detector. The HPGe used was manufactured by Canberra, model GC 8023 with serial number 9744. It is coupled to a pre amplifier, model 2002CSL with serial number 13000742. The standard source used for calibration was Multi-Gamma Ray Standard (MGS6M315). The detector has a resolution (FWHM) of 2.3Kev, ^{60}Co at 1.33Mev with relative efficiency of 80%. The software used for analysis was Genie 2K.

For each soil sample, 500g of soil was measured and poured into a 500ml Marinelli beaker while 200g was used for each plant sample. The beaker was covered with the beaker lid and sealed properly to ensure that there was no space for escape of any radioactive gas. It was left for 28 days to attain secular equilibrium before being moved to the gamma analysis room for counting. Each sample was counted for 18,000seconds. Peak analysis was then done with Genie 2000 software. Activity concentration was determined by the earlier efficiency calibration done. The radionuclides considered were ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K.

2.4. Activity Concentration in Samples

The activity concentration (AC) in unit of Bq kg^{-1}, for radionuclides with detected photo peak at energy E, was calculated from Equation 2.1 given by [12].

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

Where C is the activity concentration of radionuclides in Bq kg^{-1}, N_t is the net count under corresponding photo peak, T is the counting time in seconds, P_r gamma intensity of specific gamma-ray, £ absolute efficiency, and M mass of sample in (kg), respectively. World reference value for AC in soil for ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K are 35 Bq/kg, 35 Bq/kg, 30 Bq/kg and 400 Bq/kg respectively. AC for leafy vegetables are 20 Bq/kg for ^{238}U and 15 Bq/kg for ^{232}Th [15].

2.5. Transfer Factor (TF)

The transfer mechanism of radionuclides is represented by a parameter called TF, which iswidely used to describe the soil to-plant transfer of radionuclide through the plant roots. Soil-to-plant transfer factor, afang leaves, were estimated from the measured activity concentrations of radionuclides in plant soil using the linear relationship in Equation 2.2 [12] [9].

$$TF = \frac{C_P(Bq\ Kg^{-1}, dry\ weight)}{C_S(Bq\ Kg^{-1}, dry\ weight)} \qquad \text{Equation 2.2}$$

C_P (Bq kg^{-1}, dry weight) is the concentration of radionuclide in plant or plant partwhile C_S (Bq kg^{-1}, dry weight) is the concentration in soil within the rooting zone.Maximum permissible value of TF ^{238}U, ^{226}Ra, and ^{232}Th is unity while that of ^{40}K is 5.60 [15].

3. RESULTS AND DISCUSSION

3.1. Radionuclide Activity Concentration in Soil Samples

Table 1 presents activity concentration of radionuclides in soils where afang was cultivated in the study area. The mean of activity concentrations of the radionuclides in soils in each L.G.A. and the overall mean of each radionuclide in the study area are also shown. S- Soil samples.

Table 1: Activity Concentration (AC) of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in Bq/Kg in Soils where Afang *(Gnetumafricanum)* was Sampled

LGA	Sample codes	^{238}U	^{226}Ra	^{232}Th	^{90}K
Abak	S7	54.74±2.94	22.52±1.16	31.77±1.64	19.99±1.13
	S8	50.59±2.82	21.81±1.13	31.76±1.69	18.75±1.09
EssienUdim	S12	48.53±2.78	22.54±1.16	41.65±2.20	28.81±1.57
	S16	47.38±2.62	26.69±1.38	33.92±1.92	10.03±0.66
	S17	80.11±4.26	28.71±1.48	43.48±2.27	19.11±1.09
	S18	82.98±4.39	29.41±1.51	61.02±3.21	50.85±2.71
	S19	51.40±2.82	28.29±1.46	47.32±2.49	17.72±1.01
EtimEkpo	S25	53.33±2.95	26.29±1.36	50.40±2.66	35.67±1.93
	S26	62.83±3.37	23.47±1.21	35.22±1.88	49.66±2.65
Ikono	S33	89.10±4.71	36.42±1.88	68.42±3.61	18.74±1.13
IkotEkpene	S29	53.25±3.00	25.93±1.34	50.36±2.69	28.87±1.58
ObotAkara	S35	57.00±3.10	23.91±1.23	41.57±2.21	36.12±1.95
	S36	45.32±2.66	22.61±1.17	31.14±1.63	129.32±6.84
OrukAnam	S40	33.65±1.95	16.60±0.86	21.28±1.13	2.35±0.26
Uyo	S42	123.23±6.43	46.70±2.41	82.94±4.37	10.18±0.71
	S43	71.22±3.78	29.91±1.54	48.83±2.60	18.89±1.08
	Mean	58.34±3.40	26.98±1.39	45.06±2.38	30.94±1.71

