ACTIVITY CONCENTRATION OF NATURAL RADIONUCLIDES AND TRANSFER FACTORS FROM SOIL TO VEGETABLE IN PARTS OF SOUTH SOUTH NIGERIA.

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ABSTRACT

Naturally occurring radionuclide materials are known to exist in soils and is transferred into vegetables and eventually gets into food chain. This work was aimed at determining the activity concentration of these radionuclides in soils and vegetable (fluted pumpkin) and the internal exposure due to the consumption of these materials in the vegetable in parts of South South Nigeria particularly Etim Ekpo Local Government area. The activity concentrations of twenty (20) soil samples and 20 vegetable samples from the farmlands were determined using gamma spectrometry. The activity concentration for ^{40}K ,^{232}Th and ^{238}U from the soil samples ranged from 6.69±0.35 (Bqkg^{-1}) to 168.19 ±8.82 (Bqkg^{-1}) ,0.23 ±0.01 (Bqkg^{-1}) to 5.91 ±0.35 (Bqkg^{-1}) and BDL to 21.53±2.5 (Bqkg^{-1}) respectively. The activity concentration of ^{40}K, ^{232}Th and ^{238}U in the vegetable ranged from (584.23±27.71) Bqkg^{-1} to (958.67±48.46) Bqkg^{-1}, from (1.84±0.11) Bqkg^{-1} to (9.72 ±0.56) and from (BDL) to (38.34±3.74) Bqkg^{-1} respectively. Transfer factors obtained ranged between 12.07±4.7 to 35.35 ±27.9 for ^{40}K, 1.80±0.125 to 5.76 ± 4.31 for ^{232}Th and BDL to 21.05 for ^{238}U. Effective ingestion dose due to the consumption of vegetable from the study area obtained as 0.0021mSvy^{-1}. This value is less than the 0.29mSvy^{-1} recommended dose limit for the general public; therefore, the consumption of this vegetable could not cause a radiological health effect on its consumers. However negligible or low risk could be minimised when the vegetable is washed and cooked before being consumed. Hence, the results obtained in this study indicate that the activity concentration of the farmland soils and crops represent no significant health risk on the farmers and the consumers of the vegetables.

KEYWORDS: Activity concentration; Soil; Fluted pumpkin (*Telferia occidentalis*); Radionuclides; Transfer factors; Effective Dose.

INTRODUCTION

Radionuclides are found in nature and it exists in the soil, water, air, sediments and plants. Radionuclides are atoms that exhibit radioactivity. Each radionuclide is characterized by its own half–life, which is the time required for half of the radioactive substance to undergo spontaneous decay. It is the nucleus of an atom that exhibit the property of spontaneous disintegration. Humans may breathe in and consume radionuclides which are unstable elements that degenerate and release ionizing radiation from air, food and water (Ekpo *et al.*, 2020). Radionuclides can be used to calculate the age of rocks and minerals using radiometric dating method. Natural occurring radioactivity is common in the rocks and minerals as well as the soil that make up the planet. (Araromi *et al.*, 2016 and Musamali *et al.*, 2011).

Soil-plant-human route had also been recognised as a major pathway for the transfer of radionuclides to human beings (Ademola *et al.*, 2019 and Mostafa, *et al.*, 2016). Human health status is a function of his environment (Essien *et al.*, 2016). Therefore, it is important to assess the natural radionuclide levels in different foods and diet and to estimate the intake of these radio nuclides. Their transportation to plants is possible via root uptake and deposition of dust on plant leaves and to humans through ingestion and inhalation. The uptake of radio nuclides from soil to plants is characterised by transfer factor (TF) which is defined as the ratio of radionuclide concentration in plant to soil per unit mass. This parameter is necessary for environmental transfer models which are useful in the prediction of radionuclide concentration in agricultural crops for the estimation of dose impact to consumers.

