



Assessment of Radionuclides Uptake by Melon (*Cucumeropsis mannii*) Seeds from Selected Farms in Akwa Ibom State, Nigeria

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Received: August 3, 2023 / Accepted: September 7, 2023

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Abstract

Plants and animals (including humans) are vulnerable to ionizing radiation in many ways. One of these ways is through the food chain. This research aimed at assessing the radionuclide uptake by melon seeds from soil, and the effect of ionizing radiation in humans due to melon. The activity concentrations of natural radionuclides in soil and melon seed samples from twenty locations in the study area was conducted using a Gamma ray spectrometric system coupled with a NaI(Tl). The soil samples were quartered and put in the oven at 50 – 70°C for 1440 minutes in order to obtain a constant weight. The melon seeds were ground, dried and weighed.

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The samples were packaged into labeled nylon bags before being moved to the laboratory for analysis. The average activity concentrations of ⁴⁰K, ²³⁸U and ²³²Th in soil samples were 397.56±7.61 Bq.kg⁻¹, 17.37±0.29 Bq.kg⁻¹ and 62.98±1.02 Bq.kg⁻¹ respectively. The average activity concentrations of ⁴⁰K, ²³⁸U and ²³²Th in melon samples were 521.49±8.47 Bq.kg⁻¹, 15.50±1.67 Bq.kg⁻¹ and 28.753±0.69 Bq.kg⁻¹ respectively. The average values of absorbed dose rate, external and internal hazard indices, radium equivalent, annual effective dose rate and representative level index were 46.40 Bq.kg⁻¹, 0.26 and 0.30 Bq.kg⁻¹, 93.12 Bq.kg⁻¹, 0.057 mSv.y⁻¹ and 0.730 Bq.kg⁻¹ respectively, for melon samples, while for soil samples, were 63.65 Bq.kg⁻¹, 0.37 and 0.42 Bq.kg⁻¹, 138.04 Bq.kg⁻¹, 0.078 mSv.y⁻¹ and 1.01 Bq.kg⁻¹ respectively. The average values of the transfer factors of ⁴⁰K, ²³⁸U and ²³²Th were 1.3693 (49%),

1.0041 (36%) and 0.4721 (15%) respectively. The regression analysis indicated nonlinearity between radionuclide concentrations in soil and that of melon seeds. Hence, the radionuclide concentrations in soil and melon seeds are not proportional.

Keywords: Melon seeds; Activity Concentrations; Transfer Factor; Risk Assessments.

1. Introduction

The earth is replete with ionizing radiation. This ionizing radiation is produced by both man-made and natural radionuclides and is the major source of external and internal irradiation (Hutchison and Hutchison, 1997). The natural radionuclides, ^{232}Th and ^{238}U and ^{40}K are found in large quantities in the earth's crust and these radionuclides account for 96.1 percent of the total annual radiation doses the populace receives, while the remaining percentage is from artificial sources (UNSCEAR, 1993: 2000). The human body functions maximally when it is supplied with adequate nutrients. These nutrients are derived from food crops and animals. The radionuclides in the farmlands enter the roots of the crops. The radionuclide uptake from soil to food crops is defined by the transfer factor (TF). TF is an important model used for vaticinating activity concentration in food crops and assessing dose risk to the populace (IAEA, 2000). Melon seeds are locally called egusi in some parts of Nigeria or ikon in most part of Akwa Ibom State. Nutrients such as carbohydrates, vitamins, fibres, proteins, minerals and biologically active substances can be derived from eating melon seeds (Schippers, 2000; Olaniyi, 2008). Melon seeds, when ground to a particular degree of fineness, are used for many purposes (NRC, 2006; Schippers, 2000). Radionuclide concentrations in soil can likely show the level of contaminants in melon seed grown in such, soil but they are unable to determine the radiological

effect on people consuming the melon seeds. Thus, it is necessary to estimate the radiation dose to individuals consuming the melon seeds. The radiological hazards in connection with the intake of radionuclides in the human body are in direct proportion to the total doses transmitted by the radionuclides as they are stored in different parts of the body (Shukla *et al.*, 1982). Therefore, the present study assessed the radionuclide uptake from soil to melon seeds grown in selected farmlands of Ikot Ekpene, Ikono and Ini Local Government Areas of Akwa Ibom State, Nigeria.

This study is significant because there is no data on the activity concentrations of ^{40}K , ^{238}U and ^{232}Th in melon seeds anywhere in literature for the study locations. Thus, the data would serve as baseline and a basis to assess any future changes on the activity concentrations in melon seeds for Ikot Ekpene, Ikono and Ini Local Government Areas of Akwa Ibom State, Nigeria.

2. Materials and Methods

The Study Area

Figure 1 shows the map of Akwa Ibom State indicating the study areas (LGA) and the sampling locations where this research was conducted. The coordinates of the sampling locations indicated on the map are presented in Table 1.

Sample Collection and Preparation

The soil samples were collected close to the roots of the mature melon crops on the farm land using weeding hoes, since melon crops have a shallow root system, in accordance with the method employed by Agbalagba and Onoja (2011). The soil samples were exposed to air before being put in the oven at 50 - 70°C for 1440 minutes in order to obtain a constant weight. The melon seeds, after extraction from the pulp and shell, were ground dried and weighed. The samples were packaged into labeled nylon bags and taken to the laboratory for analysis. In the laboratory,

each sample was transferred into an already washed beaker and sealed for twenty-nine to enable the buildup of radionuclides in the beaker before placing it in the shielded detector.

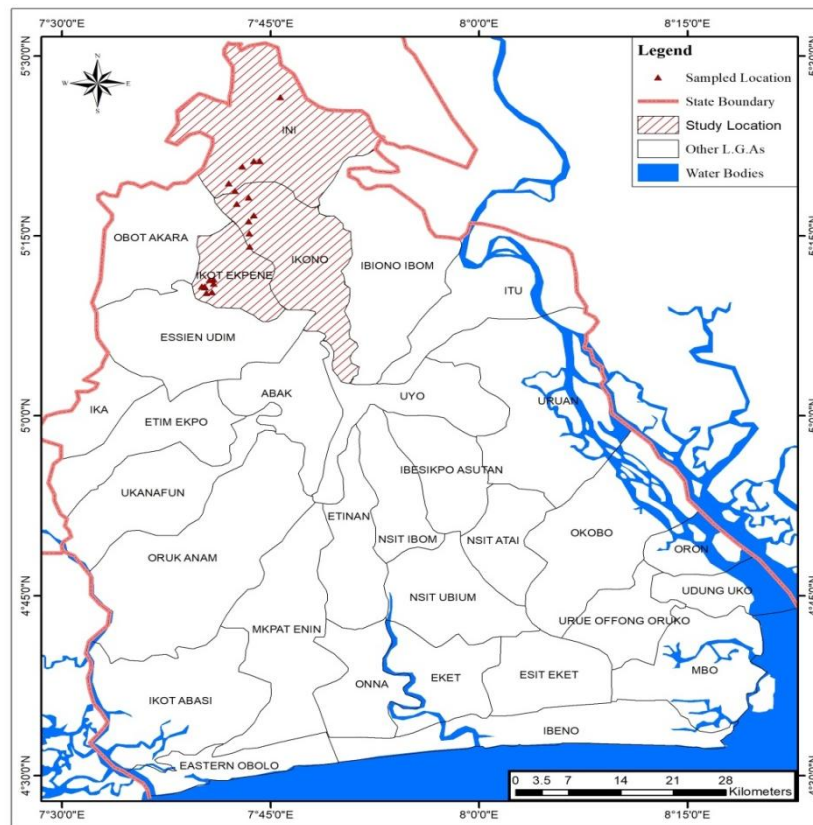


Figure 1: Sampling Points on Selected LGA of Akwa Ibom State

Sample Analysis

The prepared samples were analyzed for specific activity concentrations of ^{40}K , ^{238}U and ^{232}Th at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile Ife, Nigeria, using thallium-doped sodium iodide (NaI(Tl)). Volume source IAEA-385 was used for efficiency calibration, while ^{241}Am , ^{60}Co , ^{22}Na and ^{137}Cs point sources were used for energy calibration of the detector. The detector was shielded with lead in order to avoid interference with background radiation from the environment. The detector used Genie 2000 as its operating software in the analyses of various energies of ^{40}K , ^{238}U and ^{232}Th . The counting time for each sample was 36000 s.