Values of activity concentration of ^{238}U, $^{226}R_a$ ^{232}Thand ^{40}Kin soil from where afang leaves were sampled are shown in Table 1. The activity concentration of ^{238}U ranged from 33.64±1.95 to 123.23±6.43Bq/kg with a mean of 58.34±3.40Bq/kg. Activity concentration for $^{226}R_a$ had values thatranged from 16.60±0.86Bq/Kg to 46.70±2.41Bq/kg with a mean of 26.98±1.39Bq/kg. Activity concentration for ^{232}Th ranged from 21.28±1.13 Bq/kg to 82.94±4.37Bq/kg with mean of 45.06±2.38Bq/kg, while that of ^{40}K was observed to range from 2.35±0.26 to 129.32±6.84Bq/kg with mean of 30.91±1.71Bq/kg. The trend of activity concentration of radionuclides in afang soil is similar to that observed in soil of fluted pumpkin by [6]. There was lower deposition of ^{40} K compared with values from other studies conducted in Nigeria [1] [4]. Activity concentration for^{238}U and ^{232}Th were still slightly higher than world reference limit, with highest values obtained from a location in Ikot Eboro in Uyo. This location had been observed to have predominantly clay type of soil. This is similar to a recent study carried out in nine states of the Niger Delta region of Nigeria [4] which reported high levels of ^{232}Th particularly from areas with clay type of soil. Activity concentration of $^{226}R_a$ and ^{40}K in soils from where afang leaves were sampled were within world reference limits.

3.2. Activity Concentration of Radionuclides in Afang

Table 2 presents the activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in afang leaves cultivated in the study areas.

Table 2: Activity Concentration (AC) of ^{40}K, ^{226}Ra, ^{238}U and ^{232}Th in Bq/Kg for Afang Samples From the Study Areas

LGA	Sample codes	^{238}U	^{226}Ra	^{232}Th	^{90}K
Abak	A1	10.53±1.45	12.45±1.22	4.18±0.50	74.58±35.69
	A2	BDL	ND	0.54±0.14	271.89±14.41
	Mean	5.26±0.72	6.22±0.61	2.36±0.32	173.23±25.05
EssienUdim	A3	ND	BDL	BDL	397.68±21.04
	A4	BDL	ND	2.18±0.21	332.13±17.57
	A5	BDL	ND	6.59±0.69	838.84±44.37
	A6	64.55±5.94	10.74±2.15	6.20±0.71	714.46±37.85
	Mean	16.14±1.48	2.68±0.54	3.74±0.40	570.78±30.21
EtimEkpo	A7	29.62±2.66	6.49±1.12	2.76±0.40	536.78±28.40
	A8	BDL	BDL	BDL	564.85±35.69
	Mean	14.81±1.33	3.24±0.56	1.38±0.20	550.82±32.04
IkotEkpene	A9	ND	ND	4.65±0.67	512.52±27.17
Ikono	A10	61.27±5.07	7.77±1.01	4.19±0.77	605.30±32.03
ObotAkara	A11	15.65±2.07	4.91±1.25	5.02±0.55	460.69±24.37
	A12	12.69±1.33	2.47±0.56	7.01±0.56	151.95±8.04
	Mean	14.17±1.70	3.69±0.91	6.01±0.55	306.32±16.20
OrukAnam	A13	BDL	ND	7.39±0.99	536.39±28.40
Uyo	A14	4.45±0.71	ND	7.55±0.75	468.65±24.80
	A15	BDL	25.59±2.46	36.60±0.71	428.02±22.84
	Mean	2.22±0.35	12.80±1.23	22.07±0.73	448.33±23.82
	Overall Mean	13.29±1.28	4.85±0.79	6.80±0.45	459.65±25.64

