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Evaluation of Annual Effective Dose Due to Ingestion in Some Commonly Consumed Vegetables in Lagos State, Nigeria

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Abstract: The activity concentrations of ^{40}K, ^{238}U and ^{232}Th in some commonly consumed vegetables in Badagry, Ikorodu and Ojo areas of Lagos state were determined. The highest concentration of ^{40}K was obtained in *Celosia argentea* (Lagos Spinach) with a value of 7807.51±402.48 Bq/kg, the highest concentration of ^{238}U with a value of 59.46±6.46 Bq/kg was found in *Amaranthus hybridus* (African Spinach) and the highest concentration of ^{232}Th was found in *Amaranthus hybridus* (African Spinach) with a value of 47.45± 2.80 Bq/kg. The highest concentrations were found in vegetables from Ikorodu. The lowest concentration of ^{40}K was found in *Hibiscus sabdariffa* (Roselle) with a value of 451.23±23.87 Bq/kg. *Celosia argentea* (Lagos Spinach) has the lowest concentration value of 0.79±0.10 Bq/kg for ^{238}U and a concentration value of 3.81± 0.22 Bq/kg was found in *Vernonia amygdalina* (Bitter Leaf) being the lowest concentration value of ^{232}Th. The mean annual effective doses of Badagry, Ikorodu and Ojo were 1.42mSv/y, 2.06mSv/y and 2.23mSv/y, respectively, which were higher than the world mean average of 0.294mSv/y.

Keywords: Activity concentration; Vegetables; Mean absorbed dose; Cancer risk.

Introduction

Radionuclides are found naturally in air, water and soil. They are even found in human beings. We are products of our environment, and we interact daily with radionuclides in the environment through ingestion and inhalation. [1, 2]

The level of terrestrial background radiation of radionuclides depends on the geological and geographical location which differs on regional bases [3, 4].Weathering and erosion of rocks (igneous and metamorphic) into sand, deposit minerals bearing natural radionuclides. These radionuclides are transmitted along with nutrients during mineral uptake through absorption and are accumulated in edible and non-edible parts of plants [5]. According to IAEA report [6], soil vegetables are recognized among the main path radionuclides transferred to man. Several studies have been performed in different countries to determine the radionuclides' concentrations in different food samples and dose assessment from food staff consumption by the populace [7-11].

Vegetables and fruits are important components of a healthy diet and the presence of the natural radionuclides ^{40}K, ^{238}U and ^{232}Th in them has certain radiological implications; not only on the foods, but on the consuming population [1, 12- 13].

In this study, activity concentrations of ^{40}K, ^{238}U and ^{232}Th are investigated in some common vegetables (*Corchorous olitorious*, *Vernonia*

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amygdalina, *Talium triagulare*, *Celosia argentea*, *Amaranthus hybridus*, *Telfaina occidentalise*) from Badagry, Ikorodu and Ojo areas of Lagos state, Nigeria. This study will provide a baseline data on radionuclides' concentrations in vegetables from these areas for further research.

Materials and Method

Commonly consumed vegetables were presented by the populace in the selected areas. The selection was such that six commonly consumed vegetables were collected from Badagry, Ikorodu and Ojo, respectively in the course of this study. These specimens (Veggies) were collected from local farmers. Measurements of the dry weight of the edible part (leaves) were used [6]. The vegetables were hand-cleaned to remove soil particles as to avoid contamination, then washed with tap water. The samples were air-dried for 10 days, oven-dried at 80°C in order to remove moisture and blended to powder. These were packed in 0.2kg lots by weight W_3 and airtight sealed in a white cylindrical PVC container.

$$W_3 = W_2 - W_1 . \qquad (1)$$

W_3 is the weight of the dry sample, W_2 is the weight of the PVC container and sample together and W_1 is the weight of the PVC container.

The samples were left for 4 weeks, so that the secular equilibrium of the gaseous daughters of Uranium and Thorium series would be attained before counting. A high confident background level was established by measuring background radiation with an empty container for 10 hours. The activity concentrations of the samples were determined using the formula in Eq. 2.

$$C_{samp} = [C_{std} \times W_{std} \times N_{samp}] / [W_{samp} \times N_{std}] . \qquad (2)$$

C_{samp} and C_{std} represent the activity concentrations of the sample and the standard sample, respectively. W_{samp} and W_{std} are the weights of the sample and the standard sample, while N_{samp} and N_{std} are the net counts of the photo peak area of the sample and the standard sample.

