

Evaluation of Radioactivity Contents and Excess Lifetime Cancer Risk Due to Ingestion from Natural Radionuclides in Maize Samples from Some Selected Maize Farms in Ekiti State, Nigeria

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Abstract - The study was carried out to evaluate the radioactivity concentrations of ⁴⁰K, ²³²Th and ²³⁸U in five maize samples collected from maize farms within Ekiti State, Nigeria. The activity concentration measurements were determined using n – type co-axial HPGc detectors for the state. The activity concentrations were found to vary from 994.67 – 2457.01 Bq Kg⁻¹ for ⁴⁰K, 32.84 – 91.88 Bq kg⁻¹ for ²³²Th and 43.21 – 97.77 Bq kg⁻¹ for ²³⁸U respectively. The annual effective dose to individuals from the consumption of the Maize was estimated on the basis of the measured radionuclides content in the food crop which ranged between 0.41 and 1.51 m Svy⁻¹ respectively. The value 1.04 m Svy⁻¹ were obtained for the state as the mean total annual effective dose. The mean excess life time cancer risk was also calculated to be 2.06x10⁻⁹. The value was compared with the internationally acceptable limits and found to be far less to the maximum permissible dose of 1.0 x10⁻³ recommended for the public by the United Nations Scientific Committee on the Effects of Atomic Radiation. Hence, the maize was found to be safe for human consumption.

Keywords: Effective ingestion dose, gamma spectroscopy, radioactivity, maize, excess lifetime cancer risk.

I. INTRODUCTION

The term radioactivity makes many people think only of nuclear power plant met down or atomic bomb explosions, radioactivity is actually a natural phenomenon found all around us. Every food including maize has some amount of radioactivity in it. Radionuclides are as well found naturally in air, water, soil, skies and rock [1]. And as a result, radiation is found deposited within our bodies since we are the product of the environment. The common radionuclides are potassium 40 (⁴⁰K), radium 226 (²²⁶Ra) and uranium 238 (²³⁸U). These are called primordial radionuclide formed from the left over from when the world was created. They are typically long lived with half-lives often on the order of hundreds of million years [2]. They have associated decay products of long-lived

radionuclides such as radon. Radon is naturally occurring odourless, colourless, tasteless radioactive gas and is the major contributor to human exposure from sources [3]. When inhaled or ingested with food, air or water, radon can cause mutations in lung tissue. Long - term exposure to radon has been associated with an increased risk of developing lung cancer [4]. Other contribution to the radionuclides in foods includes deposited fallouts from fission and activation products released during nuclear accidents and constituent weapon test released after detonation [5]. The radionuclides may be transported into the grains through the plant growth processes [6]. The Radionuclides eventually get into the human system through food chain and thereby constituting radiological impact on man. Maize is one of the most important cereal crops for human consumption in many different parts of the world. It is a staple food for over 3 billion people (mostly poor) constituting about half of the world population [7]. All over the world, great civilization developed only after the domestication of various cereal grains, which provided an adequate food supply for large population. These have included maize in America, Egypt, Africa, India and also in China [7].

There are now hundreds of maize recipes with each ethnic group having developed individual recipes. For instance, maize can be processed into maize flour, custard, corn flakes just to mention a few, and they could as well be boiled fresh before eating. It could also be consumed as maize grits, polenta, popcorn and other products such as maize flakes. Maize could also be fermented to give Ogi (pap) in Nigeria and other countries in Africa and pre-cooked into arepas in Columbia and Venezuela [8].

Maize nutritional quality is particularly important for small children, providing about 30 percent of daily protein intake and close to 40 percent of the daily energy intake [9]. Maize obtains radionuclides contamination from the soil and environment and so serve as source of radiation exposure. Hence, studies on radioactivity of maize have been carried out in various countries across the world [10] and [11].

Literatures reveal a small number of studies on the radionuclide content of maize grown in Nigeria [12]. Such scarcity was the main reason of conducting the present research.

