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RADIOLOGICAL HEALTH RISK ASSESSMENT OF VEGETABLES DRIED ALONG MAJOR HIGHWAYS IN NORTHWESTERN NIGERIA

Usman Musa Kankara, Rabiu Nasiru, *Nuraddeen Nasiru Garba, Aminu Ismaila, Abdullahi Muhammad Vatsa and Echeche Onuh

Department of Physics, Ahmadu Bello University, Zaria, Nigeria.

*Corresponding authors' email: nngarba@abu.edu.ng Phone: +2348034298444
ORCID: https://orcid.org/0000-0002-1620-4214

ABSTRACT

The ever presence of radionuclides in the environment made necessary the continuous assessment of health risks posed by these elements. Dried samples of five (5) commonly consumed vegetables were obtained from 4 different highway roads across the seven states of the North-Western geopolitical region of Nigeria and the concentrations of Naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were determined using NaI (Tl) gamma spectrometry. Health risk to humans due to the consumption of the radionuclides in the studied vegetables was assessed by estimating the daily intake of the radionuclides and cancer risks associated with the radionuclides. The mean annual effective dose for the four highways due to ingestion of radionuclides were found to be 184 μSv y^{-1}, 174 μSv y^{-1}, 197 μSv y^{-1} and 178 μSv y^{-1} for H1, H2, H3 and H4 respectively. The respective cancer risks factors for these highways were estimated as 9.2×10^{-6}, 8.7×10^{-6}, 9.8×10^{-6} and 8.9×10^{-6} all of which were lower than the world average of 4.5×10^{-3}respectively. The results further showed the associated health risk due to the ingestion of the samples is very low.

Keywords: Radionuclides, Gamma spectrometry, Daily intake, Annual effective dose, Cancer risk, Environment, NaI(TI), Risk factors, World average, Nigeria

INTRODUCTION

Natural radioactivity is always present in world's environmental media since its formation (Adedokun et al., 2019; Asaduzzaman et al., 2015; Kumari et al., 2015), and is found in every constituent of the environment; air, water, soil, food and in humans (Abojassim et al., 2016; Tettey-Larbi et al., 2013). Radionuclides that are found on Earth and existed since the formation of the Earth are known as primordial terrestrial radionuclides (Abdulkadir et al., 2021). The decay product of these radionuclides, which include 238U and 232Th series together with 40K, and cosmic rays forms the sources of natural radioactivity in the Earth environment (Kessaratikoon and Awaekechi, 2008). Natural radionuclides occur in soil and are incorporated metabolically into plants, and ultimately find their way into food crops and water (Kumari et al., 2015; Nyanda and Nkuba, 2017).These components may be enhanced by human activities like agricultural inputs, urbanization, use of fossil fuels, industrial activities, dumping of radioactive wastes, disposal of industrial effluents, etc. (Abojassim et al., 2016). Radiation exposure, however, varies from one location to another depending on factors such as the type of radionuclides present, local geology (Radhakrishna et al., 1993), climatic condition, soil type, industrial and agricultural activities (Adedokun et al., 2019).

Food is among the major sources of ingestion of radioactivity in humans (Adedokun et al., 2019; Jibiri et al., 2007), particularly all categories of vegetables. Vegetables are known to be of highly enriched in vitamins, and can serve as sources of antioxidants and fibre (Adedokun et al., 2019). Green leafy vegetables are very prone to external contamination during their growing season (Nyanda and Nkuba, 2017), fallout and post-harvest drying. It has been estimated that at least one-eighth of the mean annual effective dose due to natural sources is caused by the consumption of foodstuff which in turn depend upon the local geology of each region in the world (Hernandez et al., 2004). Over the years emphasis have been geared by the International Commission on Radiological Protection (ICRP) and World Health Organization (WHO) towards minimize the hazards caused by ionizing radiation from manmade or naturally occurring radioactive materials (Esen et al., 2013). In addition, due to the increasing awareness on radiation safety, protection and security, positive impact has been made in reducing radiation hazards and associated problems. Food safety is a major public concern worldwide (Gizaw, 2019). The increasing demands for food and food safety has drawn the attention of researchers to the risks associated with consumption of radiation-contaminated foodstuffs. According to the International Food Safety Authorities Network (WHO, 2011), plants used as food commonly have 40K, 232Th and 238U and their progenies (Tettey-Larbi et al., 2013).