The radionuclides with half-lives comparable with the age of the earth or their corresponding decay products existing in terrestrial materials such as ^{40}K, ^{238}U and ^{232}Th are of great interest with potassium being the most abundant because of its deleterious effect when ingested, inhaled and interacted with the environment. The radio isotopes found in the soils are also transferred to the surface of the soil through activities like mining and cultivation of the soils and consequently, radiating ionizing radiation to the environment. It is obvious that radionuclides found in the surface of soils could also be transferred through infiltration process thus changing the chemical and physical processes of the soil (Essien, *et al.*, 2021) and could also be transferred to plants which acts as one of the pathways through which radioisotopes and radiation get to man.

Fluted pumpkin (*Telferia occidentalis*) is one of the most important vegetable crops grown extensively in almost every State in the Southern part of Nigeria by most households (Ekpo, *et al.*, 2021) and consumed by majority of Nigerians because of its dietary importance. It is among the major income generating crops in many parts of Africa. The crop is often planted in flat land or in moulds. The crop is recommended to be planted on raised beds to reduce the effect of flooding during raining seasons common to the southern part of Nigeria (Akpaeti, *et al.*, 2015). Fluted pumpkin has medicinal values because it is rich in fibres as sources of omega 3 fatty acids which help in the prevention of heart related diseases. The macro nutrients in vegetables also contribute to reducing incidence of colon and stomach cancer (Grubben *et al.*, 2016).

Radionuclides are introduced in the soil (which is significant in the yield of our planet ecosystems (Atat *et al.*, 2017)) through application of inorganic fertilizers, chemical sprays, pesticides and erosion of NORM (Natural Occurring Radionuclide Materials) emit radiations that pose danger to human beings. There is no information about the level of radionuclides in the soil and its transfer factors for the vegetables in this location. It is for this reason that the concentration of the radionuclides in soil is measured to assess the possible radiological hazard to human health and to develop standards and guidelines for the use and management of the soil and fertilizers. This study was carried out to determine activity concentration of ^{238}U, ^{232}Th and ^{40}K in soils, vegetables (fluted pumpkin) grown in parts of South South Nigeria, Etim Ekpo Local Government Area of Akwa Ibom State and also to evaluate the soil-to-plant transfer factor of the radionuclides.

MATERIALS AND METHOD

Location and Geology of the study Area

The study is carried out in Akwa Ibom state, Nigeria. The state is located between Latitude 4^0 32^0N and 5^0 33^0N and Longitude 7^0 25^0E and 8^0 25^0 East. The state is an agrarian with six agricultural zones viz: Abak, Oron, Ikot Ekpene, Etinan, Uyo and Eket. Her favourable climate favours the production of both permanent and arable crops, bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the south by the Atlantic Ocean and the southernmost part of Cross River State. Akwa Ibom is one of Nigeria's 36 states, with a population of over five million people and more than 10 million people in diasporas. It consists of 31 Local Government Areas and covers an area of about 7,249square kilometers (Essiet *et al.*, 2019). The state's capital is Uyo, with over 500,000 inhabitants. Etim Ekpo local government area is situated in Akwa Ibom state, South-south geopolitical zone of Nigeria. A number of towns and villages make up Etim Ekpo LGA and some of these include Ikot Akpan, Ntak Inyang, Ikot Inyang, Uruk Ata Nsidung, Nto Edet, Atan, Ikot Obio Nta, Ikono, Obong etc. The estimated population of Etim Ekpo LGA is 105,418 inhabitants according to 2006 population census. The area occupies a total land mass of about 25,985square kilometres. (Effiong, *et al.*, 2015). The study area is in the Niger Delta region experiencing two distinct seasons which are the dry and the rainy (wet) seasons (Atat and Umoren, 2016; Atat *et al*., 2020a; Atat *et al*., 2020b). The average temperature of the area is put at 25 degrees centigrade while the average humidity of the area is put at 88 percent. The average total rainfall recorded in Etim Ekpo LGA is 3,250 per annum. Utu Etim Ekpo is the Local Government Headquarter. (Effiong, *et al*., 2015).