BDL = Below Detection Limit, ND: not detected

Results for AC in afang leaves are presented in Table 2. The AC of radionuclides in afang leaves ranged from BDL to 64.55±5.94Bq/Kg, BDL to 25.59±2.46Bq/Kg, BDL to 36.6±0.71Bq/Kg and 74.58±35.69 to 838.84±37.83Bq/Kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K respectively with mean values of 13.29±1.28Bq/kg, 4.85±0.79Bq/kg, 6.80±0.45Bq/kg and 459.65±25.64Bq/kg for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. Whereas ^{40}K was detected in all of the 15 afang leaf samples collected, ^{238}U was below detection level (BDL) in about 6 samples and not detected (ND) in 2 samples, ^{226}Ra was BDL in 2 samples and ND in 5 samples, while ^{232}Th was BDL in 2 samples. Values of AC of radionuclides in afang leaf samples were lower compared to values obtained for fluted pumpkin leaves in similar work done in the area, even with AC of the radionuclides in the corresponding soil being comparatively lower than in the leaf samples [6]. This suggests that the quantity of transferred radionuclide to plant may not be directly proportional to the quantity of the radionuclide present in the soil [10] [2]. Mean AC of ^{238}U, ^{226}Ra and ^{232}Th obtained in this work were low compared to results obtained for other leafy vegetables and food crops in the country (such as that of [20] [4]. Mean AC of ^{238}U, ^{226}Ra and ^{232}Th obtained in this work are within the world average of 20Bq/kg for ^{238}U and ^{226}Ra and 15Bq/kg for ^{232}Th for leafy vegetables [15].The distributions of mean AC of radionuclides in each LGA of the study area are presented in Figure1Ikono LGA still had the highest concentration while Abak LGA had the lowest mean activity concentration.