It is, therefore, the focus of this paper to measure the activity concentration of ^{40}K , ^{232}Th , ^{238}U in the maize grown in the soil of Ekiti state, and the estimate of annual effective doses to the general public due to this consumption and the excess life time cancer risk. In view of the foregoing, comparison of the results obtained with similar studies globally and world averages are presented.

from ten agricultural farm settlements, five samples each from each state. Their geographical coordinates were recorded using a Global Positioning System (GPS). The map with the sample location points is shown in figure 1 and figure 2. All the samples were each oven-dried at a temperature of 110°C to a constant weight of 350 g. The maize grains were milled to remove the husk. The maize was then crushed by grinding machine and sieved using a 2mm sieve mesh to obtain a fine texture of the samples. Then each sample was packaged separately into a plastic bag and labelled for identification and sealed for a month to allow a sufficient time for both ^{232}Th and ^{238}U to attain a state of secular equilibrium with their corresponding progenies before the gamma spectroscopy.

2.2 Sample Analysis

Each sample of the maize were subjected to a gamma ray spectrometer at the laboratory of Ghana atomic energy commission Accra, Ghana. The gamma spectrometer used for the analysis consists of an ORTEC Coaxial N-type HPGe gamma-ray detector ORTEC coupled to a computer based ORTEC Multichannel Analyzer (MCA) mounted in a cylindrical lead shield (100mm thick and cooled in liquid Nitrogen). The radionuclides were identified using gamma ray spectrum analysis software ORTEC MAESTRO-32. The relative efficiency of the detector was 28.5 % with energy resolution of 1.8 keV at gamma ray energy of 1332 keV of ^{60}Co .

The gamma lines 609.31 and 1764.49 keV of ^{214}Bi was used to determine ^{238}U . The gamma line 583.19 of ^{208}Tl was used to determine ^{232}Th and that of ^{40}K was determined from the gamma line of 1460.83 keV. The samples were counted for 18,000 seconds (5 hours). Background measurements were made for the same period. The energy and efficiency calibrations were performed using mixed radionuclide calibration standard in the form of solid, serial number NW 146 A with approximate volume 1000 mL and density 1.0 g cm^{-3} in a 1.0 L Marinelli beaker. The standard was supplied by Deutscher Kalibrierdienst (DKD-3), QSA Global GmbH, Germany. The background radiation distribution in the environment around the detector was determined. The background spectra were used to correct the net peak area of gamma rays measured isotopes. The minimum detectable activities were gotten. Density corrections were also made where appropriate.

The specific activity (A_{sp}) of ^{238}U , ^{232}Th , and ^{40}K were determined in Bq kg^{-1} for the maize samples using the following expression after decay correction [13] and [14].

The specific activity (A_{sp}) of radio nuclides in the sample was estimated using the relation



Figure 1: Map of Nigeria showing Ekiti state

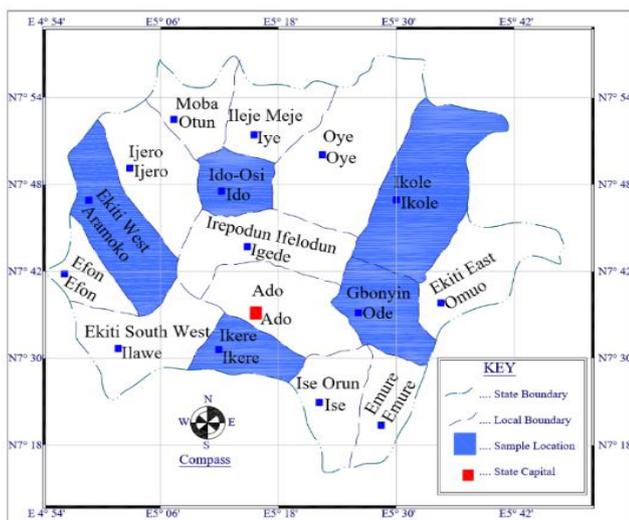


Figure 2: Map of Ekiti State Showing Sample Locations

II. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

In order to measure the natural radioactivity in the maize, a total number of 10 maize samples were collected directly

