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Determination of Food Crops Contamination in Osun State, Nigeria Due to Radium-226, Thorium-232 and Potassium-40 Concentrations in the Environment

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Abstract

One of the three goals of the United Nations for sustainable food security is to ensure that all people have access to sufficient, nutritionally adequate, and safe food. The south-west area of Nigeria especially Osun State is home to some of the most important minerals, which include bitumen, gold, kaolin, salt limestone, tantalite, coal and phosphate. As a result of the mineral occurrence, some parts of Osun State have become associated with significant levels of natural radioactivity. The exploration and exploitation of these minerals are known to have enormous consequences on the environment. This work is to measure the baseline radioactivity levels in some major food crops in Osun State and hence predict the potential radiological health effects. The study area (Osun State) has a total land mass of about 12820 km2, with a projected population of 5.1 million inhabitants. Osun State lies within latitudes 07o00 N and 08o25 N and longitudes 04o00 E and 05o11 E. Maize, Yam and cassava tubers that constitute the major food nutritive requirements were collected directly across farmlands in the State. The sampling locations were purposely chosen by considering the possibility of mineral resources, water resources, industry and farmlands. In order to have a total coverage of the study area, Osun State was divided into eight zones comprising the thirty local government areas in the State. Maize, yam and cassava were dried at room temperature until a constant weight was achieved. They were ground, homogenized and 250 g sealed in 1-liter Marinelli beaker and kept for 28 days in order to attain secular equilibrium before the gamma counting. The activity concentrations of Ra-226, Th-232, and K-40 were determined in the food samples using γ-ray spectrometry in the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife. The mean activity concentration of Ra-226, Th-232 and K-40 for yam were 1.72 ± 0.10 Bqkg-1, 2.24 ± 0.21 Bqkg-1 and 37.84 ± 2.40 Bqkg-1 respectively. The content of the radionuclides in maize gave a mean value of 2.49 ± 0.48 Bqkg-1 for Ra-226, 2.12 ± 0.06 Bqkg-1 for Th-232 and for K-40, the mean value is 30.92 ± 2.15 Bqkg-1 . The mean specific radionuclide concentrations in cassava is 2.00 ± 0.41 Bqkg-1 for Ra-226, 1.81 ± 0.12 Bqkg-1 for Th-232 and 40.35 ± 3.94 Bqkg-1 for K-40. The committed effective doses were 0.66 μSvy-1 for the consumption of yam, 0.54 μSvy-1 for maize, and 0.66 μSvy-1 for cassava which are lower than the annual dose guideline for the general public. Therefore, the values obtained in this work show that there is no radiological contamination of foodstuffs consumed in Osun State.

Keywords: Environment, Contamination, Minerals, Radioactivity, Committed Effective Dose.

1. Introduction

Radiation has been implicated in the development of malignant disease and very probably, of other damage to human health. Radioactive materials from the atmosphere are transferred through the terrestrial environment and may lead to the irradiation of humans via the ingestion of contaminated foodstuffs. (Jones and Sherwood, 2009). Conventional industries such as colouring, clothing, luminous paint, lime-burning and

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construction make use of naturally occurring radioactive materials (NORM) which can be enriched and are discharged into the environment by the industrial processes. Contaminants from the human activities pass into the air, into the soil and water, into the fish, animals, food crops and vegetables. The south-west area of Nigeria especially Osun State is home to some of the most important minerals, which include bitumen, gold, kaolin, salt limestone, tantalite, coal and phosphate. As a result of the mineral occurrence, some parts of Osun State have become associated with significant levels of natural radioactivity. The exploration and exploitation of these minerals are known to have enormous consequences on the environment. It is therefore necessary to measure the food crops in Osun State, Nigeria, in order to ascertain if there are contaminations due to ^{226}Ra, ^{232}Th and ^{40}K concentrations in the environment. Also, the knowledge of intake of ^{226}Ra and ^{232}Th via the food chain is necessary to estimate the uptake and retention of these radionuclides in the human body. In studies by Shiraishi et al (2000) and Okoji et al (2012) food crops and vegetables were identified as contributors to daily intakes of ^{226}Ra and ^{232}Th.

