MPRI-JNSA | INTERNATIONAL JOURNAL OF NATURE AND SCIENCE ADVANCE RES.
VOL. 1 NO. 1 JUN-2022

A STUDY OF NATURAL RADIONUCLIDES IN FREQUENTLY CONSUMED FOODSTUFFS IN ODE-IRELE, ONDO STATE, NIGERIA

ABIMBOLA I. ODUDU[1], OLUWAKEMI A. OYEBANJO [2], DAMILARE S. ADEPEHIN[3]* AND MOROMOKE O. ADELAYI[1]

[1]*Department of Physics, Adeyemi College of Education, Ondo, Ondo State, Nigeria.*
[2]*Department of Physics, Tai Solarin University of Education, Ijagun, Ogun State, Nigeria.*
[3]*Department of Physics, Federal University of Health Sciences, Otukpo, Benue State, Nigeria.*

Abstract

Identifying the natural radionuclides in frequently consumed foodstuffs has attracted research interests from many researchers. Here in, we reported the quantities of natural radionuclides in frequently consumed foodstuffs in the community of Ode-Irele in Ondo State, Nigeria. Data obtained for this study were analyzed using the gamma ray spectrometer. Careful examination of six (6) different foodstuffs obtained at random for four (4) different times from the local market of the community was done and all of them were discovered to be rich in Th-232, U-238 and K-40. The activity concentrations of the foodstuffs ranged from 58.21±5.93 Bqkg^{-1} to 1.91±0.41 Bqkg^{-1} with mean value of 11.74±1.22 Bqkg^{-1} for Th-232, 41.82±9.48 Bqkg^{-1} to 3.12±0.39 Bqkg^{-1} with mean value of 12.38±2.27 Bqkg^{-1} for U-238 and 1854.12±126.83 Bqkg^{-1} to 134.72±12.62 Bqkg^{-1} with mean value of 280.22±30.08 Bqkg^{-1} for K-40. The minimum and maximum dose rates discovered from the foodstuffs are respectively 8.03nGyh^{-1} and 132.35nGyh^{-1}. The mean value of all absorbed dose rate (28.99nGyh^{-1}) was found to be less than the world average limit of 55.0nGyh^{-1}. Comparison of

KEYWORDS:
Concentration, Dose, Gamma spectrometer, Radionuclides, activity

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

the annual committed effective doses determined from the mean of the natural radionuclides (0.155mSvy^{-1}) in the foodstuffs to the global recommended limit (1mSvy^{-1}), showed that the frequently consumed foodstuffs by the people in the community posed no important radiation related risk to them.

INTRODUCTION

Food is any consumable substance that is rich in nutrients which satisfies hunger, facilitates growth and provides energy (Moore, 1957). The definition of food has, from all indications pointed to the fact that the nutritional values, such as the percentage of proteins, carbohydrates, vitamins and fats were considered to give a clearer picture of what foods should contain. Beyond the constituent nutrients from proteins, carbohydrates, vitamins, fats and the likes, percentage of naturally occurring radionuclides in foodstuffs is one of the major factors to be consider before consumption (Pearson et al., 2016). The work of Pearson et al. (2016) revealed that naturally occurring radionuclides such as ^{232}Th, ^{238}U and ^{40}K have significant effects on the foodstuffs we consume when taken in very high quantity. Consumption of ^{238}U for instance, can result to serious cancer of the lung and damage of the kidney cells (Abojassim et al., 2014). According to Abojassim (2014) the damage done by ^{238}U is traceable to decays of uranium to emit alpha particles ($^{4}_{2}\alpha$) which are dangerous to human's health both externally and internally. ^{232}Th is a naturally occurring radioactive element present in rocks, soil and some of the foodstuffs we consume (Jibiri and Abiodun, (2012). Findings from Jibiri and Abiodun (2012) made it known that when too much of ^{232}Th is consumed, it can result to cancer of the lung and bones. The isotope of potassium (^{40}K) is considered to be harmless to human based on its very small content in the volume of potassium which was discovered to be naturally present. It constitutes just 0.012% of the sum total of the isotopes of potassium. Despite the harmless nature of this isotope, literatures have it recorded that the ^{40}K decays by emitting beta particles with no indication of gamma elements (Khan et al., 2020). Consumption of ^{40}K in large quantities can snowball into damage of cells which happens as a result of ionization emanating from radioactive disintegration (Sowole and Amodu, 2019). The distribution of radionuclides in different parts of the plant from which the foodstuffs we consume were obtained depends on the environmental contributions to the geological, geophysical and geographical attributes (Chiozzi *et al*., 2000). The earth contains different levels of radioactivity

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

due to chain delay of naturally occurring radioactive materials (NORMs) (^{238}U, ^{232}Th and ^{40}K). Some of the foodstuffs we consume contain very small amount of natural radionuclides (Khan et al., 2020). Brazil nuts and Bananas for instance, contain some naturally occurring radionuclides, such as potassium, radium and carbon (Zagatto et al., 2008). The work of Zagatto et al. (2008) showed that products of the radioactive disintegration of the aforementioned elements are present in most of the foods we eat but because of the negligible contents of these radiations in foods, they are believed not to be capable of posing radiations related risks on consumers. A more accurate way of measuring natural radionuclides in locally consumed foodstuffs especially in areas where radioactive disasters recently happened is to examine the water, food items and the air people breathe in around the environment where the disaster happened (Murakami and Oki, 2014). Just as the purchased foodstuffs can harbor a lot of natural radionuclides, food crops and vegetables grown locally can as well carry a lot of NORMs due to the radioactive nature of the soil and the environment (Murakami and Oki, 2014). Foodstuffs consumed locally are either purchased from the community market or grown in the locality for subsistence reason (McMahon et al., 2015). Findings from literatures show that the accumulation of these radioactive materials in foodstuffs, even when the contents are small put consumers under long lasting radioactive risk (Tawalbeh et al., 2012). Naturally occurring radioactive materials (NORMs) which are taken in by the foodstuffs we eat constitute a large percentage of radiations present in the body system: some of which are present in doses donated to different organs which remained affected over a very long period of time (Fathabadi et al., 2017). Fathabadi et al. (2017) opined that the concentration of NORMs may be high in locally produced foodstuffs because their cultivation may be from areas where concentration of natural radionuclides are very high both in the atmosphere and the soil. The foodstuffs consumed by people of an area have different effects from the same foodstuffs in another area (El-Gamal et al., 2019). The peculiarity of the NORMs in the environment and the soil of a particular area determine the extent to which people will be affected from the consumption of the local foodstuffs (El-Gamal et al., 2019). The consumption of NORMs can also result from a complete food chain in which radionuclides absorbed by plants are taken to the leaves which are in turns eaten by animals we feed on. These animals after harboring some quantities of harmful radionuclides in their organs become very harmful to human's health when eaten (Fathabadi et al., 2017). This explains the reason foodstuffs should be