$$A_{sp} = \frac{N_{sam}}{P_E \cdot \epsilon \cdot T_c \cdot M} \quad (1)$$

Where N_{sam} is the net count of each of the radio nuclide, P_E is the gamma emission probability, ϵ is the total counting efficiency of the detector, T_c is the sample counting time while M is the mass (kg) of the sample.

The specific activities were computed electronically using equation (1) incorporated into the MAESTRO-32 software coupled with appropriate conversion factors which were used for the sample analysis and processing. The specific activities form the basis for the evaluation of the radiological health hazard posed by the ingestion of the food crops from the studied area.

2.3 Annual Effective Dose Equivalent (AEDE) (H)

Estimation of annual effective dose H_{rf} ($Sv\cdot y^{-1}$) to an individual due to the ingestion of the natural radionuclides present in the foodstuff samples were reported by [15] which they found to be dependent on the radionuclide's concentration of the food and the quantity taken. The effective dose incurred from a single radionuclide by an individual consuming the foodstuff is therefore given by [16]

$$H_{rf} = G_{rf} U_r C_{rf} + \dots \quad (2)$$

Where C_{rf} is the activity concentration of the radionuclide in the foodstuff ($Bq\cdot kg^{-1}$), U_r is the foodstuff consumption

per annum or annual intake of the foodstuff ($kg\cdot y^{-1}$), (maize = $25\ kg\ y^{-1}$) as given by [17] and G_{rf} is the ingested dose conversion factor for radionuclides ($Sv\ Bq^{-1}$), which varies from one radionuclide to another. The total annual effective dose H_{rf} ($Sv\ y^{-1}$) to an individual was established by summing the contributions from all radionuclides present in the food samples. Thus, equation 2 can be rewritten as

$$H_{rf} = \Sigma G_{rf} U_r C_{rf} + \dots \quad (3)$$

Radiation doses ingested will be obtained by measuring radionuclides activities in foodstuff ($Bq\cdot kg^{-1}$) and multiply this by the masses of food consumed over a period of time ($kg\cdot y^{-1}$). A dose conversion factor can then be multiplied to give an estimate of ingested dose. The dose calculations were based on the assumptions that each person obtained food according to the consumption defined in the food balance sheet [18], and the radionuclides dose conversion factor are 2.8×10^{-7} for ^{238}U , 2.3×10^{-7} for ^{232}Th , and 6.2×10^{-9} for ^{40}K for adult members of the public [19].

2.4 Excess lifetime cancer risk (ELCR)

Excess life time cancer risk (ELCR) was obtained on the bases of the relation in equation 4:

$$ELCR = E_f \cdot D_L \cdot R_c \quad (4)$$

Where $ELCR$, E_f , D_L , and R_c are the excess lifetime cancer risk, annual intake of radionuclide (Bq), average duration of life (70 years) and mortality risk coefficient (Bq^{-1}). The mortality risk coefficient in (Bq^{-1}) are 9.56×10^{-9} for ^{238}U , 2.45×10^{-9} for ^{232}Th and 5.89×10^{-10} for ^{40}K [20].