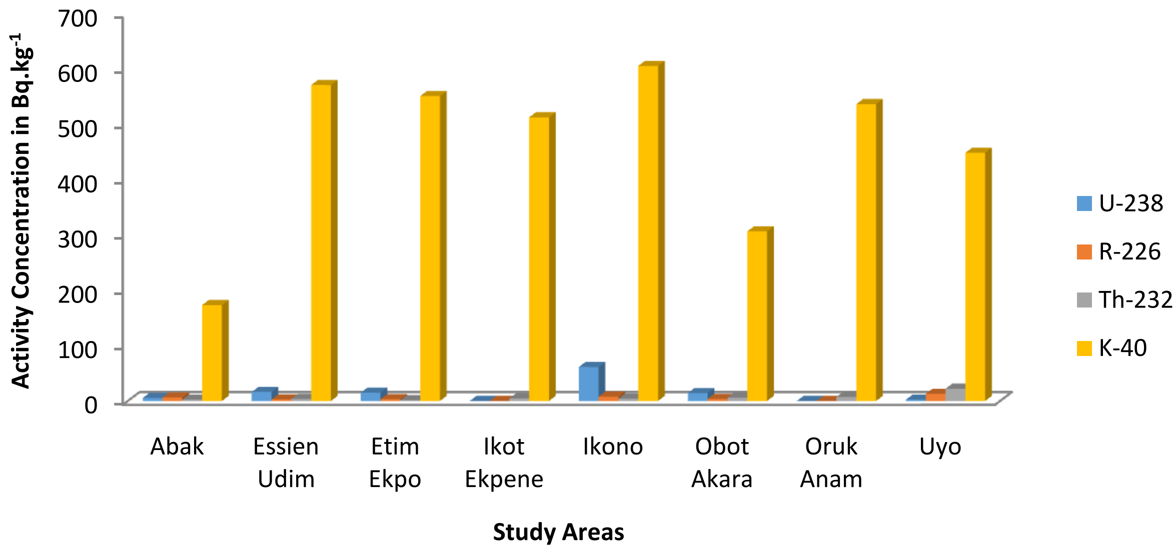

Figure 1: Distribution of the mean activity concentration in Bq/Kg of the afang samples from the study area

3.3. Transfer Factor of Radionuclides from Soil to Afang Leaves.

Table 3 presents the results of transfer of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K from soil to afang leaves.

Table3: Transfer factors of radionuclides from soil to afang leaves from the study area

Sample codes	^{238}U	^{226}Ra	^{232}Th	^{90}K
A1	0.29	0.56	0.12	4.16
A2	BDL	ND	0.02	13.60
A3	ND	BDL	BDL	13.80
A4	BDL	ND	0.05	17.38
A5	BDL	ND	0.13	15.44
A6	0.78	0.36	0.10	14.05
A7	0.55	0.24	0.05	15.05
A8	ND	ND	0.13	10.32
A9	1.15	0.30	0.08	20.97
A10	0.17	0.13	0.07	24.58
A11	0.28	0.11	0.22	1.17
A12	BDL	ND	0.35	228.25
A13	0.04	ND	0.09	46.04
A14	BDL	0.85	0.75	22.66
A15	BDL	0.71	0.45	20.70
Mean	0.22	0.22	0.17	31.21

Transfer factors obtained for afang samples are presented in Table 3. TF varies from farm to farm with range between 1.17 to 228.25 for ^{40}K, BDL to 0.22 for ^{238}U, BDL to 0.75 for ^{232}Th and BDL to 0.22 for ^{226}R. The mean values obtained of TF obtained for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K were 0.22, 0.22, 0.17 and 31.21 respectively. It is also observed that the TFs of the radionuclides are higher while their activity concentrations in the soil are low which agrees with findings obtained in other works such as [5] showing that TF are not linearly related to radionuclide activity concentration in soil [17]. TF values obtained in this work for ^{238}U, ^{226}Ra, ^{232}Th in afang leaves were lower than unity which is the world recommended value while TF for ^{40}K was however greater than 5.60 which is the world recommended value by [15] [9] reports. Figure 2 shows the distribution of the mean transfer factors of radionuclides from soil to afang samples from the study areas. From Figure 2 it is observed that AC and TF for afang in this work are also lower compared to that obtained for fluted pumpkin leaves [13]. This may be due to high mineral content of afang leaves, giving it a low chance to accept a high amount of radionuclides [11].