This work measured the baseline radioactivity levels in some major food crops in Osun State and hence predict the potential radiological health effects.

2. Materials and Method

2.1 Study Area

The study area covered the entire Osun State which has a total land mass of about 12820 km^2, with a projected population of 5.1 million inhabitants (NPC, 1998). Osun State lies within latitudes 07^{o}00 N and 08^{o}25 N and longitudes 04^{o}00 E and 05^{o}11 E. It shares boundaries with Oyo State in the west, Ondo State in the east, Kwara and Oyo States in the north, Ogun and Ondo States in the south. Osun State is underlain by crystalline rocks of Precambrian Basement Complex of southwestern Nigeria. Minerals that are found in Osun State include bitumen, gold, kaolin, salt limestone, tantalite, coal and phosphate (MSMD, 1990)

2.2 Sampling and Sample Preparation

In order to have a total coverage of the study area, Osun State was divided into eight zones comprising the thirty local government areas in the State. In each zone, there were two sampling locations of at least 10.0 km apart. At each sampling location, sets of samples were collected for each food crop. The choice of sampling locations was based on the possible occurrence of minerals, farmlands and industries. The food crops collected are widely grown and consumed by the local community such as yam, maize and cassava. They were dried at room temperature until constant weight is achieved, crushed in a mortar and then sieved with a 2 mm - sieve. Marinelli beakers designed to fit into the sodium iodide gamma spectrometer counting chamber were washed in 0.1M hydrochloric acid, rinsed in distilled water and dried to avoid contamination. The empty Marinelli beakers were weighed before 250g of the samples were packed and hermetically sealed. The sealed samples were left for 28 days for the short-lived radionuclides of ^{238}U (^{226}Ra) and ^{232}Th to attain secular equilibrium.

2.3 Gamma Spectrometric Analysis

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th were measured using gamma ray spectroscopy method. The measuring system consists of a scintillation detector sealed with a photo multiplier tube and connected through a preamplifier base to a Canberra series 10 – plus multi-channel analyzer (MCA). The detector is a 3 cm × 3 cm NaI(Tl) (Model No. 3M3/3). The detector has a resolution of about 8% at 0.662 MeV of ^{137}Cs. The detection Energy calibration of the system was carried out using reference standard source (IAEA- 444) prepared from the Radiochemical Centre, Amersham, England. The 1.460 MeV photopeak was used for the measurement of ^{40}K while the 1.120 MeV photopeak from ^{214}Bi and the 0.911 MeV photopeak from ^{288}Ac were used for the measurement of ^{238}U(^{226}Ra) and ^{232}Th, respectively. Efficiency calibration was done using standard reference source (IAEA- 375) whose energies and activities are known (Nwankpa, 2004). Each sample was counted for 7 hours and the data acquired.
The MAESTRO software program automatically searches for the peak, evaluates the peak position in energy, identifies the radionuclides by use of nuclide library. It calculates the net peak areas, subtracts the background count and then displays the activity concentration in selected units. Also, an empty Marinelli beaker was counted under identical geometry as the samples in other to determine the background spectrum distribution which was subtracted from the values.