Table 1: Locations, coordinate, activity concentration ($Bq\cdot kg^{-1}$) and annual effective doses ($mSv\cdot y^{-1}$) and ELCR for Ekiti state

EKITI STATE								
No	Locations	Latitudes	Longitudes	^{40}K	^{232}Th	^{238}U	AEDE	ELCR
1.	Ode	$7^{\circ}47'N$	$5^{\circ}40'E$	2443.2 ± 54.10	91.88 ± 5.00	86.24 ± 4.11	1.51	5.10×10^{-10}
2.	Ikole	$7^{\circ}47'N$	$5^{\circ}30'E$	2082.2 ± 104.5	86.08 ± 27.88	46.66 ± 21.58	1.15	8.71×10^{-9}
3.	Ido	$7^{\circ}45'N$	$5^{\circ}48'E$	994.67 ± 51.40	52.05 ± 7.81	43.21 ± 6.48	0.41	2.53×10^{-10}
4.	Aramoko	$7^{\circ}42'N$	$5^{\circ}18'E$	2457.01 ± 68.14	32.84 ± 4.42	97.77 ± 5.78	1.25	5.06×10^{-10}
5.	Ikere	$7^{\circ}30'N$	$5^{\circ}14'E$	1369.83 ± 78.78	46.77 ± 7.01	53.56 ± 8.03	0.86	3.05×10^{-10}
	Total			4849.60	184.60	173.30	5.18	1.03×10^{-8}
	Mean			969.90	36.90	34.70	1.04	2.06×10^{-9}

III. RESULTS AND DISCUSSION

Table 1; summarizes the measured concentrations of the naturally occurring radioactive elements ^{40}K , ^{232}Th and ^{238}U ,

and annual effective doses ($m\ Sv\cdot y^{-1}$) values for the maize at the various locations. Also stated in the Table are locations,

coordinates, the mean activity concentration and the excess lifetime cancer risks due to ingestion of the maize.

The specific activity of ^{40}K , ^{232}Th and ^{238}U of Ekiti State were found to vary between $994.67 - 2457.01\text{BqKg}^{-1}$ for ^{40}K , $32.84 - 91.88\text{Bq kg}^{-1}$ for ^{232}Th and $43.21 - 97.77\text{Bq kg}^{-1}$ for ^{238}U respectively. Most of the radioactivity in the maize is from ^{40}K . The specific activity from ^{232}Th was slightly higher than that of the ^{238}U in all the samples except in Aramoko and Ikere maize samples.

Ekiti State has the highest activity concentrations of ^{40}K in Aramoko maize sample (2457.01 Bqkg^{-1}) and lowest concentration of (994.67 Bqkg^{-1}) in Ido sample (Fig.3), ^{232}Th was found to have (91.88 Bqkg^{-1}) as highest activity concentrations in Ode and ^{232}Th (32.84 Bqkg^{-1}) as lowest in Aramoko maize sample. While ^{238}U (97.77 Bqkg^{-1}) was as well found to have the highest activity concentrations in Aramoko and lowest in Ido (43.21 Bqkg^{-1}) maize samples respectively as given in Fig. 4 and Fig. 5.

The high distribution of radionuclides in the samples from the areas, especially at Aramoko and Ode might be due to the local geology of the area [21]. The increase in ^{232}Th and ^{238}U in Ode and Aramoko both in Ekiti State samples might be attributed to the small-scale industries springing up around the areas. While the increase in ^{40}K in maize samples from the Ekiti State might as well be due to the extensive phosphate fertilizer application involved to improve the crop yields.

The annual effective dose calculated using equation 2 have the highest value in the samples collected from Ode, Ikole and Aramoko and found to be 1.51, 1.15 and 1.25 m

Svy^{-1} respectively, according to Figure 6. The annual effective dose value for all the maize samples from the state were on the higher side when compare with globally recommended value of 0.29 mSvy^{-1} by UNSCEAR [3].

The total annual effective dose using equation 3 was also determined to be 1.04 mSvy^{-1} which is a bit higher than the limit of 1 mSvy^{-1} set by the International Commission on Radiological Protection [22]. The calculated values obtained for the excess life cancer risk for the state varies from 8.71×10^{-9} to 5.10×10^{-10} and also the average ELCR from the total ELCR was calculated to be 2.06×10^{-9} and lower compared with acceptable ELCR limit of 10^{-3} for radiological risk in general [3].