In Nigeria, green leafy vegetables have widespread acceptance as a dietary constituent and generally forming a substantial portion of the diet, in the preparation of soups and stews in homes (Hart et al., 2005). Fresh okra is among the most important vegetable crops cultivated in Nigeria with the country being ranked as the 44th largest okra producing nation in the world (Agunsoye et al., 2020). Presently in Nigeria, okra production is about 2,060,280 tons produced on 1,480,386 hectares (Agunsoye et al., 2020). In Northern Nigeria Okra is often sliced and sun-dried before been grinded and later used in making soup. Other vegetables produce in mass quantity in Northern Nigeria are tomatoes and pepper. Because of the perishable nature of these vegetables and the lack of mechanized farming, local farmers in Northern Nigeria widely used open sun drying as the means of preservation.

Open sun drying of vegetables and agricultural products has been widely practiced in the world for ages and is by far the most common means of preservation of farm produce (Kankara et al., 2021). Though the drying technique differs in different locality and for different commodity, the customary technique of open sun drying involves spreading the material to be dried on a thin layer on ground/mats or plastic sheet and exposing it to sun and wind (And and Barrett, 2006). The process of drying vegetables and other foodstuffs locally by open sun drying and especially along the roadside may lead to the contamination of the dried items by heavy metals or airborne radioactive elements (Kankara et al., 2021). The aim of this research is to assess the radiological contamination on vegetables dried along major highways in Northern Nigeria.

MATERIALS AND METHOD

Sample Collection and Preparation

A total of 60 samples of 5 commonly consumed vegetables locally dried along the roadside were obtained from 4 different highway roads across the seven states of the North-western geopolitical region of Nigeria. The highways considered are Katsina - Kaduna, Zaria-Kano, Zamfara - Sokoto and Kaduna - Abuja. The samples were placed in polythene bags, tagged properly according to the highways and the type of vegetables, and later taken to the herbarium, Botany Department, Ahmadu Bello University, Zaria for identification as presented in Table 1.

Table 1: Sample specification

S/N	Sample code	Common Name	English Name	Botanical Name	Part used
1	TT	Tattasai	Bell Pepper	*Capsicum annuum*	Fruit
2	KK	Kuka	Baobab leaves	*Adansonia digitata*	Leaf
3	KB	Kubewa	Okra	*Abelmoschus esculentus*	Fruit
4	ZB	Zobo	Roselle	*Hibiscus sabdariffa*	Fruit
5	ZG	Zogale	Moringa	*Moringa oleifera*	Leaf

The samples were washed under running water to remove dirt, sand and insect (Adedokun et al., 2019) and then dried with blotting paper and filter paper at room temperature to remove surface water. The samples were broken into smaller pieces, oven dried at 55^0C and grinded into fine powder using a porcelain mortar and pestle. The resulting powder was kept in air tight polythene packet at room temperature for 30 days for the long-lived radionuclide parent to be in secular equilibrium with their short lived daughter in the ^{238}U and ^{232}Th decay series (Mahur et al., 2008) before being taken to the laboratory for radioactivity analysis.

Measurement of Gamma Activity

NaI (TI) scintillation detector, situated at the Center for Energy Research and Training (CERT) Ahmadu Bello University Zaria, was used for the gamma activity measurement. The detector has a 6cm thick lead shield, cadmium lined assembly with copper sheets and is coupled to a photomultiplier tube. The choice of this detector is due to its high efficiency (because of its density and high atomic number) and low resolving time of $2.5\,\mu s$. Energy and efficiency calibrations were carried out using two calibration sources of ^{137}Cs and ^{60}Co. The specific activity of ^{238}U and ^{232}Th were measured using property of secular equilibrium with their decay products such as transition lines of ^{214}Bi (1765 keV) and transition lines of ^{208} Tl (2614 keV) respectively. Potassium-40 was measured directly from the photo peak at 1460 keV. The measuring time for all samples under study was 8 hours.