Absorbed Dose Rate (D)

The absorbed dose rate due to γ - radiation of ^{238}U , ^{232}Th and ^{40}K was calculated using Equation 1 (UNSCEAR, 2000).

$$D(n\text{Gy}\cdot\text{h}^{-1}) = (0.462)S_U + (0.621)S_{Th} + (0.0417)S_K \quad (1)$$

where S_U , S_{Th} and S_K are the specific activities of ^{238}U , ^{232}Th and ^{40}K , respectively.

Hazard Indices

The radiological hazard index reflecting the external exposure is called the external hazard index H_{ex} defined by Equation 2 (UNSCEAR, 2000).

$$H_{ex} = \frac{S_U}{370} + \frac{S_{Th}}{259} + \frac{S_K}{4810} \quad (2)$$

$$H_{in} = \frac{S_U}{185} + \frac{S_{Th}}{259} + \frac{S_K}{4810} \quad (3)$$

Also, the internal exposure to radionuclides is expressed by the internal hazard index, H_{in} , which is given by the Equation 3 (Raad and Hayder, 2011).

* ^{232}Th and ^{40}K , respectively.

For radiation hazard to be negligible, values of the indices (H_{ex} , H_{in}) must be less than unity.

Table 1: Radionuclide Activity Concentrations for Soil and Melon

Coordinates		Activity Concentrations (Bq.kg ⁻¹)					
		Soil			Melon		
Longitude	Latitude	⁴⁰ K	²³⁸ U	²³² Th	⁴⁰ K	²³⁸ U	²³² Th
05°10.717`	007°40.278`	391.67±7.64	56.28±0.42	39.87±0.81	515.53±8.73	18.02±0.30	24.28±0.64
05°10.773`	007°40.262`	423.81±7.92	13.80±0.27	64.30±1.04	515.97±8.73	13.16±0.26	30.65±0.72
05°10.233`	007°40.390`	560.65±9.11	10.65±0.23	59.79±1.00	501.47±5.78	16.68±0.29	29.83±0.71
05°10.289`	007°40.780`	365.97±7.36	13.60±0.26	61.20±1.01	497.18±5.78	13.90±0.27	19.05±0.57
05°11.015`	007°40.913`	391.56±7.61	15.86±0.28	54.63±0.96	481.06±8.44	15.56±0.28	27.91±0.69
05°11.360`	007°40.921`	221.60±5.72	12.32±0.25	64.75±1.04	449.85±8.16	11.06±0.24	23.07±0.62
05°11.316`	007°40.614`	519.55±8.69	18.39±0.31	67.79±1.07	519.23±8.76	13.29±0.26	23.05±0.62
05°10.771`	007°40.662`	564.64±9.14	12.04±0.25	83.71±1.14	668.93±9.95	15.63±0.28	31.56±0.73
05°14.008`	007°43.494`	332.98±7.02	13.75±0.27	60.60±1.01	577.21±9.24	13.82±0.27	23.20±0.62
05°16.211`	007°43.419`	376.18±7.46	16.51±0.29	64.35±1.04	358.87±7.29	12.54±0.25	25.62±0.66
05°15.205`	007°43.473`	273.52±6.36	11.00±0.24	55.20±0.96	325.88±6.94	15.26±0.28	67.32±1.08
05°16.689`	007°43.794`	275.29±6.38	15.80±0.28	67.32±1.08	596.00±9.39	20.27±0.32	35.13±0.54
05°18.180`	007°42.428`	350.44±7.20	21.81±0.34	65.81±1.05	610.50±9.50	13.00±0.26	28.50±0.69
05°17.655`	007°42.518`	383.58±7.53	14.16±0.27	55.59±1.00	459.76±8.24	15.97±0.28	16.74±0.53
05°18.726`	007°42.430`	406.65±7.76	15.71±0.28	61.62±1.02	630.32±9.57	15.12±0.28	33.80±1.02
05°19.365`	007°41.981`	366.42±7.35	13.75±0.27	61.66±1.02	624.55±9.61	18.68±0.31	32.96±0.74
05°20.770`	007°43.972`	350.00±7.20	15.09±0.30	60.70±1.01	489.49±8.51	14.79±0.27	23.15±0.62
05°21.253`	007°43.792`	497.78±8.58	21.25±0.33	86.98±1.21	517.89±8.75	14.77±0.30	33.39±0.75
05°22.230`	007°44.230`	385.06±7.54	17.14±0.30	84.61±1.11	549.99±9.02	19.61±0.31	22.93±0.62
05°26.555`	007°45.702`	513.90±8.72	18.50±0.30	39.08±0.81	540.08±8.94	18.88±0.31	22.93±0.62

Radium Equivalent

Radium equivalent is a model that takes into consideration the radiological hazards accompanying the activity levels of ^{238}U , ^{232}Th and ^{40}K (Equation 4) (UNSCEAR, 2000).

$$Ra_{eq} = S_u + (1.43)S_{Th} + (0.077)S_K \quad (4)$$

where S_U , S_{Th} and S_K represent the specific activities of ^{238}U , ^{232}Th and ^{40}K , respectively.

Annual Effective Dose Rate (AEDR)

The annual effective dose rate (mSv.yr⁻¹) was

calculated using Equation 5.

$$AEDR(mSv.yr^{-1}) = (1.2264 \times 10^{-3})D \quad (5)$$

where D is absorbed dose rate due to γ -radiation of ^{238}U , ^{232}Th and ^{40}K (Equation 1).

Representative Level Index (I_γ)

The representative level index (I_γ) is derived from Equation 6 (Ahmed and El-Arabi, 2005). It values must be less than or equal to one for the exposure to be within the permissible limits of safety. Thus, $I_\gamma \leq 1$ can be compared to annual effective dose less than or equal to 1mSv, while

$I_\gamma \leq 0.5$ can be compared to annual effective dose less or equal to 0.3 mSv (Turhan *et al.*, 2008).

$$I_\gamma = \frac{S_U}{150} + \frac{S_{Th}}{100} + \frac{S_K}{1500} \quad (6)$$

Transfer Factor

The ratio of plant activity concentrations (S_p) to those of soil (S_s) is what is referred to as transfer factor (TF). It is a very useful tool for estimating radiation hazards to human beings when the affected crop plant is in contact with the body by way of eating the food crops or using it as ointments. The soil-to-melon seed transfer factors of ^{40}K , ^{238}U and ^{232}Th were estimated using Equation 7 (IAEA, 2010).

$$TF = \frac{S_P}{S_S} \quad (7)$$

where S_p is the activity concentration of radionuclides in plant (Bq.Kg^{-1}) and S_s is the activity concentration of radionuclides in soil (Bq.Kg^{-1}).