3. Result and Discussion

The mean activity concentration of radionuclides in the yam samples range from 0.43 ± 0.07 to 3.75 ± 0.83 Bq/kg for ^{226}Ra, 1.11 ± 0.50 to 3.22 ± 0.15 Bq/kg for ^{232}Th and 20.96 ± 3.21 to 51.27 ±7.06 Bq/kg for ^{40}K (Table 1). The mean activity concentration of radionuclides in the maize samples range from 1.76 ± 0.06 to 4.09 ± 0.35 Bq/kg for ^{226}Ra, 1.42 ± 0.20 to 4.62 ± 0.90 Bq/kg for ^{232}Th and 13.43 ± 1.01 to 42.06 ± 3.93 Bq/kg for ^{40}K (Table 2). For cassava, the mean activity concentration range from 0.41 ± 0.13 to 3.73 ± 0.14 Bq/kg for ^{226}Ra, 0.37 ± 0.01 to 2.51 ± 0.31 Bq/kg for ^{232}Th and 12.95 ± 1.28 to 46.13 ± 4.36 Bq/kg for ^{40}K (Table 3). These values are within the average ranges, 8(1-9) Bq/kg for ^{226}Ra, 3(2-10) Bq/kg for ^{232}Th and 50(25-75) Bq/kg for ^{40}K respectively (UNSCEAR, 2000). The larger values of ^{238}U (^{226}Ra) and ^{232}Th contents in yam flour and maize could have been acquired during the process of sun drying in the open air, during which time airborne natural radioactive particles could settle on them (Nwankpa and Essiett, 2010).
The radionuclide intake is activity concentration of radionuclides multiplied by usage or dietary intake (Akinloye et al., 1999). The usage factor of food crop in Nigeria is 0.55 x 10^{-3} kg/day (0.2 kg/yr)(FAO, 1992). This value is adopted due to lack of site specific data. According to NCRP (1984), when the food consumption pattern of a population is not unusual, the general consumption pattern is applied. The mean annual intake of ^{238}U (^{226}Ra) and ^{232}Th from consumption of yam were 1.71 Bq/kg and 2.06 Bq/kg. For maize the mean annual intake of ^{238}U (^{226}Ra) and ^{232}Th were 2.38 Bq/kg and 2.24 Bq/kg and for cassava, 2.12 Bq/kg and 1.87 Bq/kg respectively. The values of annual intake of ^{238}U(^{226}Ra) in the three food crops were observed to be below the reference level of 5.7 Bq/kg. However, the values of annual intake of ^{232}Th in yam and maize were twice the

reference of 1.5 Bq/kg in the diets (UNSCEAR, 2000). The consumption of these food crops can lead to enhanced dietary intakes of thorium series radionuclide (Okoji, et al, 2012)

The committed effective dose to members of the public due to $^{238}U(^{226}Ra)$ and ^{232}Th radionuclides from the consumption of food crops by members of the communities in Osun State is given by

$E_u = I_u \times e(g)_u$ (Misdaq et al., 2000)

$E_{Th} = I_{Th} \times e(g)_{Th}$ (Rzama, et al., 1994)

Where I_u (Bq) and I_{Th} (Bq) are the annual intake of ^{238}U and ^{232}Th radionuclides respectively, $e(g)_u$ and $e(g)_{Th}$ are the ICRP ingestion dose coefficients for ^{238}U and ^{232}Th radionuclides respectively. (ICRP,1996). The ICRP values of ingestion coefficient for ^{238}U ($e(g)_u$) and ^{232}Th ($e(g)_{Th}$) radionuclides for age groups above 17 years are 4.5×10^{-8} $SvBq^{-1}$ and 2.3×10^{-7} $SvBq^{-1}$ respectively.

The committed effective doses from the consumption of yam, maize and cassava were 0.66 μSvy^{-1}, 0.54 μSvy^{-1} and 0.66 μSvy^{-1} respectively. These values are below the UNSCEAR (2000) reference values of 0.75 μSvy^{-1}, 0.65 μSvy^{-1} and 0.70 μSvy^{-1}.

Table 1: The Mean Specific Activities, the Annual Intake and the Committed Effective Doses for Yam