Sample Collection, Preparation and Analysis

Soil Samples were collected at depths 0.3m from the surface at each point using a hand trowel. Also, the vegetable samples were collected at the spot. A total of twenty soil and vegetable samples were collected from 5 sample points across the study area. The spacing between each sample point was about 2m apart according to. After collection, the wet samples each weighing about 2Kg were placed in polythene bags and carefully labelled to prevent sample mix up. The sampling was done in the month of December 2021 and January 2022 from different location across the study area. The Soil samples were sun dried for three days in order to remove moisture. Its constant weight was reached. The samples were crushed to powder with mortar and then sieved with a 2 mm mesh sieve to obtain a homogenized sample. Thereafter, approximately 500 g of each of the samples was transferred to cleaned washed, uncontaminated cylindrical plastic containers of approximately uniform sizes and labelled from SL1 to SL20. The vegetable samples were washed with normal water, weighed and chopped into small parts. Each sample was placed in a plastic bag and labelled by name VEG1 to VEG20. Then they were kept moisture-free before radioactivity measurement, in an oven for (2-4) days at a temperature of 42 to 44℃ in order to reach a constant weight (500g) and avoid any humidity adsorption. Then the samples were crushed with mortar and pestle for homogeneity, the sample were sieved with a 0.8-mm- pore-size sieve and then packed in marinelli beakers to attain a good homogeneity around the NaI(Ti) detector. The samples were properly marked, catalogued and taken to the National Institute of Radiation Protection and Research (NIRPR) Ibadan, Oyo State Nigeria for analysis. During each sample collection, Global Position System (GPS) was incorporated for the location of the coordinate of each sample station

Determination of Specific Activity in the Samples

The specific activity for each detected photo peak was calculated in (Bqkg^{-1}) using (Abojassim, *et al.,* 2016) given in Equation 1.

$$A_r\left(\frac{Bq}{kg}\right) = \frac{N-N_0}{I\gamma\ \xi mt} \qquad (1)$$

Where A_r is the specific activity 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, Iγ is the number of gamma photons per disintegration, ξ 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.

Transfer Factor (TF)

This is the ratio of activity concentration in plant part (in Bq kg^{-1} dry weight) to the activity concentration of the soil (in Bq kg^{-1} dry weight). The soil to plant transfer factor is a measure of transport of radionuclides from soil to plant through as absorbed by the plants' roots. The transfer factor of ^{40}K, ^{232}Th and ^{238}U for all the vegetable sample were calculated using Equation 2 (Adejisi, *et al*., 2019).

$$TF= \frac{Activity\ concentration\ of\ radionuclide\ in\ plant\ (Bqkg\ ,^{-1} dry\ weight\ )}{Activity\ concentration\ of\ radionuclides\ in\ soil\ (Bq\ kg^{-1}, dry\ weight)} \qquad (2)$$

Effective Dose Due to Consumption of Radionuclide in Foodstuff

Calculation of Consumption Annual Effective Dose

The annual effective dose due to the consumption of Vegetable depends on the vegetable consumption rate and radioactivity in vegetable. The effective dose from a radionuclide in vegetables can be determined using Equation 3 (Abojassim, *et al.*, 2016).

$$D_{rf}\ (\text{mSvy}^{-1}) = \sum(C_r\ A_{rf}) \times R_f \qquad (3)$$

Where D_{rf} is the Annual effective Dose, C_r is the effective dose conversion factor of the Radionuclide r, A_{rf} is the specific activity of the nuclide (r) in the ingested food (vegetable in Bqkg^{-1}), R_f is the consumption rate of the food item (vegetable), which is equal to 42.67kcal/capita/year.