3. Results and Discussions

Radionuclide Activity Concentrations

The specific activity concentrations S (Bq.kg^{-1}) of ^{40}K , ^{238}U and ^{232}Th in the samples analyzed were obtained from Equation 8 (Awudu *et al.*, 2010; Faanu *et al.*, 2011).

$$S = \frac{N}{\xi t \gamma M} \quad (8)$$

where N represents the net peak area of the radionuclide, ξ represents the detector energy dependent efficiency, t represents the counting live time (s), γ represents the gamma ray yield per disintegration of the nuclide, and M represents the mass (kg) of the sample.

Table 1 shows the radionuclide activity concentrations of ^{238}U , ^{232}Th and ^{40}K in soil and melon samples collected from Ikot Ekpene, Ikono and Ini Local Government Areas of Akwa

Ibom State, Nigeria. Forty samples were analyzed (twenty soil samples and twenty melon seed samples). The average activity concentrations of ^{238}U , ^{232}Th and ^{40}K in melon samples were 15.50 ± 1.67 , 23.75 ± 0.69 and $521.49 \pm 8.47 \text{ Bq.kg}^{-1}$ respectively. The average radionuclide activity concentrations for ^{238}U , ^{232}Th and ^{40}K in soil samples were 17.37 ± 0.29 , 62.98 ± 1.02 and $397.56 \pm 7.61 \text{ Bq.kg}^{-1}$ respectively. The average activity concentration of ^{40}K in soil calculated was observed to be higher than that obtained elsewhere (Al-jundi *et al.*, 2003; Dowdel *et al.*, 2003; Avadhani *et al.*, 2005; Santawamaitre *et al.*, 2010; Agbalagba and Onoja, 2011; Avwiri and Ononugbo, 2012; Essen *et al.*, 2021; Essiett *et al.*, 2022 and Ejoh *et al.*, 2023) but lower than that obtained by UNSCEAR, (2000); Sarkar *et al.*, (2011) and Tyovenda *et al.*, (2022). The variation may likely be due to geological formation and the nature of manure used, since the study locations were farmlands.

The average activity concentrations of ^{232}Th in soil obtained in this study was also observed to be higher than that obtained elsewhere (UNSCEAR, 2000; Al-jundi *et al.*, 2003; Dowdel *et al.*, 2003; Avadhani *et al.*, 2005; Santawamaitre *et al.*, 2010; Agbalagba and Onoja 2011; Avwiri and Ononugbo, 2012; Essen *et al.*, 2021; Essiett *et al.*, 2022 and Ejoh *et al.*, 2023) but lower than that obtained by Sarkar *et al.*, (2011) and Tyovenda *et al.*, (2022). While the average activity concentrations of ^{238}U in soil obtained in this study was seen to be lower than that obtained elsewhere (UNSCEAR, 2000; Al-jundi *et al.*, 2003; Dowdel *et al.*, 2003; Avadhani *et al.*, 2005; Santawamaitre *et al.*, 2010; Agbalagba and Onoja 2011; Sarkar *et al.*, 2011; Avwiri and Ononugbo, 2012; Essen *et al.*, 2021; Essiett *et al.*, 2022 and Tyovenda *et al.*, 2022). The variation may be due to geological formation. The average activity concentrations of

^{40}K in melon seeds obtained in this study were observed to be higher than those obtained in cassava (Amakom *et al.*, 2017; Ejoh *et al.*, 2023), Afang (Essiett *et al.*, 2022), cucumber (Rand *et al.*, 2021) but lower than ^{40}K in pumpkin leaf (Essen *et al.*, 2021). The average activity concentrations of ^{238}U in melon seeds obtained in this study were observed to be lower than those obtained in cassava (Amakom *et al.*, 2017) and pumpkin leaf (Essen *et al.*, 2021) but higher than those obtained in Afang (Essiett *et al.*, 2022) and cucumber (Rand *et al.*, 2021). The average activity concentrations of ^{232}Th in melon seeds obtained in this study were also observed to be higher than those obtained in Afang (Essiett *et al.*, 2022) and cucumber (Rand *et al.*, 2021) but lower than ^{40}K in pumpkin leaf (Essen *et al.*, 2021) and cassava (Amakom *et al.*, 2017). These disparities in specific activity concentrations of ^{40}K , ^{238}U and ^{232}Th in the food crops are largely due to the individual crop's affinity for the

radionuclides and their uptake (UNSCEAR, 2000).

Figure 2 shows the graphs of ^{40}K activity concentrations in melon (k_m) and soil (k_s) samples against sample locations, with distinctively higher K_m concentrations in most locations except at Abia okpo and Ibong. Figure 3 shows the graphs of ^{238}U activity concentrations in melon (U_m) and soil (U_s) samples against sample locations with slight variations except at Atai essien while Figure 4 shows the graphs of ^{232}Th activity concentrations in melon (Th_m) and soil (Th_s) samples, indicating high Th_s at most locations except at Mbiafun. Figures 5 – 7 show the regression analyses with R^2 values of 0.095, 0.002 and 0.051 for ($^{40}\text{K}_s$, $^{40}\text{K}_m$), ($^{232}\text{Th}_s$, $^{232}\text{Th}_m$) and ($^{238}\text{U}_s$, $^{238}\text{U}_m$) in soil and melon samples respectively; the high activity concentrations of ^{40}K , ^{238}U and ^{232}Th in soils do not give rise to high activity concentrations of ^{40}K , ^{238}U and ^{232}Th in melon seeds.

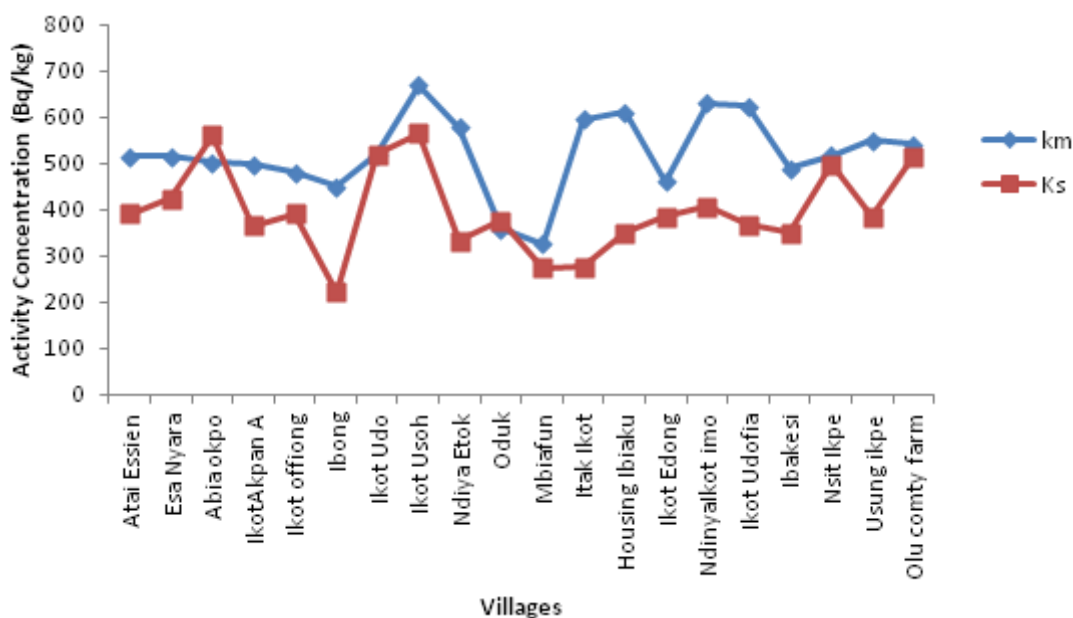


Figure 2: ^{40}K in Soil (k_s) and Melon (k_m)