The present study results were compared to those reported in the literature. Table 1 shows the values of the activity concentration of the present study which were higher with respect to cases reported in the literature and the world average value of ^{40}K (310 Bq kg^{-1}), but in tandem with the findings by [23] and [24] on the soils of Ekiti State. In the same vain, it is evident that the mean activity concentrations of ^{232}Th and ^{238}U in the maize samples from the state were a bit higher when compare to results obtained from other countries but still found to be within the recommended internationally limit of $82\text{ and }67\text{ Bq kg}^{-1}$ respectively [3] except in the maize samples from Ode and Ikole which were higher than the internationally acceptable values of $82\text{ (}^{232}\text{Th) Bq kg}^{-1}$ and $67\text{ Bq kg}^{-1}\text{ (}^{238}\text{U)}$ as shown by Table 1 and reported by UNSCEAR [3]. However, the average concentrations of ^{232}Th and ^{238}U found in this study for the state are below the UNSCEAR [3] recommended values.

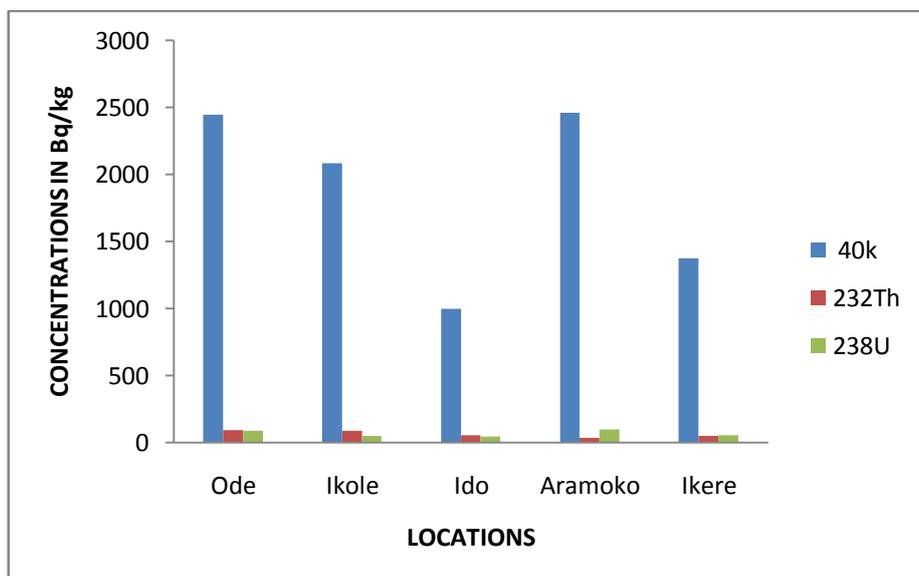


Figure 3: Radionuclides Concentration (Bq kg^{-1}) of Maize samples from Ekiti State