This is determined by measuring radio nuclide activities concentration in the material and multiplying the activities by dose conversion factors and the mean annual consumption of food stuff (vegetable). The dose conversion factor for the respective radionuclides is given as 6.2×10^{-6}, 6.9×10^{-4} and 2.8×10^{-4} mSvBq^{-1} for ^{40}K, ^{232}Th and ^{238}U respectively (Essien, *et al.*, 2021). The vegetable consumption rate (R_f) given by Food Agricultural Organization (FAO) is 42.67kcal/capita/day.

RESULTS AND DISCUSSION

Activity concentration of radionuclides in soils per districts

Table 1. The Activity concentration in soil per district.

S/N	District	Sample Code	^{40}K (Bq/Kg)	^{232}Th (Bq/Kg)	^{238}U(Bq/Kg)
1.	Utu	SL1	84.34 ± 4.5	2.09 ± 0.12	21.46 ± 2.52
2.		SL2	74.55 ± 3.94	0.23 ±0.01	1.18 ± 0.16
3.		SL3	168.19 ±8.82	5.04 ± 0.30	8.89 ± 1.16
4.		SL4	6.69 ± 0.35	4.15 ± 0.25	8.23 ± 1.15
5.	Ikono	SL5	36.89 ± 1.94	2.77 ± 0.17	BDL
6.		SL6	154.75 ± 8.16	4.88 ± 0.29	11.88 ± 1.54
7.		SL7	27.51 ± 1.46	4.46 ± 0.26	16.92 ±2.00
8.		SL8	65.44 ± 3.46	4.39 ± 0.26	3.42 ± 0.50
9.	Obong	SL9	30.34 ± 1.60	0.76 ± 0.05	12.57 ± 1.51
10.		SL10	130.27 ± 6.84	1.48 ± 0.09	0.20 ±0.03
11		SL11	51.17 ± 2.70	3.05 ±0.18	21.53 ± 2.52
12		SL12	29.45 ±1.55	5.16 ± 0.31	5.92 ±0.78
13	Uruk	SL13	85.44 ±4.49	4.25 ± 0.25	3.65 ± 0.51
14		SL14	62.55 ± 3.30	3.52 ± 0.21	5.86 ± 0.7 7
15		SL15	34.48 ± 1.75	0.42 ± 0.02	BDL
16		SL16	95.79 ± 5.06	4.39 ± 0.26	13.59 ± 1.66
17	Utut Annang	SL17	111.03 ± 5.84	5.91 ± 0.35	11.29 ± 1.41
18		SL18	99.03 ± 5.21	4.16 ± 0.25	10.40 ± 1.31
19		SL19	11.38 ± 0.61	1.86 ± 0.11	BDL
20		SL20	64.75 ± 3.43	4.30 ± 0.26	13.59 ± 1.64
Mean			71.2±8.1	3.36±0.2	8.529±1.1

Table 2: Mean and range values for soil activity concentration (Bqkg^{-1}) per districts.

S/N(District)		^{40}K	232Th	^{238}U
1-4 (Utu)	Range	168-6.69	21.46- 1.18	21.46 -1.18
	Mean	83.44 ± 40.3	2.88 ± 5.07	9.94 ± 5.07
5-8 (Ikono)	Range	16.92- BDL	16.92 - BDL	16.92 - BDL
	Mean	71.15 ± 4.2	3.05 ± 4.23	8.06 ± 4.23
9-12 (Obong)	Range	130.27± 29.45	21.53- 0.2	21.53 - 0.2
	Mean	60.31 ±25.2	4.21 ± 5.33	10.06± 5.3
13-16 (Uruk)	Range	95.79 ± 34.48	13.9- BDL	13.59 - BDL
	Mean	69.57 ±15.3	4.07 ± 3.47	5.78 ± 3.39
17-20 (UtutAnnang)	Range	111.03- 11.38	13.9 - BDL	11.29 - BDL
	Mean	71.55 ± 24.9	4.13 ± 3.47	8.82 ± 2.8