The specific activity for each detected photo peak was calculated using the Equation 1 (Abojassim et al., 2016).

$$A = \frac{N - N_o}{I_\gamma \varepsilon m t} \qquad (1)$$

Where A is the specific activity of the radionuclide in the sample, N is the net counts of a given peak for a sample, N_o is the background count of the given peak, I_γ is the number of gamma photons per disintegration, ε is the detector efficiency at the specific gamma-ray energy, m is the measured mass of the sample, and t is the measuring time.

Daily Intake of Radionuclide

The estimated daily intake of the radionuclides was obtained using Equation 2 (Adedokun et al., 2019; Choi et al., 2008; Shanthi et al., 2010).

$$DI = A \times DCR \times F \qquad (2)$$

where A is the specific activity of the sample in mBq/kg, DCR is the daily consumption rate in kg and F is the number of days the vegetable is consumed in a week divided by 7 (days in a week).

Annual Effective Dose (AED)

Effective dose is a useful concept that enables the radiation doses from different radionuclides and from different types and sources of radioactivity to be added (Amin and Ahmed, 2013). The annual effective dose equivalent was obtained from the measured activity using Equation 3 (Adedokun et al., 2019).

$$\text{AED} = \sum_i^n A_i \times DCF_i \times DCR_v \times 365 \qquad (3)$$

The vegetable consumption rate used in this study was 65 g/day for an adult person (Adedokun et al., 2019; Osagie and Eka, 1998) and the DCF of 0.28µSv/Bq, 0.23 µSv/Bq and 0.0062 µSv/Bq for ^{238}U, ^{232}Th and ^{40}K respectively (UNSCEAR, 2000) was used.

Cancer risk

According to (ICRP, 1996) practice, the risk incurred by a population assuming a linear dose-effect relationship without any threshold can be estimated from Equation 4.

$$Risk = Dose \times risk\ factor \qquad (4)$$

The risk factor as obtained from (IAEA, 1989) is 0.05 Sv^{-1}. The risk factor states the probability of a person dying of cancer increases by 5% for a total dose of 1 Sv received during his lifetime (Amin and Ahmed, 2013).

RESULTS AND DISCUSSION

Radionuclides Concentration in Dried Vegetables

The activity concentration (Bq/kg) of the naturally occurring radioactive materials (^{238}U/^{226}Ra, ^{232}Th and ^{40}K) in the vegetable samples is presented in Fig. 1. The radioactivity concentrations ranged from 2.11– 2.80 Bq/kg, 1.66 – 2.27 Bq/kg and 82.06–107.11 Bq/kg for ^{238}U, ^{232}Th and ^{40}K respectively. As shown in Fig. 1, in all the vegetable samples, activity levels of ^{238}U and ^{232}Th were found to follow the order Okro > Bell pepper > Roselle > Moringa > Baobab leaves. As expected, the specific activity of ^{40}K was notably higher than that of ^{232}Th and ^{226}Ra. High levels of ^{40}K were recorded in Baobab leaves followed by Moringa and Okra all from the same location. The lowest activities were found in Roselle and Bell pepper indicating that these two vegetables are poor accumulators of ^{40}K. The high specific activity of ^{40}K might be due to its high relative abundance and the use of fertilizer by local farmers (Hassan et al., 2021; Kumari et al., 2015). The high concentration may also be due to the environmental conditions and the geo-morphology of the study areas.