Zone/ Location		Mean Specific Activities of Radionuclides in Samples **(Bq/kg)**			Annual Intake of ^{238}U and ^{232}Th. **(Bq/kg)**		Committed Effective Doses Due to ^{238}U (E_u) and ^{232}Th (E_{Th}) **(μSvy^{-1})**		
Zone	Loc.	$^{238}U(^{226}Ra)$	^{232}Th	^{40}K	^{238}U	^{232}Th	(E_u)	(E_{Th})	E_{Total}
1	1	2.08 ± 0.19	1.74 ± 0.02	23.05 ± 3.01	2.29	1.91	0.10	0.44	0.54
	2	0.46 ± 0.23	1.88 ± 0.35	32.66 ± 3.42	0.51	2.09	0.02	0.48	0.50
2	1	0.53 ± 0.08	1.93 ± 0.25	31.37 ± 5.36	0.58	2.12	0.03	0.49	0.52
	2	0.59 ± 0.17	2.41 ± 0.43	20.96 ± 3.21	0.65	2.65	0.03	0.61	0.64
3	1	0.75 ± 0.24	1.62 ± 0.43	30.91 ± 4.22	0.83	1.78	0.04	0.41	0.45
	2	0.43 ± 0.07	2.11 ± 0.10	30.85 ± 4.08	0.47	2.32	0.02	0.53	0.55
4	1	3.42 ± 0.51	2.42 ± 0.63	25.25 ± 2.72	3.76	2.66	0.17	0.61	0.78
	2	2.37 ± 0.53	1.26 ± 0.51	30.24 ± 4.16	2.61	1.39	0.12	0.32	0.44
5	1	0.92 ± 0.14	1.17 ± 0.03	51.27 ± 7.06	1.01	1.29	0.05	0.30	0.35
	2	1.35 ± 0.50	1.51 ± 0.72	36.11 ± 3.20	1.49	1.66	0.07	0.38	0.45
6	1	1.96 ± 0.17	1.94 ± 0.42	39.62 ± 4.72	2.16	1.80	0.10	0.42	0.52
	2	3.75 ± 0.83	1.11 ± 0.50	38.55 ± 5.06	4.13	1.22	0.19	0.28	0.47
7	1	3.18 ± 0.38	2.47 ± 0.43	23.22 ± 2.16	3.50	2.71	0.16	0.63	0.79
	2	1.15 ± 0.12	3.22 ± 0.15	26.31 ± 2.62	1.27	3.54	0.06	0.82	0.88
8	1	1.95 ± 0.13	2.24 ± 0.12	37.27 ± 3.57	2.15	2.46	0.10	0.57	0.67
	2	0.87 ± 0.07	1.27 ± 0.22	32.53 ± 4.15	0.96	1.39	0.04	0.32	0.36

Table 2: The Mean Specific Activities, the Annual Intake and the Committed Effective Doses for Maize

Zone/ Location		Mean Specific Activities of Radionuclides in Samples **(Bq/kg)**			Annual Intake of ^{238}U and ^{232}Th. **(Bq/kg)**		Committed Effective Doses Due to ^{238}U (E_u) and ^{232}Th (E_{Th}) **(μSvy^{-1})**		
Zone	Loc.	$^{238}U(^{226}Ra)$	^{232}Th	^{40}K	^{238}U	^{232}Th	(E_u)	(E_{Th})	E_{Total}
1	1	1.85 ± 0.05	2.83 ± 0.06	42.06 ± 3.93	1.67	2.55	0.08	0.59	0.67
	2	2.15 ± 0.53	3.50 ± 0.19	25.94 ± 2.02	1.94	3.15	0.09	0.72	0.81
2	1	2.02 ± 1.87	1.91 ± 0.51	19.56 ± 1.96	1.82	1.72	0.08	0.39	0.47

	2	2.98 ± 1.90	3.12 ± 0.27	13.43 ± 1.01	2.68	2.81	0.12	0.65	0.77
3	1	2.36 ± 0.19	4.62 ± 0.90	18.04 ± 1.77	2.12	4.16	0.10	1.00	1.10
	2	1.76 ± 0.06	1.54 ± 0.44	23.08 ± 2.99	1.58	1.39	0.07	0.32	0.39
4	1	2.15 ± 0.07	2.33 ± 0.07	39.02 ± 3.40	1.94	2.10	0.09	0.48	0.57
	2	2.84 ± 0.36	2.58 ± 0.31	20.62 ± 2.75	2.56	2.32	0.12	0.53	0.65
5	1	2.92 ± 0.99	1.86 ± 0.62	28.16 ± 2.11	2.63	1.67	0.12	0.39	0.51
	2	2.78 ± 0.93	1.93 ± 0.86	27.41 ± 2.61	2.50	1.74	0.11	0.40	0.51
6	1	2.86 ± 0.21	1.64 ± 0.23	23.04 ± 3.73	2.57	1.48	0.12	0.34	0.46
	2	2.67 ± 0.25	1.92 ± 0.44	28.03 ± 2.90	2.40	1.73	0.11	0.40	0.51
7	1	2.72 ± 0.09	2.93 ± 0.06	35.08 ± 3.40	2.45	2.64	0.11	0.61	0.72
	2	4.09 ± 0.35	3.23 ± 0.18	24.98 ± 2.70	3.68	2.91	0.17	0.67	0.84
8	1	3.49 ± 0.42	2.51 ± 0.23	25.14 ± 2.74	3.14	2.26	0.14	0.52	0.66
	2	2.63 ± 0.25	1.42 ± 0.20	27.05 ± 2.28	2.37	1.28	0.11	0.29	0.40