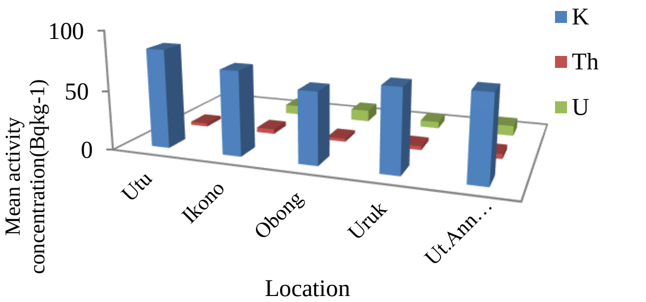

Figure 1: Mean activity concentration for ^{40}K, ^{232}Th and ^{238}U in soil samples.

Specific Activity of Radionuclides in soil of the Area

Radioactivity concentration of ^{40}K,^{232}Th, and^{238}U have been measured in the soil samples collected from each district of Etim Ekpo Local Government Area of Akwa Ibom State. The activity concentration of ^{40}K, ^{232}Th and ^{238}U in the soils were found to be in the range of (11.38±0.61-168.19±8.82) BqKg^{-1}, (0.23±0.01-5.91±0.35) BqKg^{-1} and (BDL–21.46±2.52) BqKg^{-1} respectively for the soil (Table1). The mean activity of ^{40}K, ^{232}Th, and ^{238}U in the soil samples were found to be (71.202±7.8) Bqkg-1, (3.36±0.3)BqKg^{-1} and (8.529±1.1)BqKg^{-1} respectively. It was observed in Figure 1, that the soils in Utu districts have the highest activity concentrations of all the radionuclides. The activity concentration values of ^{40}K in the sample is higher than the worldwide weighted mean of 33 BqKg^{-1} for ^{238}U, 45 BqKg^{-1} for ^{232}Th and 420 BqKg^{-1} for ^{40}K (UNSCEAR, 2000b). The mean activity concentration of ^{40}K was 9.13 ±1.03BqKg^{-1}, 5.91 ±0.66BqKg^{-1} for ^{232}Th and 8.13 ±0.91BqKg^{-1} for ^{238}U reported in farms soils from Ibiono Ibom. These values were lower than the values obtained in farm soils from the area under study and the recommended values. The higher value of ^{40}K in the study area could be attributed to the variation in distribution of these radionuclides in their soils.

Activity Concentration of Radionuclide in Vegetable

Specific Activity of Radionuclides Vegetable in the Area

The activity concentration of ^{40}K, ^{232}Th and ^{238}U in the vegetable were found to be in the range of and (548.23±27.71-958.67±48.46) BqKg^{-1}, (1.84±0.11-9.72± 0.56) BqKg^{-1} and (BDL-27.55±3.58) BqKg^{-1} (Table 3) respectively for vegetable. and the mean activity for vegetable sample were found to be (729.56±20.5) BqKg^{-1}, (6.78±0.4) BqKg^{-1} and (14.28±1.4) BqKg^{-1} respectively. The radionuclides activity concentration values of ^{40}K in the vegetable sample is higher than the worldwide weighted mean of 33 BqKg^{-1} for ^{238}U, 45 BqKg^{-1} for ^{232}Th and 420 BqKg^{-1} for ^{40}K (UNSCEAR 2000b). The mean activity concentration of ^{40}K was 459.65±25.64 BqKg^{-1}, 6.80±0.45BqKg^{-1} for ^{232}Th and 13.29±1.28BqKg^{-1} for ^{238}U reported in farms soils from Akwa Ibom State. (Essiet *et al.*, 2022). These values were slightly lower than the values obtained in vegetable sample from the area under study and the recommended values. The higher value of ^{40}K in the study area could be attributed to the variation in distribution of these radionuclides in their soils. Again, the high value of ^{40}K in the leaves than other radionuclides is from the fact that ^{40}K is an essential element required for plant growth, hence plant contain natural potassium (Adesiji, *et al.*, 2019). When ^{40}K is ingested into the body system, it gets neutralised by the ^{40}K present in the body (Essiet, *et al.*, 2022).