Radioactivity counting in this work was carried out using a lead shielded 76mm X 76mm NaI (TI) crystal detector (Model Number: 802 Series) by Canberra Inc., which is coupled to a Canberra series plus 10 Multi- Channel Analyzer (MCA) (Model number 1104) through a preamplifier base. The detector used has a resolution of about 8% at 0.662MeV line of ^{137}Cs for the measurement of ^{40}K, ^{238}U and ^{232}Th concentrations. Photo peak regions of (1.460MeV) ^{40}K, (1.76MeV) ^{214}Bi and (2.615MeV) ^{208}TI were used, respectively. Each sample E1- E7 in Table 1 was counted for 36,000 seconds for each study area using the same technique as in the background radiation.

TABLE 1. List of vegetables used in the study and their code names

S/N	Vegetable code	Vegetable name	Vegetable traditional name	Botanical name of the vegetable
1	E1	Jute Leaves	Ewedu	*Corchorous olitorious*
2	E2	Bitter Leaf	Ewuro	*Vernonia amygdalina*
3	E3	Water Leaf	Gbure	*Talinium triangulare*
4	E4	Lagos Spinach	Shoko Yokoto	*Celosia argentia*
5	E5	African Spinach	Efo Tete	*Amaranthus hybridus*
6	E6	Fluted Pumpkin Leaf	Ugu	*Telifairia occidentalis*
7	E7	Roselle	Ishapa	*Hibiscus sabdariffa*

Results and Discussion

The value and the associated tolerance (±) in the concentration of ^{40}K, ^{238}U and ^{232}Th were measured in vegetable samples in Badagry. As shown in Table 2, the activity concentration of ^{40}K ranges from 451.23 ± 23.87 Bq/kg to 5835.84 ± 309.12 Bq/kg, with the lowest concentration in Roselle (*Hibiscus sabdariffa*) and the highest concentration in Water Leaf (*Talium triagulane*). The activity concentration of ^{238}U ranges from ND to 39.80 ± 4.27 Bq/kg, with the highest concentration in Jute Leaves (*Corchorous olitorious*), while the activity concentration of ^{232}Th ranges from ND in Water Leaf (*Talium triangulane*) and Roselle (*Hibiscus sabdariffa*) to 35.83 ± 2.11 Bq/kg in Fluted Pumpkin Leaf (*Telfairia occidentalis*). The activity concentration values of ^{40}K, ^{238}U and ^{232}Th measured in Ikorodu are shown in Table 3. The activity concentration of ^{40}K ranges from 1269.75 ± 66.89 Bq/kg to 7807.51 ± 402.48

Bq/kg, with the lowest concentration in Jute Leaves (*Corchorous olitorious*) and the highest in Lagos Spinach (*Celosia argentea*). The activity of ^{238}U ranges from 15.21 ± 1.86 Bq/kg to 59.46 ± 6.46 Bq/kg, with the lowest concentration in Jute Leaves (*Corchorous olitorious*) and the highest concentration in African Spinach (*Amaranthus hybridus*). The activity concentration of ^{232}Th ranges from ND in Jute Leaves (*Corchorous olitorious*) to 47.45 ± 2.80 Bq/kg with the highest concentration in African Spinach (*Amaranthus hybridus*).

TABLE 2. Radioactivity concentration in vegetables in Badagry, Lagos

SAMPLES	^{40}K (Bqkg^{-1})	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})
E_1	4622.37 ± 238.83	39.80 ± 4.27	11.83±0.70
E2	2339.12 ± 122.34	25.31 ± 2.85	26.23±1.55
E3	5835.84 ± 309.12	ND	ND
E4	3376.06 ± 176.00	0.79 ± 0.10	6.20±0.37
E6	2539.33 ± 131.97	35.73 ± 3.88	35.83±2.11
E7	451.23 ± 23.87	6.79 ± 1.16	ND
WEIGHTED MEAN	3193.77 ± 167.02	18.07 ± 2.04	13.35 ± 0.79

TABLE 3. Radioactivity concentration in vegetables in Ikorodu, Lagos

SAMPLES	^{40}K (Bqkg^{-1})	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})
E1	1269 ± 66.89	15.21 ± 1.86	ND
E2	4036.57±209.16	18.99 ± 2.31	18.71± 1.11
E3	6637.95±344.13	41.96 ±5.00	17.50 ± 1.05
E4	7807.51±402.48	43.51 ±4.63	14.32 ± 0.85
E5	3007.58±156.47	59.46 ± 6.46	47.45 ± 2.80
E6	4524.65±234.34	32.20 ± 3.57	22.26 ± 1.32
WEIGHTED MEAN	4547.25±235.58	35.22 ± 3.97	20.04 ± 1.19