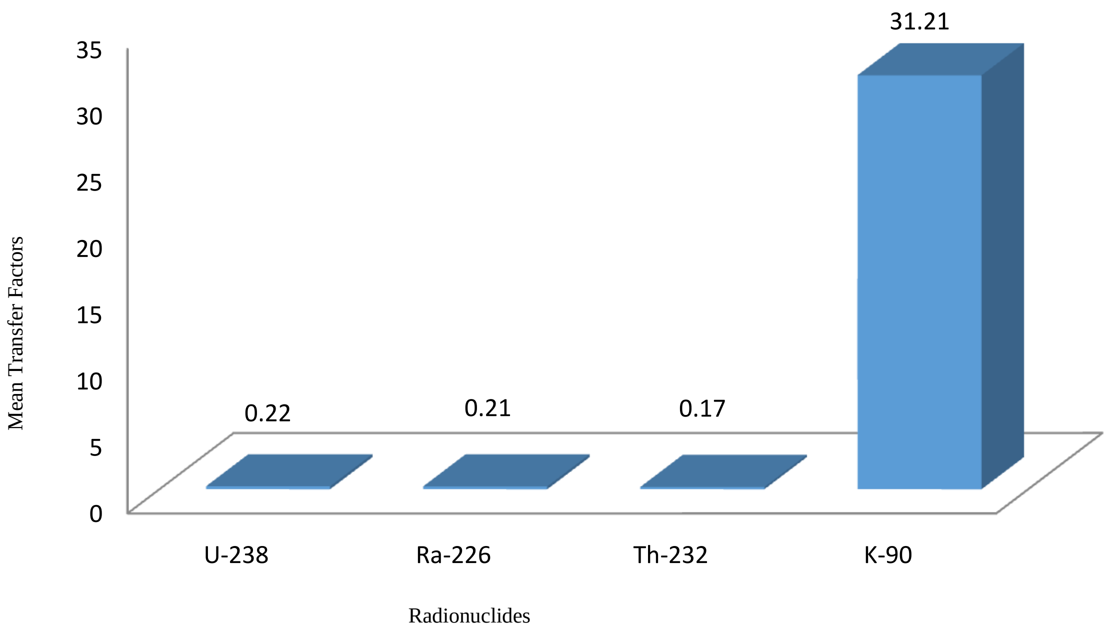

Figure 2: Distribution of the mean transfer factors of radionuclides from soil to afang samples from the study areas.

Figure 3 shows the Percentage distribution of the radionuclides transfer from soil to afang obtained from the study area.

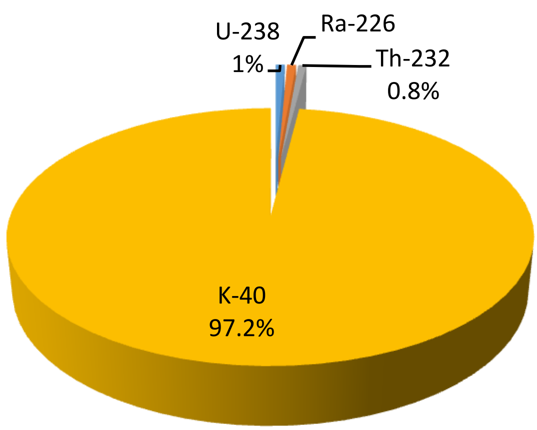

Figure 3: Percentage contribution of the radionuclides in the transfer from soil to afang

^{40}K has the highest contribution with a percentage of 97.2% while ^{238}U, ^{232}Th and ^{226}Ra have 1%, 0.8% and 1% respectively.

4. CONCLUSION

For the four radionuclides studied, ^{40}K only was found to have a significantly higher AC in the plant (Afang leaf) than in the corresponding soil sample.The mean value of Transfer factor for ^{40}K was also significantly higher compared to other radionuclides. However from literature potassium is an abundantly available element and the body has a way of coping with it. Hence the consumption of Afang leaves in the study area is safe.

REFERENCES

[1] Ademola, A. K. (2021). Radiological risks from natural radionuclides in surface soil of Agbaraindusrial area, Ogun State Nigeria. J. Appl. sci. Environ. Manage. Vol 25 (5) 733-739.

[2] Adesiji, N. E. and Ademola, J. A. (2019).Soil-to-cassava plant transfer factor of natural radionuclides on a mining impacted soil in a tropical ecosystem of Nigeria. Journal of Environmental Radioactivity,201(10):1

[3] Alsaffar, M. S., Suhaimi, J. M., Ahmad K., N. and Nisar, A. (2016). Impact of fertilizers on the uptake of 226Ra, 232Th, and 40K by pot grown rice plants. *Pollution*, 2(1): 1-10. DOI: 10.7508/pj.2016.01.001.

[4] Avwiri, G. O., Ononugbo, C. P., Olasoji, J. M. (2021). Radionuclide transfer factors of staple foods and its health risks in Niger Delta region of Nigeria. *International Journal of Innovative Environmental Studies Research* 9(1): 21-32.