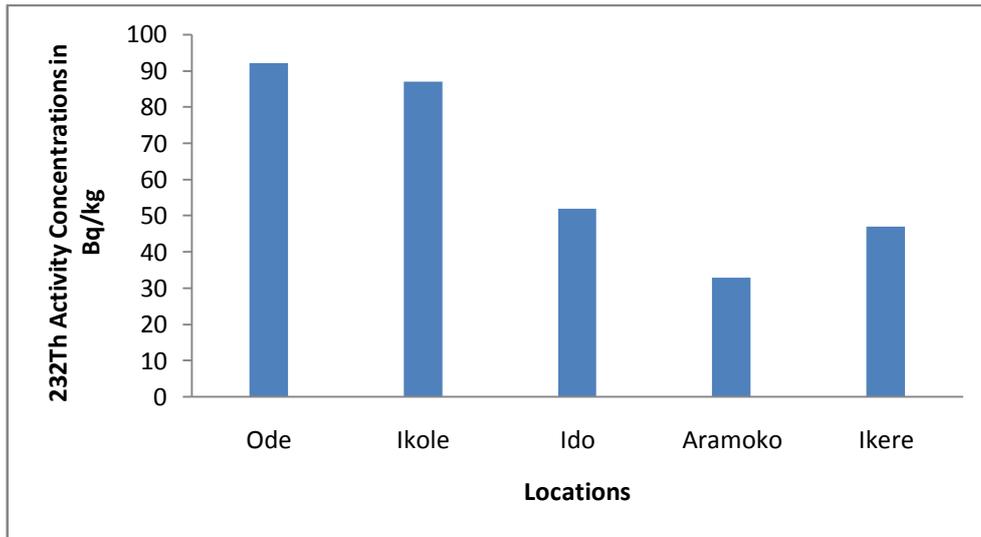


Figure 4: ²³²Th Activity Concentrations (Bq kg⁻¹) of Maize samples for Ekiti State

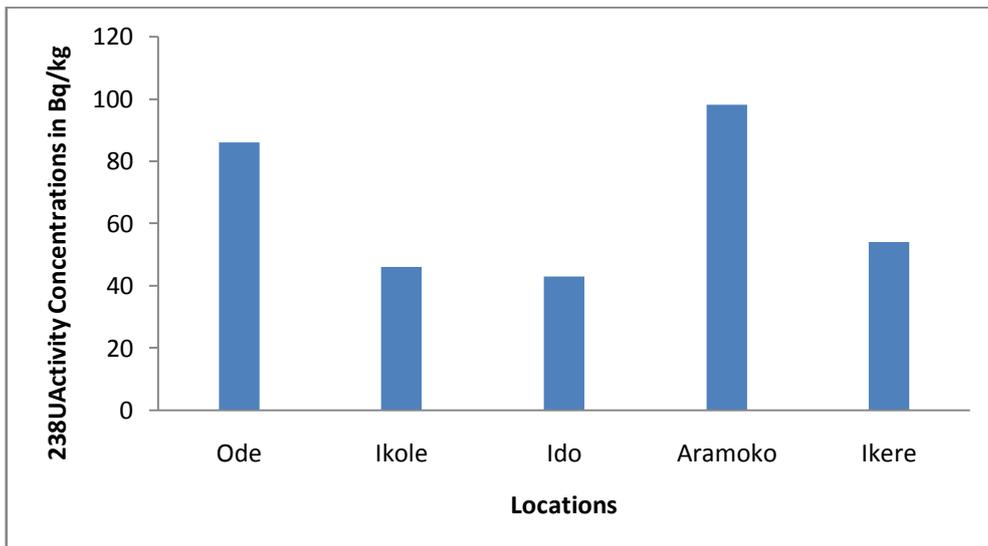


Figure 5: ²³⁸U Activity Concentrations (Bq kg⁻¹) of Maize samples for Ekiti State