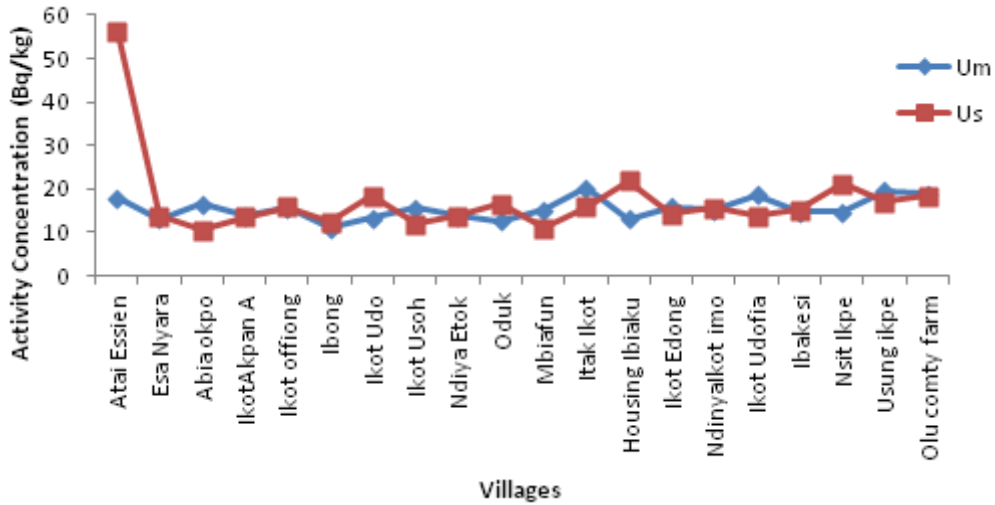


Figure 3: ²³⁸U in Soil (U_s) and Melon (U_m)

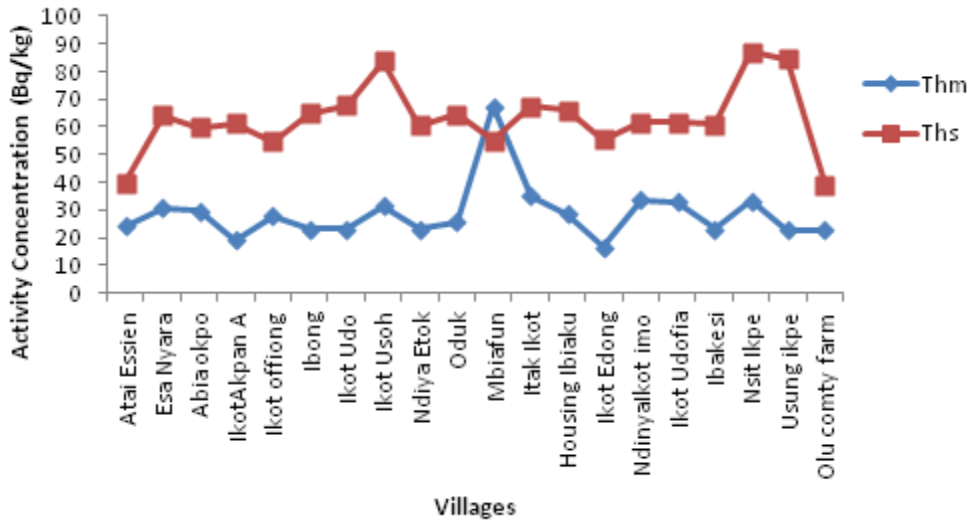


Figure 4: ²³²Th in Soil (Th_s) and Melon (Th_m)

Contour Map

Contour maps were produced using the coordinates of sampling points, the activity concentrations of ²³⁸U, ²³²Th and ⁴⁰K in the samples and the Surfer software program. The contour maps highlight the activity distribution of ²³⁸U, ²³²Th and ⁴⁰K in melon and soil samples in the study area (Figures 8 - 13). These contours were used to presage the specific activity concentrations in locations within the three LGAs not sampled.

Transfer Factor

Transfer factors range for ⁴⁰K, ²³⁸U and ²³²Th from 0.89 to 2.16, 0.32 to 1.57 and 0.27 to 1.22 respectively (Table 2). It was observed to be in the order ⁴⁰K > ²³⁸U > ²³²Th. This agrees with other studies (Essen *et al.*, 2021; Essiett *et al.*, 2022 and Tyovenda *et al.*, 2022). The observed result is due to the fact that the radionuclide uptake from soil to plant is element-specific and facilitated by the radionuclide, similar to plant essential nutrients. Therefore, the high values observed for the ⁴⁰K could be a result of its

similarity to the stable potassium which is one of the important elements needed for effective growth in plants. Most transfer factor values obtained were found to be less than one, aside from ^{40}K . The use of melon seeds obtained from the study locations in whatever form may not subject users to elevated radiation doses since the level of radionuclide contamination is minimal, notwithstanding high transfer values of ^{40}K (Jibiri *et al.*, 2009). The average contribution (%) of

^{40}K , ^{238}U and ^{232}Th to the transfer factor in the studied samples is shown in Figure 14.

Radiological Hazard Indices

Tables 3 and 4 show the calculated values of absorbed dose, external and internal hazard indices, radium equivalent, annual effective dose rate and representative level index due to activity concentrations of ^{238}U , ^{232}Th and ^{40}K in soil and melon samples, respectively.

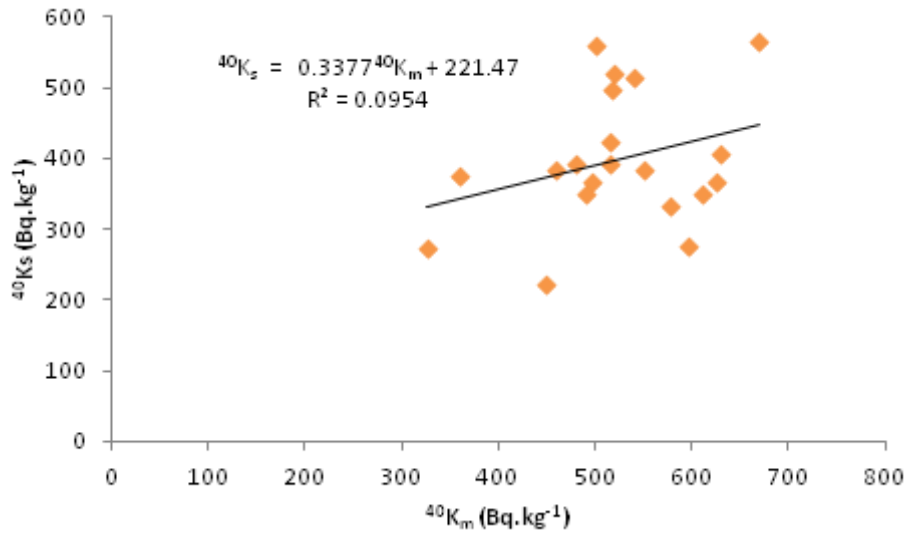


Figure 5: Correlation of ^{40}K in Soil ($^{40}\text{K}_s$) and ^{40}K in Melon ($^{40}\text{K}_m$)