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

well assessed before allowing people to purchase for consumption (Fathabadi et al., 2017). Supplementation of foodstuffs in a local community with radiation free items can also serve as a better way to improve people's health especially in communities where NORMs have been released into the environment due to some unplanned incidents (McMahon et al., 2015). Food items produced in local communities are most times rich in naturally occurring radionuclides due to the general belief that locally made foodstuffs are the best for human consumption (Yablokov et al., 2009). The Chernobyl incident in large parts of Ukraine released a lot of natural radionuclides into the atmosphere (McMahon et al., 2015). The focus of the work of McMahon et al. (2015) was on providing foodstuffs to supplement the contaminated consistently consumed foodstuffs in Narodichi, a rural area of Ukraine; it later became evident that reduction in the supplement led to increase in some NORMs related diseases like anemia, cough, cold, bronchitis and cancer. These disease reduced to the bearest minimum when supplementation was increased. It is imperative for organizations responsible for food control to educate people of the harmful effects of consuming radiation-rich foodstuffs (McMahon et al., 2015). Adoption of food supplementation will reduce the concentration of NORMs in local areas where people are susceptible to radiation related diseases (McMahon et al., 2015). NORMs such as U-238, Th-232 and K-40 are able to contaminate our foodstuffs due to natural disintegration; as the elements disintegrate to half their original atoms for a period as long as when the earth has been in existence (Merli et al., 2015). Merli et al. (2015) established that some of the products obtained from animals may be rich in NORMs. Pork, Chicken, Eggs, Beef and Milk purchased from the market should be well assessed by relevant authorities to be sure that they are NORMs free because there exist various alternatives of different qualities to these product everywhere (Cengiz, 2020). As it is known that almost every household in every community consume one or more of these products from animals; we therefore need to be well informed of the aftermath effects of their consumptions if there's any (Cengiz, 2020). Cancers of the lung, liver, kidney, breast, blood and bones do not just happen overnight in patients diagnosed with the diseases (Sowole and Amodu, 2019). It must have been situations resulting from unnoticed accumulation of radiations in the body over a long period of time (Sowole and Amodu, 2019). In summary, natural radionuclides get into our foods through the following means:

(i) **Roots Uptake:** Soil has a very high percentage of natural radionuclides. This is why plants, during conduction take water containing natural

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

radionuclides from the soil through the roots to other parts like the stem and leaves which are sometimes consumed by human (Paatero 1 and Paatero 2, (2021).

(ii) **Crops Deposition**: The air we breathe in is not totally free from natural radionuclides as there are many activities such as pollution (contamination of the environment with harmful substances) resulting from burning of fossil fuel which makes the air impure. Some of these NORMs can settle on crops and if the content is much, it can pose radiation risk on consumers (Adedokun et al., 2019).

(iii) **Biological Accumulation**: Naturally occurring radioactive materials get accumulated in some animals that feed on plants, roots of plants, soil and water which contains radioactive elements. Whenever some animals ingest NORMs in plants and humans also feed on such animals, it can put the lives of such persons at risk, especially when the content keeps increasing over a long period of time. Fishes in water may consume water which contains NORMs which can find their ways into human bodies when consumed (Zehringer, 2016).

Zehringer (2016) stressed that radiological activities in foods are usually guided and monitored by certain organizations saddled with the responsibility of the maintenance of food security in different parts of the country in order to prevent the public from consuming foods and any other substances presumed to be capable of posing radiological abnormalities to people. The National Agency for Food and Drug Administration and Control (NAFDAC) in Nigeria and the Food and Drug Administration (FDA) in the United States, are some of the agencies that test foods and make sure they are free from contaminants such as radiations, before allowing producers release them to the public (Lordford et al., 2013). Lai (2009) emphasized that food security is one of the important goals of the United Nations Food and Agriculture Organization. It speaks volume of social and economic access to safe, nutritious and sufficient food for every living being at all times in order to meet their dietary and food preferences for an active and healthy living (Lai, 2009). Most of the researches done on foodstuffs consumed for the past two decades have overtimes focused only on the nutritional constituents but little or no attentions have been on the quantity of radionuclides (naturally occurring radioactive material, NORMs) inherent in such foodstuffs consumed particularly in local communities like the study area. This research work is aimed at determining