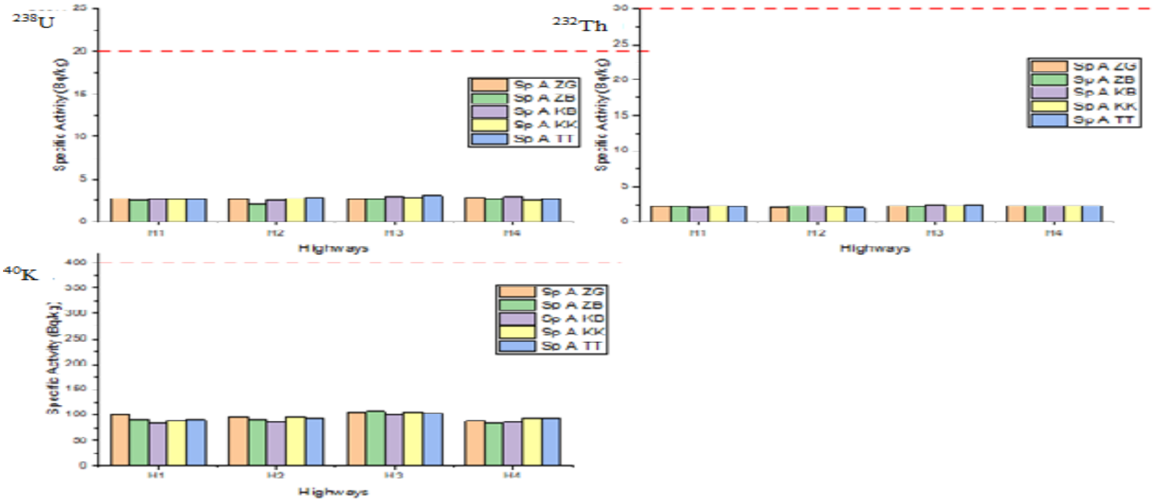

Figure 1: Specific activity of ^{238}U, ^{232}Th and ^{40}K from the vegetable samples dried along highways in Northwestern Nigeria.

Estimated Daily Intake of Radionuclides

Table 2 shows the number of radionuclides ingested daily due to the selected vegetables. The highest values of naturally occurring radionuclides ingested are from the consumption of baobab leaves, followed by Okra, while values from Roselle are the least.

Table 2: Daily intake of naturally occurring radionuclides from leafy vegetables

Vegetables	Activity Concentration (mBq/day)			
	U^{238}	Th^{232}	K^{40}	Total
TT	390	290	2360	3050
KK	370	300	14450	15130
KB	380	230	13340	14030
ZB	50	50	2310	2420
ZG	60	50	2390	2500

Comparing the estimated daily intake of radionuclides with other similar studies as shown in Table 3. The average daily intake of ^{238}U, ^{232}Th, and ^{40}K from leafy vegetables from this study were respectively found to be about 1.125 times, 5 times and 1.141times higher than the values reported for leafy vegetables by (Adedokun et al., 2019).

Table 3: Comparison of daily intake of naturally occurring radionuclides from present study with other similar studies

Vegetables	Activity Conc. mBq/kg				Reference
	^{238}U	^{232}Th	^{40}K	Total (mBq/kg)	
Lagos spinach	54.700	10.66	2360.53	2425.89	(Adedokun et al., 2019)
Indian spinach	0.80	-	1360.00	-	Shanthi *et al.,* 2010
Leafy vegetables	240.93	40.31	8814.80	9095.11	(Adedokun et al., 2019)
Tanzanian vegetables	2.09	1.55	168.80	172.44	(Nyanda and Nkuba, 2017)
Leafy vegetables	270.00	193.33	10060	10523.33	Present study

Annual Effective Dose (AED)

The effective dose due to the naturally occurring radionuclides is presented in Table 4. As suggested by UNSCEAR, the total exposure per person due to ingestion of terrestrial radionuclides should be less or equal to 290 μSvy^{-1}, of which 170 μSvy^{-1} is from potassium (^{40}K) and 120 μSvy^{-1} is from thorium (^{232}Th) and uranium series (^{238}U). The annual effective ingestion doses due to intake of ^{238}U range from 13.64μSvy^{-1} to 18.11 μSvy^{-1}. The dose received from ^{232}Th due to consumption of vegetables samples varied from 1.17 μSvy^{-1} to 10.28 μSvy^{-1}. For ^{40}K the effective doses varied from 12.13 μSvy^{-1} to 18.01 μSvy^{-1}.