Table 3: Activity concentration of radionuclide in vegetables.

S/N	Districts	SAMPLE CODE	^{40}K (Bq/Kg)	^{232}Th (Bq/Kg)	^{238}U(Bq/Kg)
1	Utu	VEG1	618.31 ± 31.28	9.55 ± 0.55	16.11 ± 1.59
2		VEG2	830.32 ± 41.95	3.32 ± 0.19	15.43 ± 1.51
3		VEG3	948.67 ± 47.96	7.85 ± 0.45	38.34 ± 3.74
4		VEG4	784.76 ± 39.68	5.88 ± 0.34	BDL
5	Ikono	VEG5	805.41 ± 40.71	3.83 ± 0.22	10.61 ± 1.05
6		VEG6	958.67 ± 48.46	9.08 ± 0.52	24.54 ± 2.37
7		VEG7	560.99 ± 28.37	8.70 ± 0.50	BDL
8		VEG8	721.88 ± 36.52	8.72 ± 0.50	25.55 ± 2.50
9	Obong	VEG9	740.24 ± 37.41	8.58 ± 0.50	18.45 ± 1.82
10		VEG10	817.04 ± 41.29	1.84 ± 0.11	16.02 ± 1.58
11		VEG11	694.12 ± 36.28	2.70 ± 0.16	13.17 ± 1.74
12		VEG12	616.11 ± 31.15	7.11 ± 0.41	11.95 ± 1.18
13	Uruk	VEG13	549.01 ± 27.78	3.27 ± 0.19	BDL
14		VEG14	548.23 ± 27.71	7.19 ± 0.41	12.49 ± 1.24
15		VEG15	875.06 ± 44.27	7.57 ± 0.44	13.00 ± 1.27
16		VEG16	739.46 ± 37.37	9.72 ± 0.56	14.91 ± 1.48
17	Utu Annag	VEG17	677.62 ± 34.24	8.77 ± 0.51	BDL
18		VEG18	572.32 ± 28.97	5.29 ± 0.31	22.07 ± 2.17
19		VEG19	685.22 ± 36.14	13.37 ± 0.79	27.55 ± 3.58
20		VEG20	847.77 ± 42.86	3.20 ± 0.18	5.33 ± 0.53
		Range	548.23±27.71-958.67 ±48.46	1.84±0.11-9.72 ±0.56	BDL–38.34 ±3.74
		Mean	729.56 ± 20.5	6.78 ± 0.39	14.28 ± 1.38

Table 4: Mean and range values for activity concentration of radionuclide in vegetable (Bqkg^{-1}) in the study area.

S/N	District		^{40}K	^{232}Th	^{238}U
1-4	Utu	Range	948.67-618.31	9.55- 3.32	38.4- BDL
		Mean	795.51 ± 82.6	6.65 ± 1.56	17.47 ± 9.6
5-8	Ikono	Range	958.67-560.99	9.08- 3.83	25.55 -BDL
		Mean	761.74 ± 99.4	7.5825 ± 1.31	15.18 ± 6.4
9-12	Obong	Range	817.04-616.11	8.58-1.84	18.45 -11.95
		Mean	716.88 ± 50.2	5.0575 ± 1.69	14.90 ± 1.62
13-16	Uruk	Range	875.06-548.23	9.72-3.27	14.91-BDL
		Mean	677.94 ± 81.7	6.9375 ± 1.61	10.1 ± 3.72
12-20	Utut Annang	Range	847.77-572.2	13.37-3.2	27.55-BDL
		Mean	695.73 ± 68.9	7.6575 ± 2.54	13.74 ± 6.89

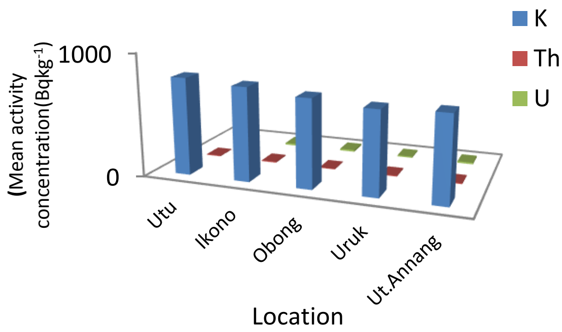

Figure 2: Mean activity concentration for ^{40}K, ^{232}Th and ^{238}U in vegetable samples.