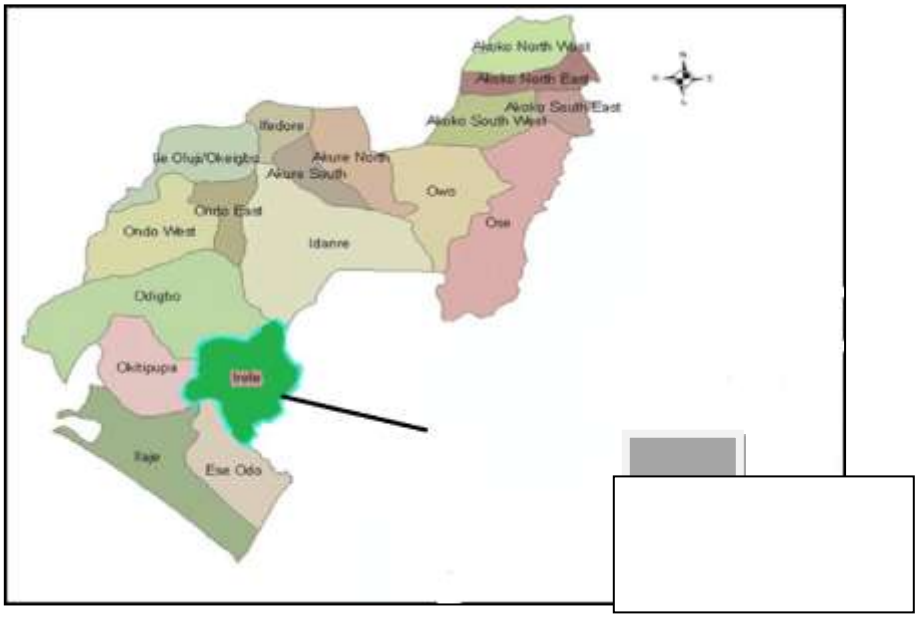
EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

the activity concentrations of twenty four food samples purchase from different selling points for four different days in the local market of the study area through gamma ray spectrometry, determining the minimum and maximum dose rates of the foodstuffs, relating the mean dose rates to the world average limit and comparing the annual committed effective doses obtained from the average of the natural radionuclides to the global recommended limit. This research findings is expected to assist food regulatory bodies put a measure to determine the percentage of natural radionuclides in foodstuffs before allowing wholesalers sell to retailers who sell in small quantities to the consumers. This will help to reduce radiation related risks which consumers are exposed to, from the consumption of unregulated foodstuffs. In doing this, cells damaging diseases like cancers of the lung, liver, kidney and bones will be reduced.

STUDY AREA

The community of Ode-Irele is bounded by latitudes $6°29'18°N$ and longitudes $4°52'12.78°E$. The Ode-Irele community located in Ondo State, southwest of Nigeria in West Africa has fertile soil type which supports the major occupation of farming in the community. This community is generally characterized by two major tropical seasons: the dry and rainy seasons. Study shows that some naturally occurring radioactive materials (NORMs) exist in the soil of the community but a considerably high percentage of natural radionuclides can be found in Gbeleju-Loda in the suburb of Ode-Irele community. The work done on NORMs by (Ilori *et al*. 2018) revealed that a high percentage of NORMs are noticed in the environment due to the effects from the Bitumen. Other areas of the community have soil with very low NORMs and this is evident in the nutritious and harmless farm produce from the community. This community is the administrative headquarter of the Irele Local Government Area. It is located 10 kilometers by road west of the town of Okitipupa according to Omosule (2011). The occupants of this town were the Ikales with the same language and culture. One major source of income of the people in this community for the past ten decades has been majorly farming and partly fishing because of the limited numbers of rivers and most of the food items like 'garri', corn, cassava flour (pupuru), plantain flour, and palm oil consumed by the people in the community are locally produced. Figure 1 below shows the map of Ondo state from which the community of Ode-Irele is identified.

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]



Ode-Irele

Figure 1: Map of Ondo state showing Irele town.

MATERIALS AND METHODS

Sample collection and preparation

Twenty-four food samples used for this research work were obtained from the local market of Ode-Irele community. This was done by obtaining six different food samples at random from different traders for four different market days. The targeted food samples used for this research were cassava flour (pupuru), beans, corn, garri, plantain flour and rice. Some of the samples which were not fully in their powdered forms like the rice, beans, corn and garri were pulverized and sieved to get them in powder form and given codes as shown in table 1 accordingly. The samples were weighed 165g and sealed in small plastic containers and then stored for four (4) weeks before counting to allow for secular equilibrium to be reached. Gamma ray spectrometry analysis was carried out in order to determine the Activity Concentration (A), Gamma Dose Rate (GDR) and the Annual Committed Effective Dose (ACED).

Gamma Spectrometry analysis

A gamma ray scintillation spectrometry system was used for the measurements of the natural radionuclides content of the soil samples. The Gamma ray spectrometer used for this research is the Canberra 7.6cm x 7.6 cm NaI (Tl)

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

detector (Model No. 802-series). The spectroscopic system is connected to Canberra series 10 plus Multichannel Analyses (MCA) (Model No. 1104) through a preamplifier base, which enables data acquisition, storage and display of the acquired spectra. The resolution of the detector is about 8% at 0.662 MeV 137Cs which is capable of distinguishing the gamma-ray energies used for the measurements.

The efficiency calibration of the system was done using reference soil sample prepared from Rocket dyne Laboratories, California, USA. The reference soil sample is traceable to a mixed standard gamma source (No. 48722-356) by Analytics Inc., Atlanta, Georgia. The net count under each photo peak was related to the specific activity of the radionuclide using the calibration factors obtained for ^{238}U, ^{228}Th and ^{40}K by the following relation (Tzortzis *et al.,* 2003):

$$A_{Ei} = \frac{N_{Ei}}{M_E \times t \times Y \times M_S} \qquad (1)$$

Where A_{Ei} is the specific activities in Bq/kg of a nuclide *i.* N_{Ei} is for peak at energy *E,*M_E is the detection efficiency at energy, *t* is the counting of life time, *Y* is the gamma ray yield per disintegration of specific nuclide for transition at energy *E,*M_S is Mass in kg of the measured sample.