The activity concentration values of ^{40}K, ^{238}U and ^{232}Th measured in Ojo are shown in Table 4. The activity concentration of ^{40}K ranges from 608.07 ± 32.05 Bq/kg to 7320.47 ± 378.06 Bq/kg, with the lowest concentration in Fluted Pumpkin Leaf (*Telfairia occidentalis*) and the highest in Water Leaf (*Talium triangulane*). The activity concentration of ^{238}U ranges from 9.75 ± 1.23 Bq/kg to 57.70 ± 6.19 Bq/kg, with the lowest concentration in Bitter Leaf (*Vernonia amygdalina*) and the highest concentration in Lagos Spinach (*Celosia argentea*). The activity concentration of ^{232}Th ranges from 3.81 ± 0.22 Bq/kg to 43.65 ± 2.58 Bq/kg, with the lowest concentration in Bitter Leaf (*Vernonia amygdalina*) and the highest concentration in Lagos Spinach (*Celosia argentea*). The errors show the spatial variation within the samples and the weighted mean represents the average mean of each radionuclide in all vegetables in each study area.

Table 4: Radioactivity concentration in vegetables of Ojo, Lagos

SAMPLES	^{40}K (Bqkg^{-1})	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})
E1	6078.93 ± 314.09	18.85 ± 2.33	27.29 ±1.62
E2	4873.07 ± 250.54	9.75 ± 1.23	3.81 ± 0.22
E3	7320.47 ± 378.06	26.14 ± 3.31	33.36 ± 1.98
E4	4927.90 ± 255.10	57.70 ± 6.19	43.65 ± 2.58
E5	4951.89 ± 255.50	35.73 ± 3.88	35.83 ± 2.11
E6	608.07 ± 32.05	13.04 ± 1.91	19.24 ± 1.16
WEIGHTED MEAN	4793.38 ± 247.55	26.87 ± 3.14	27.19 ± 1.61

The doses received by a person consuming aquatic food stuff depends on the radionuclide concentration in the food and the quantity taken [1]. The effective dose equivalent by ingestion of nuclides was calculated using Eq. 3.

$$\text{Ingested dose} = \text{Concentration of radionuclides} \times \text{Annual intake per year} \times \text{DCF}\,; \quad (3)$$

where DCF is the dose conversion factor and the annual intake of vegetables per year of an adult is 60 kg/y [4].

The mean annual effective dose values of Badagry, Ikorodu and Ojo were 1.42mSv/y, 2.06mSv/y and 2.23mSv/y, respectively, which were higher than the world mean value of 0.29mSv/y [4]. The annual collective effective dose equivalent was obtained using Eq. 4 [14].

$$S_e = H_i \times N\,(H)_i\,; \quad (4)$$

where S_e is the collective effective dose equivalent, H_i is the average annual effective dose equivalent and $N\,(H)_i$ is the number of individuals in the population of the study area. The populations of Badagry, Ikorodu and Ojo are 237,731, 527,971 and 609,173 [15], which translate to a collective dose equivalent of 0.34 x 10^3 manSv/y, 1.09 x 10^3 manSv/y and 1.36 x 10^3 manSv/y.

Excess Lifetime Cancer Risk (ELCR) is calculated using Eq. 5 below.

$$ELCR = AEDE \times DL \times RF\,; \quad (5)$$

where AEDE, DL and RF are the annual effective dose equivalent, duration of life and risk factor (S/v) of fatal cancer risk per Sievert for stochastic effects. ICRP 60 uses a value of 0.05 for the public [3]. A life time duration of 50 years is used. The calculated ELCR values are 0.36 x 10^{-3}, 0.52x 10^{-3} and 0.56 x 10^{-3} for Badagry, Ikorodu and Ojo, respectively which are higher than the world average value of 0.29 x 10^{-3}. This indicates that the possibility of developing cancer cases among residents cannot be neglected.

Conclusion

The method of gamma spectrometry has been used to determine the nuclide concentration in commonly consumed vegetable samples in Badagry, Ikorodu and Ojo. The mean effective dose was also determined to assess the implication on consumer health. High concentrations of ^{40}K in all samples are due to the constant use of inorganic (N:P:K) fertilizers by farmers which are deposited in the edible parts of plants and are reflected in the high values of effective dose from ingestion of terrestrial radioisotopes and ELCR. The mean annual effective dose equivalent values for consumption of these vegetables are higher than the world mean dose equivalent of 0.29mSv/y [4]. Data from this study can serve as a reference for further studies.

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