Transfer Factor of Radionuclides from Soil to Vegetable

TF is defined as the ratio of radionuclide concentrations in vegetation and soil. This parameter is necessary for environmental transfer models which are useful in prediction of the radionuclide concentrations in agriculture crops for estimating dose intake by man.TF of ^{40}K, ^{232}Th and ^{238}U were determined and presented in Table 5 and Figure 3.

Table 5: TF of radionuclides from soil to vegetable

SAMPLE CODE	^{40}K (Bq/Kg)	^{232}Th (Bq/Kg)	^{238}U(Bq/Kg)
SL1, VEG1	7.33	4.57	0.75
SL2, VEG2	11.14	14.43	13.07
SL3, VEG3	5.64	1.56	4.31
SL4, VEG4	117.30	1.42	**0**
SL5, VEG5	21.83	1.38	**0**
SL6, VEG6	6.19	1.86	2.07
SL7, VEG7	20.39	1.95	**0**
SL8, VEG8	11.03	1.99	7.47
SL9, VEG9	24.40	11.29	1.47
SL10,VEG10	6.27	1.24	80.1
SL11,VEG11	13.56	0.89	0.61
SL,12VEG12	20.92	1.38	2.02
SL13,VEG13	6.43	0.77	**0**
SL14,VEG14	8.76	2.04	2.13
SL15, VEG15	25.38	18.02	
SL16, VEG16	7.720	2.21	1.10
SL17, VEG17	6.10	1.48	**0**
SL18, VEG18	5.78	1.27	2.12
SL19, VEG19	60.21	7.19	**0**
SL20, VEG20	13.09	0.74	0.39
MEAN	19.97± 5.6	**3.88 ± 0.68**	**5.88 ± 0.65**

The mean TFs for ^{40}K were 35.35 ± 27.9, 14.86 ± 3.9, 16.29±3.66, 12.07± 4.7, and 21.30 ± 13.6 for each district of the study area. The TF for Utu district were higher than other district of the study area. The mean TFs for ^{232}Th were 5.50 ± 3.25, 1.80 ± 0.15, 3.70 ± 2.60, 5.76 ± 4.31 and 2.67 ± 1.61 for each district of the study area, Table 6.

Table 6: Mean and range values for transfer factor of radionuclide

S/N		^{40}K	^{232}Th
1-4 (Utu)	Range Mean	5.64-117.30 35.35 ± 27.9	1.42-14.43 13.08 5.49 ± 3.25
5-8 (Ikono)	Range Mean	21.83 -6.20 14.862 ± 3.9	1.38-1.99 1.80 ± 0.15
9-12 (Obong)	Range Mean	6.27-20.91 16.29± 3.66	0.89-11.29 3.70 ± 2.60 19.9
13-16 (Uruk)	Range Mean	6.43 -25.38 12.07± 4.7	0.77 -18.02 5.76 ± 4.31
12-20 (Utut. Annang)	Range Mean	0.21 - 5.77 21.30 ± 13.6	0.74-7.18 2.67 ± 1.61