Each sample was put on the shielded Nal (TI) detector and counted for an accumulating period of 36,000 seconds (10 hours) and correction was made for background radiation level. The determination of ^{238}U and ^{232}Th were based on the measurements of photo-peaks from 214Bi (1.76 MeV) and 208TI (2.62 MeV) respectively. The primary decay of ^{40}K (1.46 MeV) was measured directly just like the work of Chiozzi et al. (2000). The lower limits of detection (LLD) of ^{238}U, ^{232}Th and ^{40}K were determined from the background radiation. The LLD obtained were 4.0, 4.8 and 17.0 $Bqkg^{-1}$ for ^{238}U, ^{228}Th and ^{40}K respectively (IAEA, 1989).

Features of the Gamma-Ray spectrometer

A gamma-ray spectrometer is used in measuring super high frequencies of radioactive materials emitted during mega-joules energy scenarios such as high explosion. It compares the intensity of the gamma ray to the photon energy.

The following are the parts of the Gamma-ray spectrometers;

1.i Detectors

These are made up of the two major types.

The scintillation sensitive detector which is capable of:

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

-responding ionizing radiations incident on the surface

-being applied as one crystal of NaI that accept impurity such as thallium (Tl) to become NaI(Tl)

-The resulting NaI(Tl) glows improve into sensitive electric signal by the process of photoelectricity.

- The photoelectric signal can thereafter be converted detectable signals by a computer

ii. The semiconductor sensitive detector –This works like the radiation sensitive detector- It helps in the:

- conversion of γ-ray small pulse
- forbidden gap exists between the conduction band and conduction band
- hitting the semiconductor with γ –rays will promote electron from valence band to the conduction band
- conductivity changes and signal can be produced. Example is the doping of pure germanium with lithium to become Ge(Li)

2. Electronics Processor

This part of Gamma-ray spectrometer (GRS) process the signals detected into a more friendly data that can be analyzed. Example is sorting of pulse

3. Amplifier

This read out data for audibility

Generally, Gamma-Ray spectrometer are useful in the following areas;

- Structural analyses of nuclear events
- Nuclear changes from one form to another
- Analysis of nuclear reactions
- Researches involving space. Example is the detection of water on different planets
- Analyses of elements and isotopes
- GRS provide raw data on the categorization and the availability of chemical elements.

EDITOR-IN-CHIEF

Prof. E. McLenna [Austrilia]

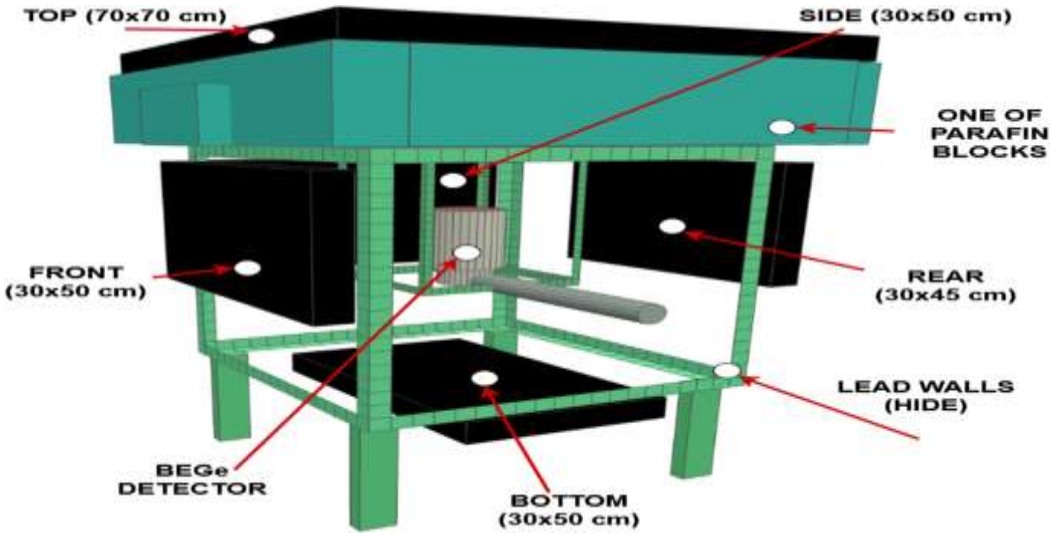


Figure 2: Features of the Gamma-Ray Spectrometer (Jodlowski et al., 2016)

Activity Concentration

The activity concentration is the determination of the standard concentration termed to be effective in the measurement of an identified species in physically combined substances (mixtures) (Adeleye et al., 2020). The chemical ability of the species is determined solely by the activity of the solution (Tzortzis *et al.,* 2003). The activity concentration is measured in Becquerel per Kilogram (BgK^{-1}).

Absorbed Dose Rate (ADR)

The dose rate refers to the intensity of the radionuclides stored in every parts of the tissue situated at every location of the body (Inoue et al., 2020). Inoue at al. (2020) emphasized that the ADR is the basis upon which damages done to the tissues or organ of humans can be estimated. This refers to the energy absorbed from radiation per unit mass of a tissue or an organ (Joel et al., 2020). It is expressed in Joules per kilogram (JKg^{-1}). Joules per Kilogram is also known as Gray (Gy). 1 JKg^{-1} = 1Gy and when a number (n) is given per Gray, we can write that 1n JKg^{-1} = 1nGy (UNSCEAR, 1993).

The absorbed dose rate is therefore, the energy absorbed (RE) per unit tissue or organ per unit time.

$$\text{ADR} = \frac{Radiation\ Energy\ (RE)}{Mass\ of\ tissue/organ\ (M)\ x\ time(T)} \qquad (2)$$

Investigation of the dose rate can be obtained through calculating the variation of activity concentrations of the primordial radionuclides in the soil as well as the

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

consequent variability of absorbed dose rate. In air, gamma dose rate is measured at one meter above the ground level and the formula to calculate it is given in equation 2 (UNSCEAR, 2000)

$$ADR(\frac{nGy}{h}) = 0.604A_{Th} + 0.462A_{Ra} + 0.042A_K \quad (3)$$

D = Absorbed dose rate (nGy/h), A_{Th}, A_{Ra} and A_K were activity concentrations of Th-232, U-238 and K-40 ($Bqkg^{-1}$) respectively.