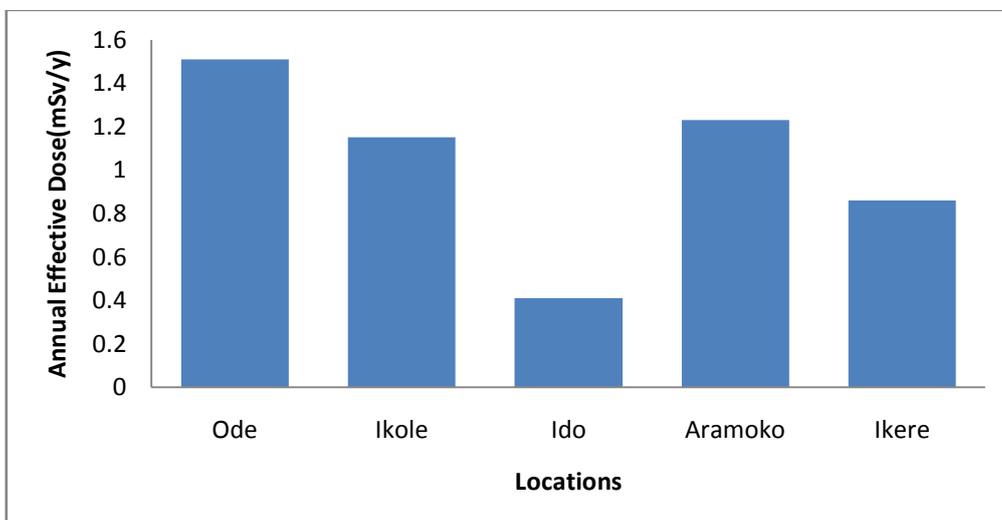


Figure 6: The Total Annual Effective Dose Rate of Maize for Ekiti State

Table 2: Comparison of Activity Concentration with similar studies

Country	Activity concentration(Maize) (Bq Kg-1)			References
	⁴⁰ K	²³² Th	²³⁸ U	
Turkey (Gediz.Basin)	491.00	NDA	25.80	[10]
Tanzania	48.80	4.10	13.20	[11]
Nig.(Plateau)	234.00	NDA	34.10	[21]
Nig (Bitsichi)	NDA	57.60	21.00	[25]
Ghana	104	NDA	5.00	[26]
Iranian	101.52	0.85	0.81	[27]
Egypt	154.00 – 233.40	6.00 – 11.00	5.00 – 14.00	[28]
Yemen	188.30	2.03	3.63	[29]
Nig.(Jigawa)	315.00	2.79	8.55	[30]
Nig (Ekiti)	1849.40	61.77	66.11	Present study
World Average	310.00	82.00	67.00	[3]

NDA: No Data Available

IV. CONCLUSION

This study investigated the activity concentrations of radionuclides found in five maize samples grown within Ekiti State. The measured activity concentrations of ⁴⁰K, ²³²Th and ²³⁸U recorded were found to vary from 994.67 – 2457.01 Bq Kg⁻¹ for ⁴⁰K, 32.84 – 91.88 Bq kg⁻¹ for ²³²Th and 43.21 – 97.77 Bq kg⁻¹ for ²³⁸U respectively.

The mean activity concentrations of these radionuclides (⁴⁰K, ²³²Th and ²³⁸U) for the are State 1849.41, 61.77 and 66.11Bq kg⁻¹ respectively. The values of ⁴⁰K in this result seem a bit higher compared to values reported in other parts of the world and the world average value reported by [3]. But this is in tandem with the findings by [23] and [24] report on the soils of both Ondo and Ekiti States. The increase in the radionuclides could be attributed to the excessive use of potassium – rich phosphate fertilizer by the farmers to improve their crop yield and the local geology across the studied area.

The annual effective dose equivalent from the maize consume by adults in the area has been estimated using dose conversion factors for the various radionuclides (⁴⁰K, ²³²Th and ²³⁸U) for both states as 6.2 x 10⁻⁹, 2.3 x 10⁻⁷ and 2.8 x 10⁻⁷ Sv Bq⁻¹ respectively. The results were found to be within the range of 0.41 and 1.51 m Svy⁻¹ for the state. The mean total annual effective dose equivalent (m Svy⁻¹) for the state is 1.04 m Svy⁻¹ which is a bit higher than the 1.0 m Svy⁻¹ recommended by the [22]. Moreover, the result of the excess life cancer risk for the state varies from 8.71 x 10⁻⁹ to 5.1x10⁻¹⁰ and the average ELCR is found to be 2.06 x10⁻⁹ which is lower compared with acceptable ELCR limit of 10⁻³ for radiological risk in general [3]. This value is significantly low to result in biological health risk of the farmers and the consumers. Hence, the maize sample is safe for human

consumption. However, people should be sensitized on the danger of planting on high background area. The scope can be increased in future to cover more farm lands within the states and therefore calculate the total annual effective dose, excess life time cancer risk and other radiation parameters to determine the safety and or otherwise of the maize samples due to ingestion.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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