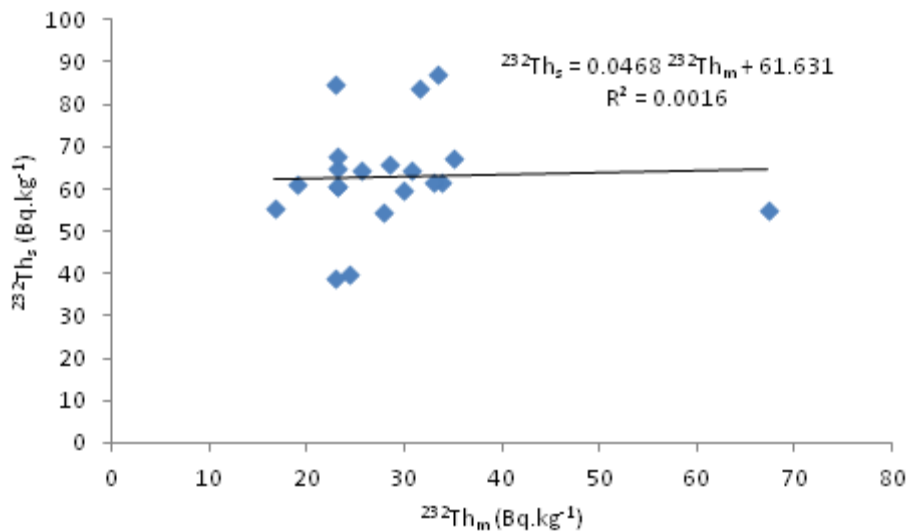


Figure 6: Correlation of ^{232}Th in Soil ($^{232}\text{Th}_s$) and ^{232}Th in Melon ($^{232}\text{Th}_m$)

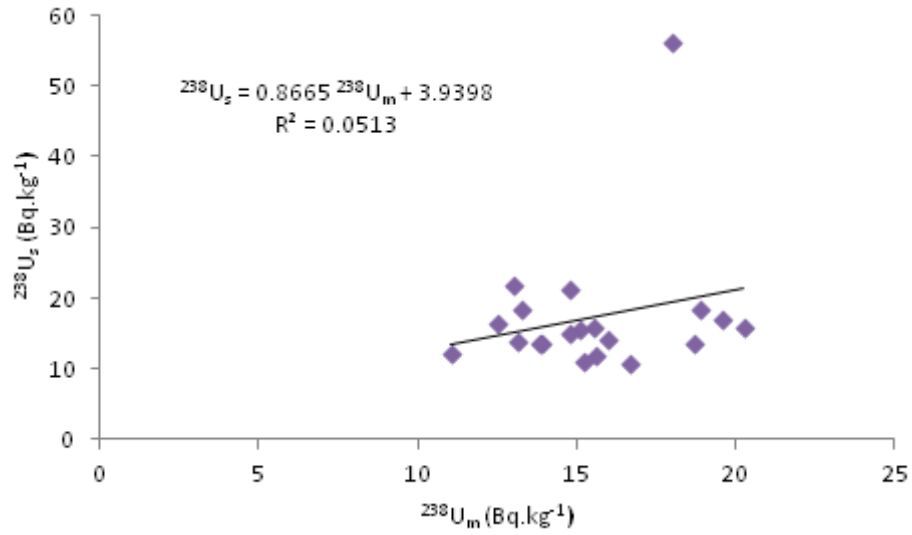


Figure 7: Correlation of ^{238}U in Soil ($^{238}\text{U}_s$) and ^{238}U in Melon ($^{238}\text{U}_m$)