Annual Committed Effective Dose

NORMs ingested by human decreases gradually over time by disintegration through natural means (Nicolov et al., 2020). The ingested radiations are thereafter given out through urine and feaces (body metabolism). The Committed Effective Dose (CED) is the NORMs dose which will be ingested for a determined period of 50 years after ingestion is taken just for the first calendar year (Chandrashekara et al., 2016). This is being utilized as the standard for estimating the effects of internal vulnerability to NORMs by what we consume. The annual committed effective dose (ACED) is the estimated outdoor conversion coefficient of the measurement of the concentrations from Th-232, U-238 and K-40. According to (Lordford *et al*. 2013), the ACED can be determined using equation (3) below.

$$ACED = A_{Ei}\ x\ DCF\ x\ CR \quad (4)$$

Where ACED = annual committed effective dose, A_C = activity concentration of the radionuclides, DCF = dose conversion factor for ingestion of natural radionuclides and CR = consumption rate of intake of the radionuclides from the foodstuffs. The ACED is expressed in Sievert (Sv) or in millisievert (mSv)

$$\text{ACED} = \frac{CED}{Number\ of\ years} \text{ in } svyr^{-1} \text{ or } msvyr^{-1} \quad (5)$$

RESULTS

Activity concentrations in the foodstuff samples

The activity concentration of samples G1, G2, G3 and G4 were discovered to be the highest when Th-232, U-238 and K-40 were compared. The activity concentration was discovered to be the highest in G1 for all the considered NORMs. The work of Orosun et al. (2018) revealed that high activity concentration can be attributed to the very high contents of the NORMs in the soil from which the food samples were harvested. The P2, R3 and R4 recorded the lowest activity concentration. This can sometimes be attributed to low percentage of NORMs in the ground from which the samples were harvested. Table 1 below shows the activity concentration for all the twenty four (24) food samples.

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

Table 1: Activity concentration (Ac) of Th-232, U-238 and K-40 for the samples.

Market Day	Sample Name	Sample Code	Th-232 ($Bqkg^{-1}$)	U-238 ($Bqkg^{-1}$)	K-40 ($Bqkg^{-1}$)
1	beans	B1	4.06±0.48	17.46±3.18	257.72±20.07
	Cassava flour (pupuru)	PU1	2.63±0.33	12.75±2.75	205.48±16.66
	Corn	C1	3.47±0.43	3.95±0.88	206.37±16.38
	Garri	G1	58.21±5.93	41.82±9.48	1854.12±126.83
	Plantain flour	PF1	4.15±0.53	BDL	261.94±20.86
	Rice	R1	2.55±0.32	BDL	154.63±13.10
2	Beans	B2	4.01±0.39	16.30±3.55	257.72±20.11
	Cassava flour (pupuru)	PU2	1.91±0.41	12.91±2.44	201.38±14.65
	Corn	C2	3.23±0.43	3.75±0.99	208.47±15.36
	Garri	G2	49.02±5.02	40.80±9.01	785.22±78.11
	Plantain flour	PF2	5.15±0.43	4.15±0.62	249.94±12.21
	Rice	R2	2.90±0.29	BDL	164.25±12.21
3	Beans	B3	4.02±0.48	17.01±2.49	246.68±18.11
	Cassava flour (pupuru)	PU3	2.43±0.11	12.01±2.11	201.34±14.24
	Corn	C3	3.13±0.23	3.54±0.54	202.42±14.48
	Garri	G3	54.26±6.01	39.47±8.98	902.12±89.68
	Plantain flour	PF3	4.25±0.49	BDL	230.64±19.98
	Rice	R3	2.60±0.32	3.47±0.43	134.72±12.62
4	Beans	B4	4.01±0.28	16.55±2.49	232.67±19.89
	Cassava flour (pupuru)	PU4	2.63±0.21	12.62±2.44	203.11±15.02
	Corn	C4	3.13±0.25	3.62±0.61	205.72±14.98
	Garri	G4	52.25±5.20	38.84±0.56	1096.23±92.45
	Plantain flour	PF4	4.95±0.45	4.02±0.58	252.54±21.21
	Rice	R4	2.72±0.25	3.12±0.39	163.28±12.10
	Average ± S.D		11.74 ± 1.22	12.38 ± 2.27	280.22 ± 30.08

BDL: Below Detection Limit, $Bqkg^{-1}$: Becquerel per Kilogram

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

In order to get a clearer picture of the activity concentration of all the foodstuffs, the daily average activity concentration with standard deviation was determined. The deviation revealed the highest and the lowest values of the (Ac) that can be obtained. Table 2 shows the daily average activity concentration

Table 2: Daily Average Activity Concentration

Days 1	**Th-232(Bqkg^{-1})±1.34**	**U-238(Bqkg^{-1}) ±2.72**	**K-40(Bqkg^{-1})±35.65**
	12.51	12.66	490.05
Day 2	Th-232(Bqkg^{-1})±1.16	U-238(Bqkg^{-1})±2.77	K-40(Bqkg^{-1})±25.44
	11.04	12.99	311.16
Day 3	Th-232(Bqkg^{-1})±1.27	U-238(Bqkg^{-1})±2.43	K-40(Bqkg^{-1})±28.19
	11.78	12.58	319.65
Day 4	Th-232(Bqkg^{-1})±1.11	U-238(Bqkg^{-1})±1.18	K-40(Bqkg^{-1})±29.28
	11.62	13.13	358.93

Determination of Absorbed Dose Rate

The absorbed dose rate was discovered to be the highest in G-food samples and lowest in R-food samples. This can be due to the high percentage of three naturally occurring radioactive materials (NORMs) considered in this study. It may also be attributed to the high content of the NORMs in soil from which the G-samples were harvested. Low dose rate in R-samples may be attributed to the low activity concentration in the samples. Table 3 shows the absorbed dose rate for all twenty four (24) food samples and Table 4 shows the summary of the absorbed dose rate in similar samples for all the four (4) days.