Table 3: The Mean Specific Activities, the Annual Intake and the Committed Effective Doses for Cassava

Zone/ Location		Mean Specific Activities of Radionuclides in Samples **(Bq/kg)**			Annual Intake of ^{238}U and ^{232}Th. **(Bq/kg)**		Committed Effective Doses Due to ^{238}U (E_u) and ^{232}Th (E_{Th}) **(μSvy^{-1})**		
Zone	Loc.	^{238}U(^{226}Ra)	^{232}Th	^{40}K	^{238}U	^{232}Th	(E_u)	(E_{Th})	E_{Total}
1	1	0.64 ± 0.07	0.37 ± 0.01	12.95 ± 1.28	0.83	0.48	0.04	0.11	0.15
	2	0.41 ± 0.13	1.78 ± 0.22	20.93 ± 2.15	0.53	2.31	0.02	0.53	0.55
2	1	0.87 ± 0.18	1.31 ± 0.39	22.10 ± 3.54	1.13	1.70	0.05	0.39	0.44
	2	0.47 ± 0.10	0.76 ± 0.12	30.64 ± 4.11	0.61	0.99	0.03	0.23	0.26
3	1	0.93 ± 0.28	1.97 ± 0.67	31.10 ± 3.33	1.21	2.56	0.05	0.59	0.64
	2	1.01 ± 0.89	0.69 ± 0.22	41.86 ± 4.07	1.31	0.90	0.06	0.20	0.26
4	1	1.61 ± 0.57	0.91 ± 0.06	15.05 ± 1.32	2.09	1.18	0.09	0.27	0.36
	2	1.85 ± 0.24	1.29 ± 0.24	21.27 ± 2.26	2.41	1.68	0.11	0.39	0.50
5	1	0.88 ± 0.21	2.51 ± 0.31	34.19 ± 3.64	1.14	3.26	0.05	0.75	0.80
	2	0.99 ± 0.21	1.73 ± 0.10	32.54 ± 3.37	1.29	2.25	0.06	0.51	0.57
6	1	1.63 ± 0.24	1.07 ± 0.27	41.13 ± 4.31	2.12	1.39	0.10	0.32	0.42
	2	3.01 ± 0.79	0.83 ± 0.02	21.73 ± 2.08	3.91	1.08	0.18	0.25	0.43
7	1	1.92 ± 0.36	1.18 ± 0.04	18.05 ± 1.31	2.50	1.53	0.11	0.35	0.46
	2	3.52 ± 0.51	2.23 ± 0.23	24.37 ± 3.32	4.58	2.90	0.21	0.67	0.88
8	1	2.66 ± 0.23	2.07 ± 0.24	28.13 ± 3.36	3.46	2.69	0.16	0.62	0.78
	2	3.73 ± 0.14	2.33 ± 0.26	46.13 ± 4.36	4.85	3.03	0.22	0.70	0.92

4. Conclusion

The baseline radioactivity concentrations of Radium-226, Thorium-232 and Potassium-40 in some major food crops in Osun State were measured. The concentrations of the natural radionuclides in the sampled food crops were observed to be below the world average in food items. The values of annual intake of ^{238}U(^{226}Ra) in the three food crops were observed to be below the reference level of 5.7 Bq/kg. However, the values of annual intake of ^{232}Th in yam and maize were twice the reference of 1.5 Bq/kg in the diets (UNSCEAR, 2000). The committed effective dose is an assessment of radiological health effect of radiations from ^{226}Ra and ^{232}Th radionuclides from the consumption of food items, hence the values obtained in this work being lower than the reference values, show that there is no radiological contamination of foodstuffs consumed in Osun State.

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