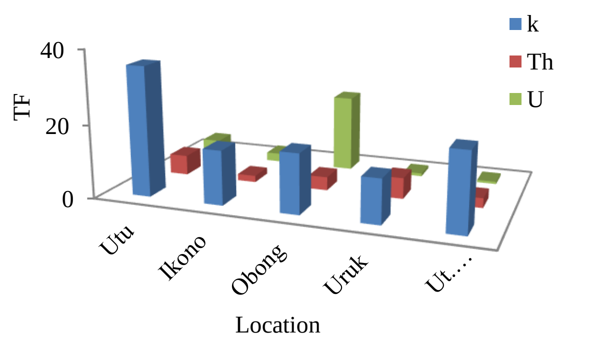

Figure 3: Mean Transfer Factor of ^{40}K, ^{232}Th and ^{238}U in the study Area

With Utu district having the highest. The mean TFs for ^{238}U were 4.53 ±3.27, 2.38 ±1.86, 21.05 ± 19.9, 0.81 ± 0.5 and

0.62858 ±0.53. The TF of ^{238}U in Obong district being the highest compared to other district of the study area. The TF value for ^{40}K obtained for this work is higher, while TF values for ^{232}Th and ^{238}U obtained for this work were unity and some were higher than unity. There was no significant transfer of ^{238}U in some soils to the vegetable collected from these soils. This is because the amount of ^{238}U in the study area was minimal such that could not be detected by the detector. TF values obtained in the literature (Adesiji *et al*., 2019) were lower than the values obtained in the present work. The variation of result may be as a result of the geological property of the area. It may also depend on the type of food crop and the radioactive level in soil. It is also observed that the TF of the radionuclides are higher while the mean activity concentration in soil and vegetable are low which agrees with findings obtained in other works such as (Essiet, *et al*., 2022) showing that TF are not linearly related to radionuclides activity concentration in soil. The concentration of ^{40}K was found to be very high compared to the World average of 420 $BqKg^{-1}$ in all sampling sites due to continuous application of phosphate fertilizers and the present of mining activities in some district of the study area which make the vegetable leaves and root to be prone to adsorption and absorption respectively.

Consumption Annual Effective Dose

The annual consumption effective dose or otherwise referred to as ingestion dose is obtained using Equation 3. The report from the Food and Agriculture Organisation (FAO) on the compilation of annual consumption rate presented to the federal office of statistics shows a consumption rate of vegetable in Nigeria as 42.7kcal/capita/day (FAO,F/W 2013). In this study, the National value is used since there is no local value from the study area. In a report by the United Nations Committee on the Effect of Atomic Radiation, it is reported that the total exposure per person due to terrestrial radionuclides should be less than or equal to 0.29 $mSvy^{-1}$ of which 0.17$mSvy^{-1}$ is from ^{40}K, and 0.12$msvy^{-1}$ from ^{232}Th and ^{238}U series (UNSCEAR 2000b). It is pertinent to compare this value with international standards to ensure safety of the consumers. The effective ingestion dose for the study area is obtained as 0.0021 $mSvy^{-1}$ with 0.19 $mSvy^{-1}$ for ^{40}K, 0.20 $mSvy^{-1}$ for ^{232}Th and 0.00171$mSvy^{-1}$ for ^{238}U. This value is less than the recommended safe dose limit of 0.28$mSvy^{-1}$ (Mostafa, *et al.*,2016). The low annual effective dose due to ingestion in the farm soil from the area under study is consistent with that obtained from the study carried out by (Abojassim *et al*., 2016) Obtaining a consumption annual effective dose of 0.117 $mSvy^{-1}$,0.122 $mSvy^{-1}$, and 0.179 $mSvy^{-1}$ for adult, children and infants respectively.

CONCLUSION

This study conducted a radiological assessment in various farms of Etim Ekpo Local Government of Akwa Ibom State, Nigeria. The activity concentration of radionuclides, transfer factor and ingestion dose has also been evaluated. The activity concentrations of radionuclides of ^{40}K, ^{232}Th and ^{238}U in soils and vegetable were lower than the world average values and figures reported in the literature exception of ^{40}K which was higher than. In addition, the transfer factor that depends on the vegetable and the soil radioactive level is higher than the reported value in the literature. The ingestion dose result for this study was lower than the recommended value. Therefore, the vegetable should be properly cooked in order to minimise radiation present.

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