Table 3: Absorbed Dose Rate for the Samples

Market Day		Sample Name	Absorbed Dose Rate (nGyh^{-1})
1		Beans	21.33
		Cassava flour (pupuru)	16.11
		Corn	12.58
		Garri	132.35
		Plantain flour	13.51
		Rice	8.03

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

2		Beans	20.77
		Cassava flour (pupuru)	15.57
		Corn	12.44
		Garri	81.44
		Plantain flour	15.52
		Rice	8.64
3		Beans	26.84
		Cassava flour (pupuru)	15.48
		Corn	12.03
		Garri	88.90
		Plantain flour	12.26
		Rice	13.03
4		Beans	19.84
		Cassava flour (pupuru)	15.95
		Corn	12.20
		Garri	95.53
		Plantain flour	15.46
		Rice	9.94
		worldwide mean value	55.0

Table 4: Summary of Absorbed Dose Rate in Similar Food Samples

Days	ADR BSample ($nGyh^{-1}$)	ADR PUSample ($nGyh^{-1}$)	ADR CSample ($nGyh^{-1}$)	ADR GSample ($nGyh^{-1}$)	ADR PFSample ($nGyh^{-1}$)	ADR RSample ($nGyh^{-1}$)
1	21.33	16.11	12.58	132.35	13.51	8.03
2	20.77	15.57	12.44	81.44	15.52	8.64
3	26.84	15.48	12.03	88.90	12.26	13.03
4	19.84	15.95	12.20	95.53	15.46	9.94

Table 5: Annual Committed Effective Dose for the Samples

Sample Name		Annual Committed Effective Dose ($mSvy^{-1}$)		
		Th-232	**U-238**	**K-40**

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

1	Beans	0.056	0.046	0.096
	Cassava flour (pupuru)	0.073	0.067	0.154
	Corn	0.016	0.004	0.025
	Garri	1.349	0.185	1.158
	Plantain flour	0.019	-	0.033
	Rice	0.047	-	0.077
2	Beans	0.056	0.043	0.094
	Cassava flour (pupuru)	0.053	0.069	0.147
	Corn	0.015	0.003	0.025
	Garri	1.136	0.181	0.476
	Plantain flour	0.024	0.004	0.030
	Rice	0.054	-	0.079
3	Beans	0.056	0.045	0.089
	Cassava flour (pupuru)	0.068	0.064	0.147
	Corn	0.015	0.003	0.026
	Garri	1.257	0.175	0.547
	Plantain flour	0.019	-	0.028
	Rice	0.047	0.012	0.065
4	Beans	0.056	0.044	0.085
	Cassava flour (pupuru)	0.073	0.067	0.148
	Corn	0.015	0.003	0.025
	Garri	1.211	0.017	0.665
	Plantain flour	0.023	0.004	0.031
	Rice	0.050	0.011	0.079
	Mean	**0.241**	**0.044**	**0.180**