In obtaining effective dose estimation values for an individual resulting from the consumption of an agricultural food product, it is significant to consider not only the availability and nature of the food source but also the study environment and population habits (Hassan et al., 2021; Jibiri et al., 2007). In regard to the present study, in habitants of Northern Nigeria typically prepare "Zobo", a traditional drink (https://en.wikipedia.org/wiki/Zobo) as supplement for lunch and "Miyan Kuka" (https://en.wikipedia.org/wiki/miyan kuka) for dinner, both types of food being based primarily prepared from Roselle and Baobab leaves respectively.

The study of (Jibiri et al., 2007) conducted in Jos Nigeria found that the annual effective dose from the ingestion of NORMs was 2.38mSv/yr which is significantly higher than the average value reported in the present study. Also a study by (Shanthi et al., 2010) in India reported an annual effective dose due to ingestion of ^{238}U, ^{232}Th and ^{40}K to be 1.73mSv/yr. All these doses were found to be significantly lower than the threshold values as reported by UNSCEAR.

Table 4: Annual effective dose due to individual radionuclides and their total dose of ingestion to the public

Highways	Radionuclides (μSvy^{-1})			
	^{238}U	^{232}Th	^{40}K	Total
Highway 1				
TT	15.98	5.73	15.42	37.14
KK	15.76	6.83	14.82	37.42
KB	18.11	10.28	13.17	41.56
ZG	17.21	6.37	14.58	38.17
ZB	13.64	1.37	15.10	30.08
Highway 2				
TT	13.86	4.90	13.96	32.73
KK	14.87	6.00	14.33	35.21
KB	15.65	1.17	13.12	29.94
ZG	17.44	6.09	15.57	38.21
ZB	15.54	9.98	13.14	38.44
Highway 3				
TT	16.77	7.56	15.39	39.73
KK	15.09	9.89	18.01	43.00
KB	16.21	7.84	15.64	39.70
ZG	16.54	6.09	15.57	38.21
ZB	15.54	5.35	15.96	36.76
Highway 4				
TT	14.87	6.55	13.46	37.14
KK	13.75	7.10	14.16	35.02
KB	15.20	6.55	13.36	35.13
ZG	14.42	6.64	12.13	33.20
ZB	15.31	9.98	13.14	38.44

However, the total annual effective dose and daily intake of radionuclides calculated in this work might be overestimated. This is because; the vegetable consumption rate was not specifically drawn from the study area. The consumption rate used is the representative of the whole country (Nigeria) and assumed that the vegetables are available throughout the year, while in the study area, during the rainy season, vegetables are usually consumed daily to several times a week, and during the dry season frequency of consumption spans from once a week to several times a week.

Cancer Risk

The cumulative annual effective dose for the four highways due to ingestion of NORMs was found to be 184 μSv y-1, 174 μSv y-1, 197 μSv y-1 and 178 μSv y-1 for H1, H2, H3 and H4 respectively. The respective cancer risks for these highways were estimated to be 9.2 x 10^{-6}, 8.7 x 10^{-6}, 9.8 x 10^{-6} and 8.9 x 10^{-6}. These values showed that at worst the percentage increase for cancer risk is one out 10,000, which is a very low risk value.

CONCLUSION

This study assessed the radiological contamination on vegetables dried along major highways in Northern Nigeria. The mean activity concentration was found to be 2.84 and 2.56 Bq/kg for ^{238}U, 2.17 and 2.02 Bq/kg for ^{232}Th and 108.1 Bq/kg for ^{40}K. Enhanced activity from ^{40}K was due to the application of fertilizer by the local farmers while the concentration of ^{238}U and ^{232}Th were all within safety limits. The concentration of these radionuclides was used to estimate the daily intake, annual effective dose equivalent and cancer risk. The highest total daily intake and annual effective dose were recorded in Baobab leave with a value of 15.13 Bq/day and 43.00 μSvy^{-1} respectively. The associated cancer risk was found to be below the world average value of 4.5×10^{-3} indicating that consumption of these vegetables posed no significant radiological health implication.

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