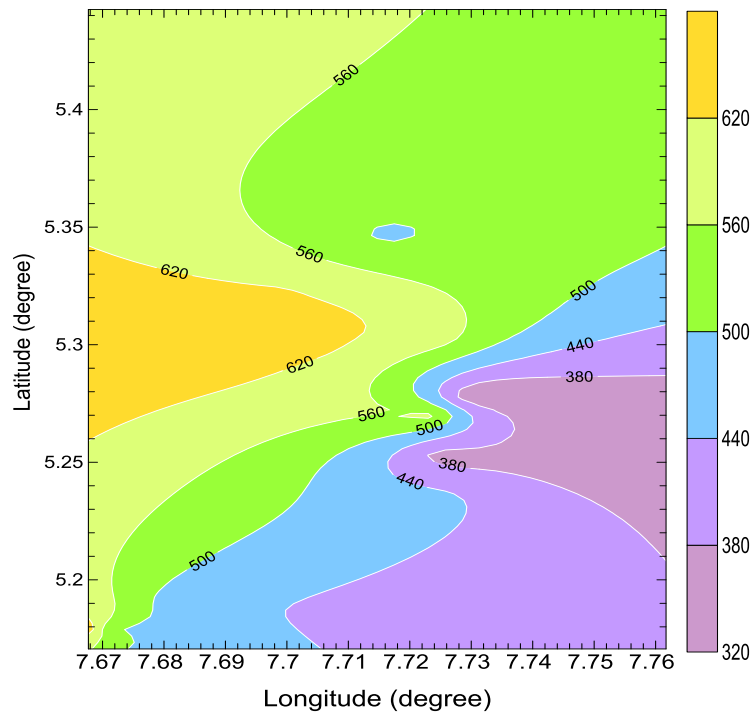


Figure 8: Contour Map for ^{40}K in Melon

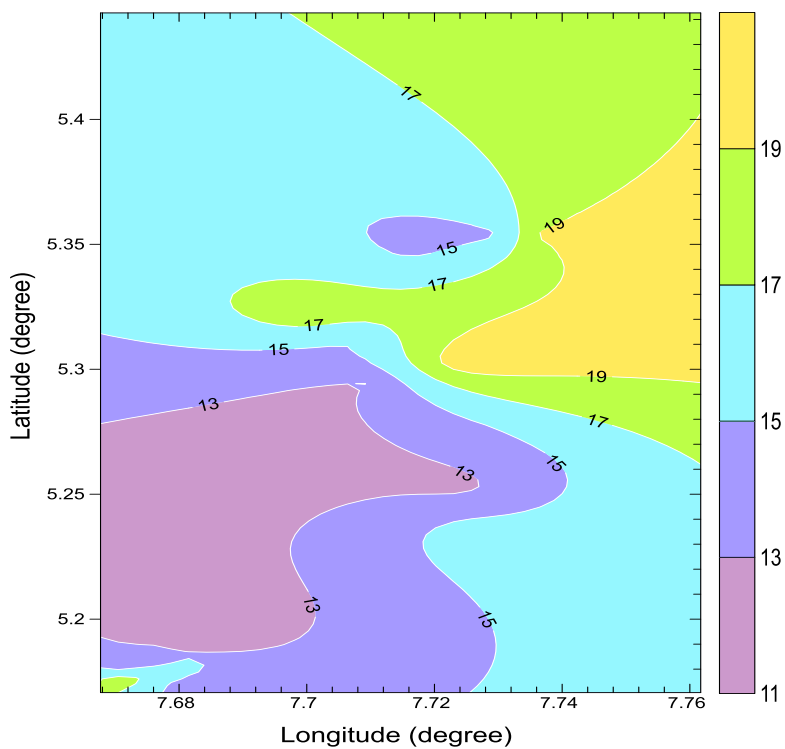


Figure 9: Contour Map for ^{238}U in Melon

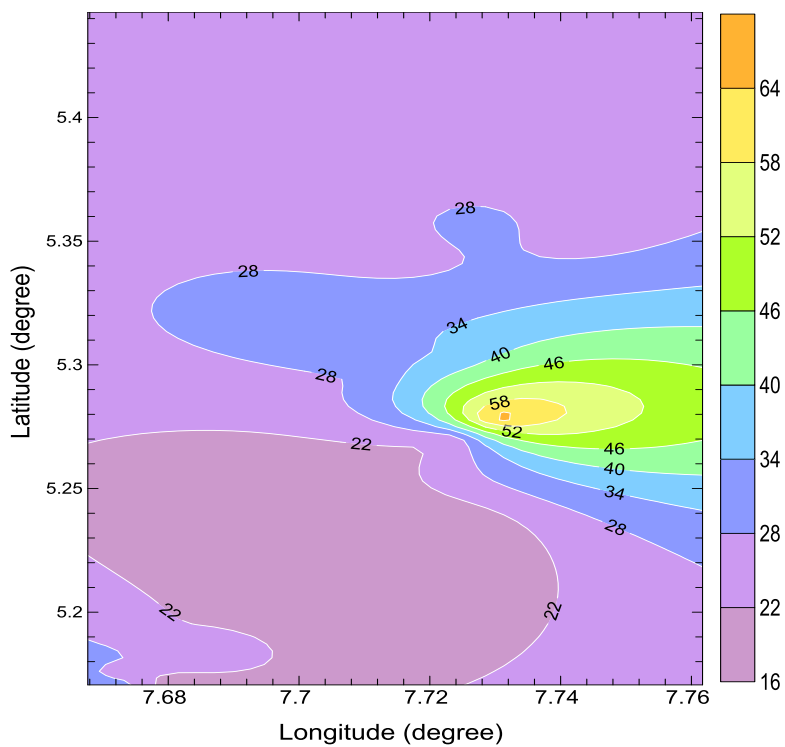


Figure 10: Contour Map for ^{232}Th in Melon

Table 2: Soil-to-Melon Transfer Factor Values

S/N	Coordinates		Transfer Factor		
	Longitude	Latitude	⁴⁰ K	²³⁸ U	²³² Th
1	05°10.717`	007°40.278`	1.316236	0.320185	0.608979
2	05°10.773`	007°40.262`	1.217456	0.953623	0.476672
3	05°10.233`	007°40.390`	0.894444	1.566197	0.498913
4	05°10.289`	007°40.780`	1.358527	1.022059	0.311275
5	05°11.015`	007°40.913`	1.228573	0.981084	0.510891
6	05°11.360`	007°40.921`	2.030009	0.897727	0.356293
7	05°11.316`	007°40.614`	0.999384	0.722675	0.340021
8	05°10.771`	007°40.662`	1.184702	1.298173	0.377016
9	05°14.008`	007°43.494`	1.733467	1.005091	0.382838
10	05°16.211`	007°43.419`	0.953985	0.759540	0.398135
11	05°15.205`	007°43.473`	1.191430	1.387273	1.219565
12	05°16.689`	007°43.794`	2.164990	1.282911	0.521836
13	05°18.180`	007°42.428`	1.742096	0.596057	0.433065
14	05°17.655`	007°42.518`	1.198603	1.127825	0.301133
15	05°18.726`	007°42.430`	1.550031	0.962444	0.548523
16	05°19.365`	007°41.981`	1.704465	1.358545	0.534544
17	05°20.770`	007°43.972`	1.398543	0.980119	0.381384
18	05°21.253`	007°43.792`	1.040399	0.695059	0.383881
19	05°22.230`	007°44.230`	1.428323	1.144107	0.271008
20	05°26.555`	007°45.702`	1.050944	1.020541	0.586745

Figure 15 shows the absorbed dose rate ($\text{nGy}\cdot\text{h}^{-1}$) for soil and melon seed at different sample locations in the study area. It indicates that those absorbed dose rates for soil samples were higher than that of melon and, also in some locations, were higher than the recommended safety standard. Hence, farmers in these locations are at higher risk of expose dose of radiation and should take precautionary measures to limit their exposure. In Figure 16, the radium equivalent for soil and melon seed were compared with the recommended safety limit. This shows that the

radium equivalents for the samples were lower than the recommended safety limit. Representative level index for soil and melon seed were compared with the recommended safety limit (Figure 17). This indicates that locations in the study areas with representative level index higher than the recommended safety limit are at risk of elevated ionizing radiation due to soil. The radiological hazard indices in this research agree with other works (Essen *et al.*, 2021; Essiett *et al.*, 2022; Tyovenda *et al.*, 2022).

Table 3: Radiological Hazard Indices and the Coordinates of the Sampling points for Soil Samples

Coordinates		D (nGyh ⁻¹)	H _{ex} (Bq.kg ⁻¹)	H _{in} (Bq.kg ⁻¹)	Ra _{eq} (Bq.kg ⁻¹)	AEDR (mSv.y ⁻¹)	I _y (Bq.kg ⁻¹)
Longitude	Latitude						
05°10.717`	007°40.278`	67.09	0.387	0.540	143.453	0.082	1.035
05°10.773`	007°40.262`	63.98	0.374	0.411	138.382	0.078	1.018
05°10.233`	007°40.390`	65.43	0.376	0.405	139.320	0.080	1.043
05°10.289`	007°40.780`	59.55	0.349	0.386	129.296	0.073	0.947
05°11.015`	007°40.913`	57.58	0.335	0.378	124.131	0.071	0.913
05°11.360`	007°40.921`	55.14	0.329	0.363	121.976	0.068	0.877
05°11.316`	007°40.614`	72.26	0.419	0.469	155.335	0.089	1.147
05°10.771`	007°40.662`	81.09	0.473	0.506	175.223	0.099	1.294
05°14.008`	007°43.494`	57.87	0.340	0.378	126.047	0.071	0.920
05°16.211`	007°43.419`	63.28	0.371	0.416	137.496	0.078	1.004
05°15.205`	007°43.473`	50.77	0.300	0.329	110.997	0.062	0.808
05°16.689`	007°43.794`	60.58	0.360	0.403	133.265	0.074	0.962
05°18.180`	007°42.428`	65.56	0.386	0.445	142.902	0.080	1.037
05°17.655`	007°42.518`	57.06	0.333	0.371	123.189	0.070	0.906
05°18.726`	007°42.430`	62.48	0.365	0.407	135.139	0.077	0.992
05°19.365`	007°41.981`	59.92	0.351	0.389	130.138	0.073	0.953
05°20.770`	007°43.972`	59.26	0.348	0.389	128.841	0.073	0.941
05°21.253`	007°43.792`	84.59	0.497	0.554	183.960	0.104	1.343
05°22.230`	007°44.230`	76.52	0.453	0.499	167.782	0.094	1.217
05°26.555`	007°45.702`	54.25	0.308	0.358	113.955	0.067	0.857

Table 4: Radiological Hazard Indices and the Coordinates of the Sampling points for Melon Samples

Coordinates		D (nGyh ⁻¹)	H _{ex} (Bq.kg ⁻¹)	H _{in} (Bq.kg ⁻¹)	Ra _{eq} (Bq.kg ⁻¹)	AEDR (mSv.y ⁻¹)	I _y (Bq.kg ⁻¹)
Longitude	Latitude						
05°10.717`	007°40.278`	44.88	0.250	0.2983	88.8275	0.055	0.7066
05°10.773`	007°40.262`	46.60	0.261	0.2967	93.1074	0.057	0.7382
05°10.233`	007°40.390`	47.11	0.265	0.3096	94.4398	0.058	0.7438
05°10.289`	007°40.780`	38.97	0.214	0.2521	75.9441	0.048	0.6146
05°11.015`	007°40.913`	44.55	0.250	0.2919	89.1455	0.055	0.7035
05°11.360`	007°40.921`	38.17	0.212	0.2424	75.5396	0.047	0.6043
05°11.316`	007°40.614`	42.08	0.233	0.2688	82.5976	0.052	0.6653
05°10.771`	007°40.662`	54.68	0.303	0.3454	107.5859	0.067	0.8658
05°14.008`	007°43.494`	44.84	0.247	0.2843	87.4007	0.055	0.7089
05°16.211`	007°43.419`	36.64	0.207	0.2413	74.2975	0.045	0.5790
05°15.205`	007°43.473`	62.38	0.369	0.4102	134.3392	0.077	0.9922