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

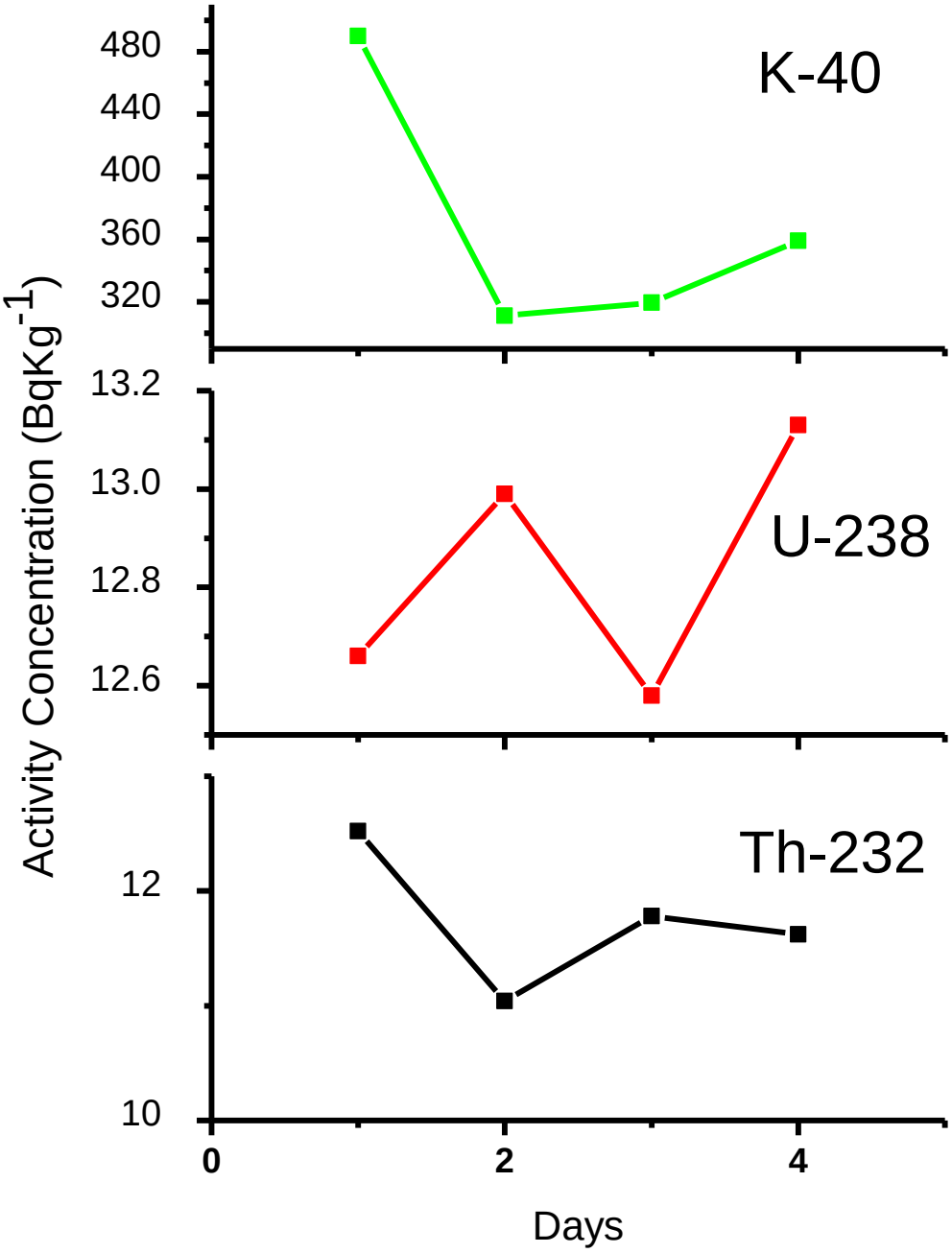


Figure 3: Daily Relationships of the NORMs Activity Concentration

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

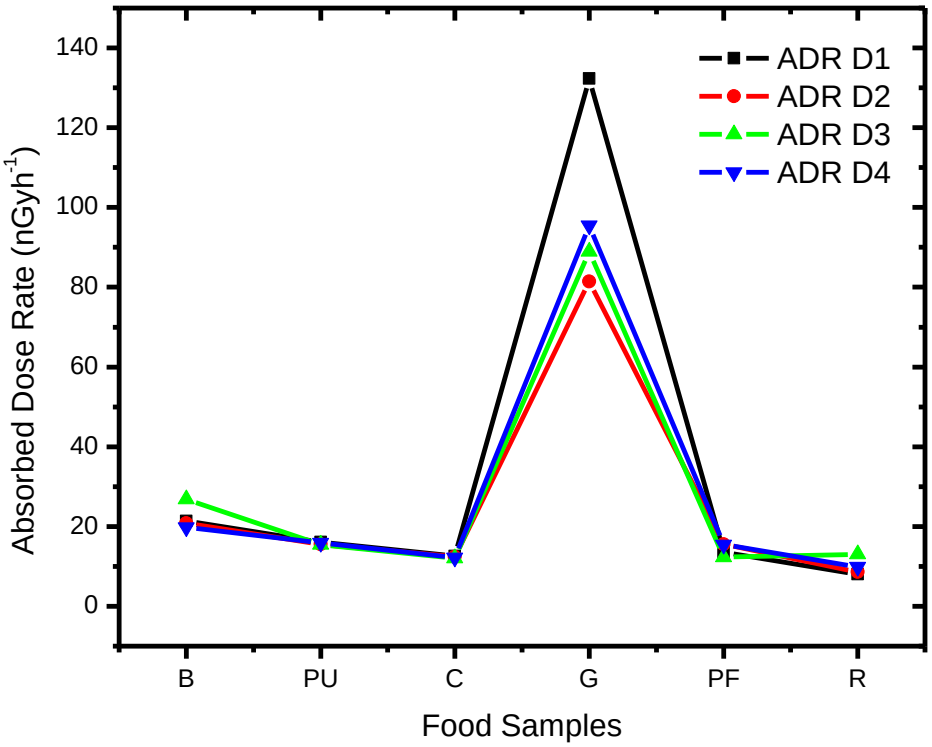


Figure 4: Relationship Between the ADR and the Food Samples Purchased for 4 Days

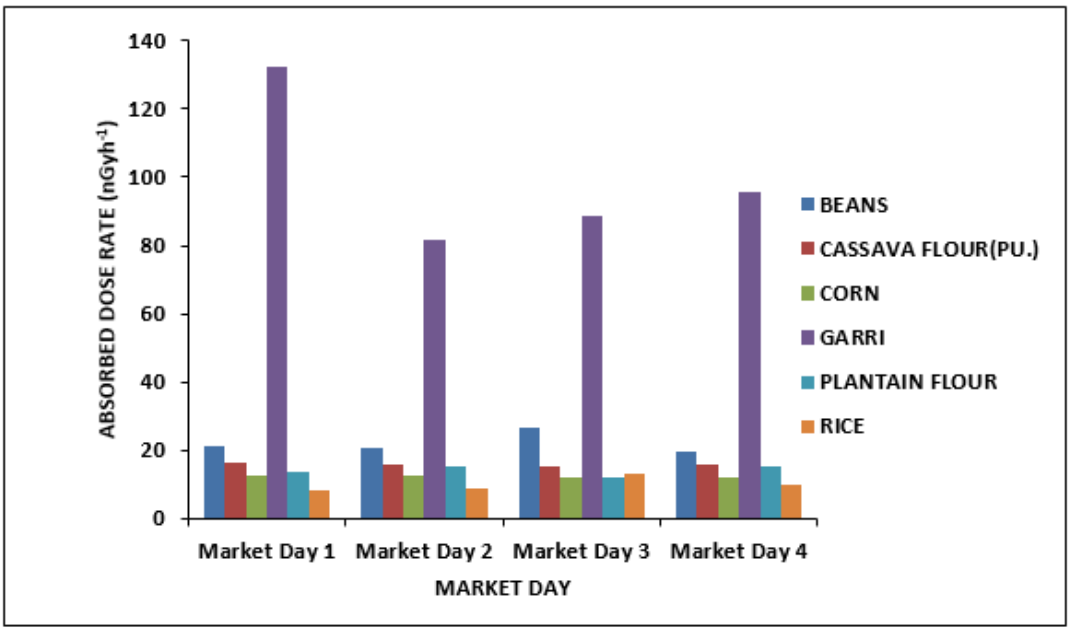


Figure 5: Absorbed dose rate values of radionuclides to the consumers.