[5] Carini, F. (2001). Radionuclide transfer from soil to fruit. J Environ Radioact 52:237–279.

[6] Essen, I. M., Essiett, A. A., Essien, I. E., Ekanem, K. R.,Bede, M. C. and Ehiwe, I. O. (2021) Soil- to- Fiuted pumpkin Transfer of natural radionuclidesin farmlands in AkwaIbom state. International Journal of progressive sciences and technologies (IJPSAT) Vol 28 pp546 – 554.

[7] Essien, I. E and Akpan, E. N. (2016). Evaluation of radiological hazards indices due to radioactivity in quarry sites in Itu, AkwaIbom State, Nigeria. *International Journal of Scientific Research in Environmental Sciences*, 4(3): 71-77.

[8] Essien, I. E**.,**Essiett, A. A., Ani, O. B., Peter, I. G and Udofia, A. E. (2017). Estimation of radiological hazard indices due to radioactivity in soils in IbionoIbom, AkwaIbom State, Nigeria. *International Journal of Scientific and Research Publications*, 7 (5):245-250

[9] FAO/IAEA/IUR (2006). Protocol for Experimental Studies on the Uptake of Radionuclides from Soils by Plants (IAEA-TECDOC--1497). A Report of International Atomic Energy Agency (IAEA), Vienna.

[10] Golmakani, S., Moghaddam, M. V. and Hosseini, T. (2008). Factors affecting the transfer of radionuclides from the environment to plants. Journal of *Radiation Protection Dosimetry.*, September 2008.Pp 1-4.

[11] Elsaman, R., Ali, G. A., Uosif, M. M. A., El-Taher, M. A. Chong, K. F. (2020). Transfer factor of natural radionuclides from clay loam soil to sesame and cowpea: radiological hazards. *International Journal of Radiation Research*, Volume 18, No 1, DOI: 10.18869/acadpub.ijrr.18.1.15.

[12] IAEA (2010). Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and freshwater Environments. Vienna - International Atomic Energy Agency Technical Reports Series No. 472, 79.

[13] Essien, I., Akankpo, A., Nyong, A., Inyang, E. (2021). Determination of activity concentrations and soil to cassava transfer factors of natural radionuclides in IkotEkpene local government area, AkwaIbom State, Nigeria. *Journal of Geography, Environment and Earth Science International*. 25(7): 28-35.

[14] Jwanbot, D.I., Izam, M. M., Nyam, G. G. and John, H. N. (2013). Radionuclides Analysis of Some Soils and Food Crops in BarkinLadi LGA, Plateau State- 2225-0948 (Online) Vol. 3, No.3, 2013

[15] UNSCEAR (2000). Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes. United Nations, New York. https.

[16] Markovic J. and Stevovic S. (2019). Radioactive Isotopes in Soils and Their Impact on Plant Growth, Metals in Soil - Contamination. *Intech Open*, DOI: 10.5772/intechopen.81881. Available from: https://www.intechopen.com/chapters/.

[17] Ononugbo C. P, Azikiwe, O and Awiri, G. O (2019). Uptake and distribution of natural radionuclides in cassava crops from Nigerian Government farms. *Journal of Scientific Research and Reports*, 23(5): P 1-15. 2019; Article no. JSRR.48782: 2320-0227.

[18] Shanthi, G., Maniyan, C. G., Allan, G., Raj, G. and Kumaran, J. T. T (2009). Radioactivity in food crops from high background radiation area in southwest India, Current Science, 97(9) : 1331-1335

[19]Tang S, Chen Z, Li H, Zheng J (2003) Uptake of 137Cs in soil shoots of Amaranthus tricolor and Amaranthuscruetus. Environ Pollut 125:305–313.

[20] Tchokossa, P., Olomo, J. B, Balogun, F. A. and Adesanmi, C. A. (2013). Assessment of radioactivity contents of food in the oil and gas producing areas in Delta State, Nigeria. *International Journal of Science and Technology,* Volume 3 No.4, April 2013. 2224-3577.