05°16.689`	007°43.794`	56.00	0.314	0.3691	112.2259	0.069	0.8838
05°18.180`	007°42.428`	49.13	0.272	0.3072	96.4900	0.060	0.7787
05°17.655`	007°42.518`	36.93	0.203	0.2465	72.0914	0.045	0.5804
05°18.726`	007°42.430`	54.23	0.302	0.3433	107.5764	0.067	0.8590
05°19.365`	007°41.981`	55.11	0.308	0.3581	109.5313	0.068	0.8705
05°20.770`	007°43.972`	41.60	0.231	0.2711	82.1588	0.051	0.6564
05°21.253`	007°43.792`	49.12	0.277	0.3164	98.7700	0.060	0.7776
05°22.230`	007°44.230`	46.21	0.256	0.3089	90.8992	0.057	0.7267
05°26.555`	007°45.702`	45.46	0.252	0.3029	89.4755	0.056	0.7152

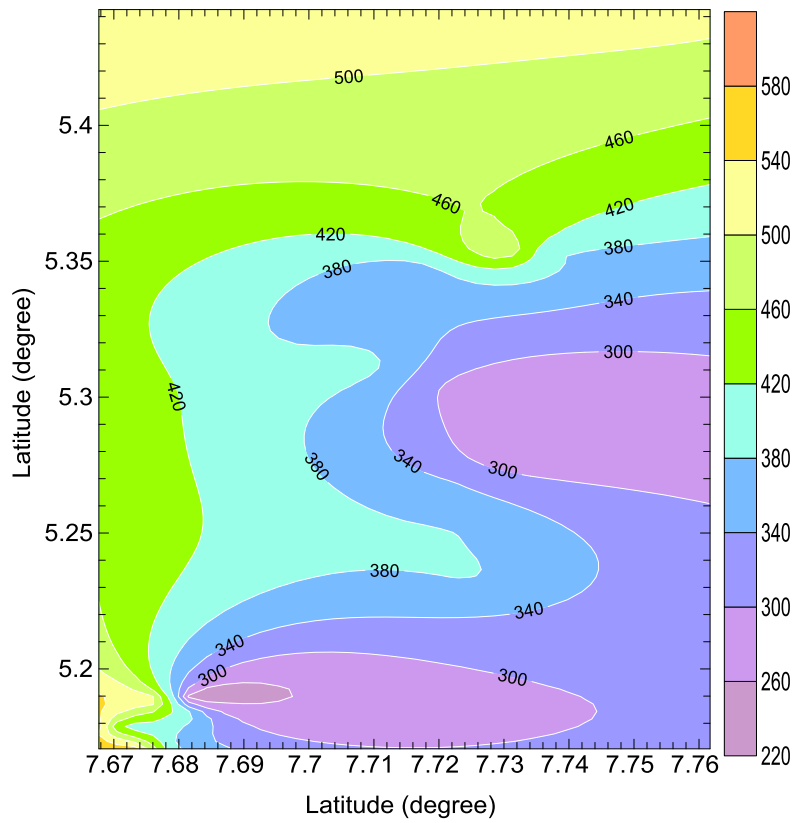


Figure 11: Contour Map for ⁴⁰K in Soil

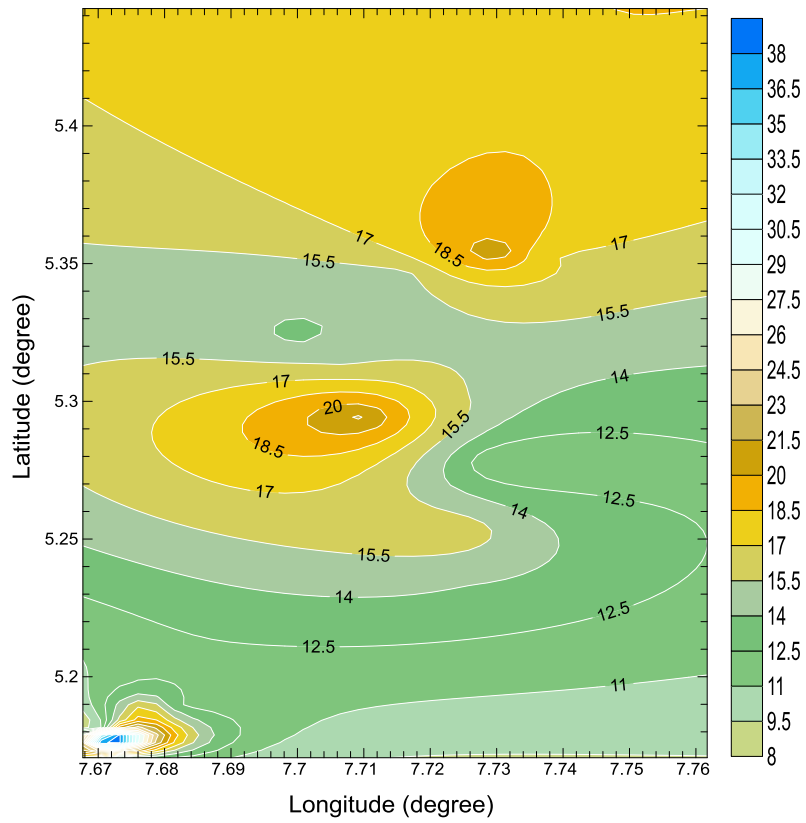


Figure 12: Contour Map for ^{238}U in Soil

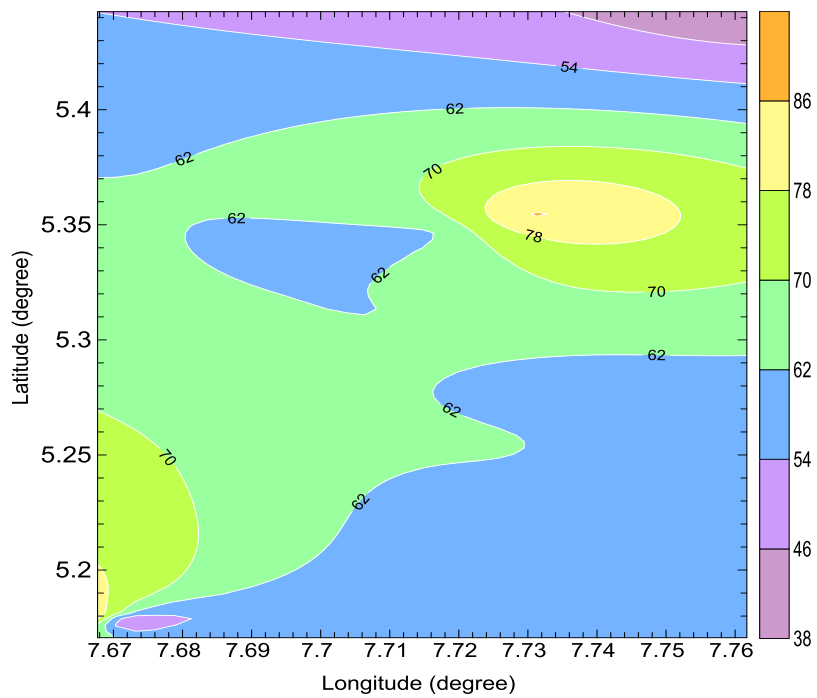


Figure 13: Contour Map for ^{232}Th in Soil

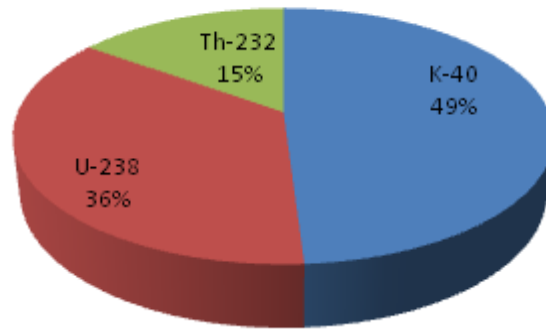


Figure 14: Average Transfer from Soil to Melon

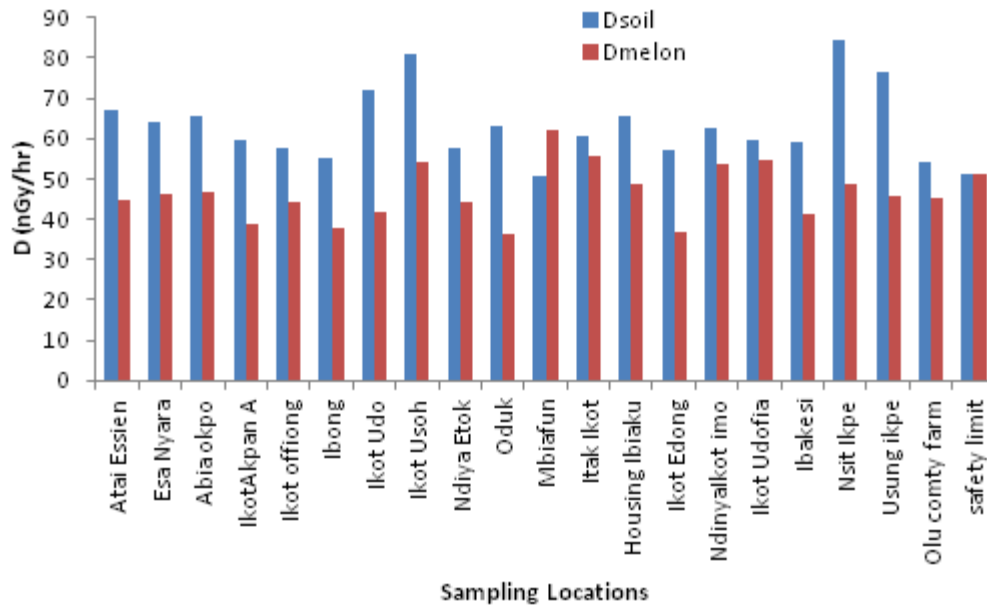


Figure 15: Absorbed Dose Rate for Soil and Melon in the Study Area

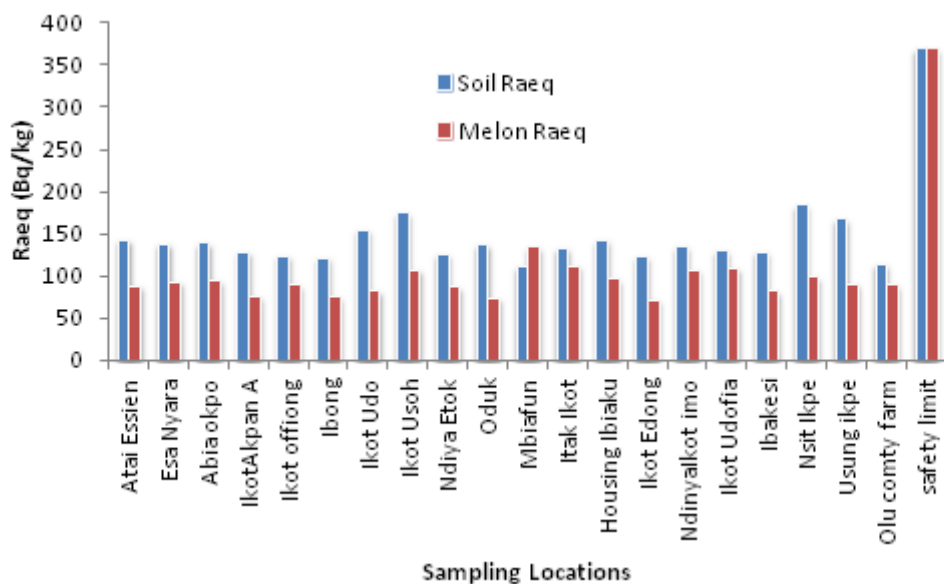


Figure 16: Radium Equivalent for Soil and Melon in the Study Area

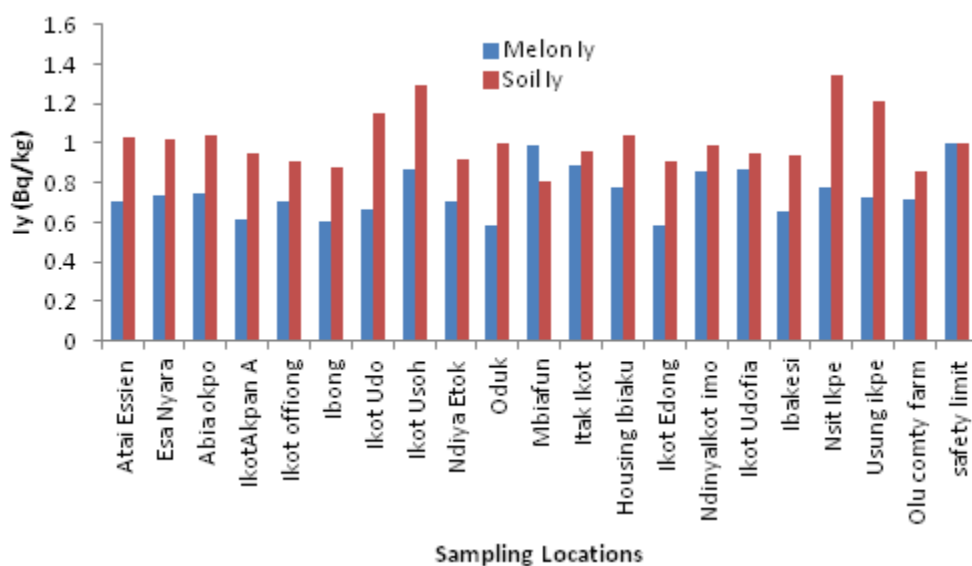


Figure 17: Representative Level Index for Soil and Melon in the Study Area

4. Conclusion

Naturally occurring radioactive materials (NORMs) can be found in the materials that make up the environment which are air, water, soil, food and even humans. The radionuclide uptakes by melon seeds from selected farms in Akwa Ibom State have been assessed. Activity concentrations of natural radionuclides in soil

and melon samples from twenty locations in the study area have been evaluated. The average activity concentrations of ^{40}K , ^{238}U and ^{232}Th in melon samples were observed to be higher than other food crops analyzed by other authors while the average activity concentrations of ^{40}K , ^{238}U and ^{232}Th in soil samples agree with averages obtained by other researchers and are found to

below the recommended safety levels. The average values of absorbed dose rate, external and internal hazard indices, radium equivalent, annual effective dose rate and representative level index for both soil and melon samples were within tolerance. The average transfer factor contributions of ^{40}K , ^{238}U and ^{232}Th in the samples were 49%, 36% and 15% respectively. The regression analysis indicated nonlinearity between radionuclide concentrations in soil and those of melon seeds. Hence, the radionuclide concentrations in soil and melon seeds are not proportional. The average value of transfer factor for ^{40}K was found to be higher compared to other radionuclides. However, potassium is an abundantly available element in the body and the body has a way of mitigating its effect. Hence, the consumption of melon seeds from the study area may not pose a radiological risk to the consumers.

Conflict of Interest

Authors have no conflicts of interest.

Acknowledgements

The authors acknowledge the contributions of other researchers whose research works have been cited and referenced and also thank workers at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile Ife, Nigeria for the sample analysis.

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