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

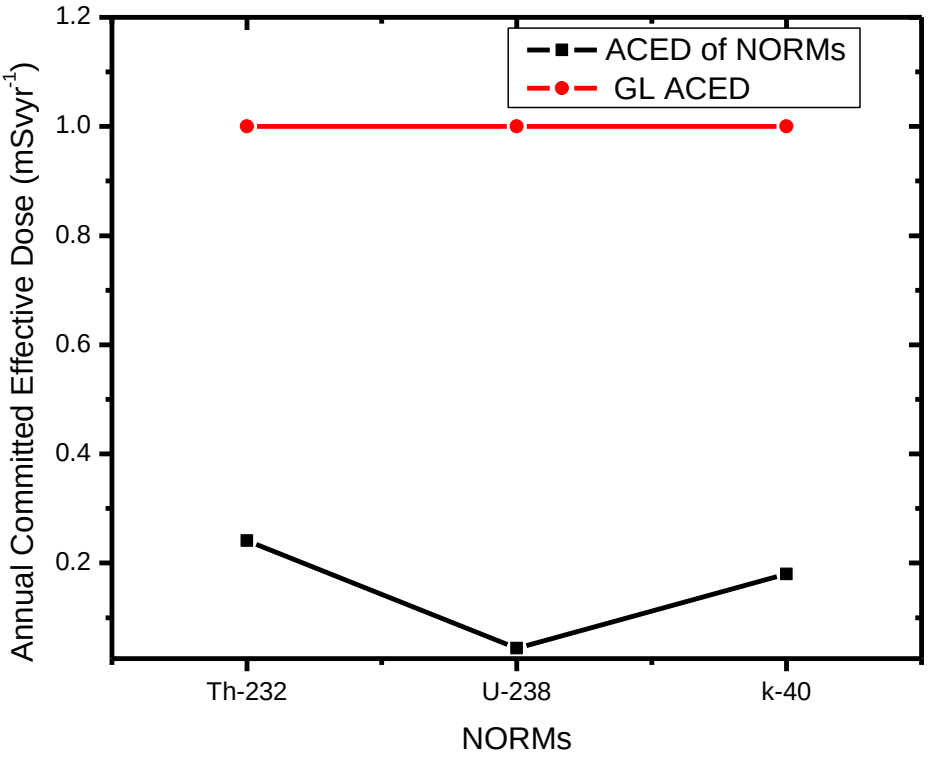


Figure 6: Comparison of the ACED to the Global Limit

DISCUSSION

Table 1 revealed that the highest value of activity concentration of Th-232 was discovered in sample G1 (58.21±5.93 Bqkg^{-1}) and the lowest was discovered in sample PU2 (1.91±0.41 Bqkg^{-1}) with an average value of (11.74 ± 1.22 Bqkg^{-1}). This shows that the activity concentration of Th-232 is below the value of the activity concentration of Th-232 global limit which is 50 Bqkg^{-1} (UNSCEAR, 2000). The highest activity concentration value of U-238 was recorded in sample G1 (41.82±9.48 Bqkg^{-1}) and the lowest value in sample R4 (3.12±0.39 Bqkg^{-1}) with an average value of (12.38 ± 2.27 Bqkg^{-1}). This value is below the activity concentration value of U-238 global limit which is 33 Bqkg^{-1}. The highest value of the activity concentration of K-40 was discovered in sample G1 (1854.12±126.83 Bqkg^{-1}) and the lowest value in sample R3 (134.72±12.62 Bqkg^{-1}) with an average value of (280.22 ± 30.08 Bqkg^{-1}). The activity concentration of K-40 is below the value of activity concentration of K-40 global limit which is 420 Bqkg^{-1}. Figure 3 showed that the activity concentrations of K-40 for day 1, 2, 3 and 4 were the highest in all of food samples. The high concentration of K-40 in some of the foodstuffs purchased per day might be responsible for this. It is worthy to mention that the activity

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

concentration of K-40 increases for the first day of sampling. The value surprisingly dropped in day 2 and then gradually increased from day 3 to 4. This fluctuation may be as a result of the difference in concentrations of K-40 in each the different soil locations from which the food samples obtained for each were harvested before processing. The low activity concentration of U-238 in the first day surprisingly increased in day 2, dropped in day 3 and increased in day 4. This instability in the activity concentration of U-238 for all the four days of sampling may be due to the reason earlier stated. The activity concentrations of Th-232 for all the four days were the lowest. This may be attributed to the low concentration of Th-232 in all the twenty four food samples collected. The concentration of Th-232 is not the same for every location in the study area. Therefore, the activity concentrations for all the four days fluctuate based on the percentage of Th-232 in each of the food samples. This is similar to the work of Shooshtari et al. (2017). The activity concentration of Ra-226 was analyzed in foodstuffs purchased from the market of Ramsar in Iran. Shoostari et al. (2017) however discovered that the activity concentration of NORMs in the foodstuffs considered is less than the acceptable value by UNSCEAR (1993) and concluded that no significant radiation hazard from Ra-226 was posed on the inhabitants of Ramsar from the consumption of the foodstuffs. Canbazoglu and Dogru (2013) studied the activity concentrations of fruits and vegetables commonly consumed by the people in the region of Elazig in Turkey. They however discovered that the activity concentration of fruits and vegetables taken by the people of Elazig is less than the global limit and therefore posed no health hazard to inhabitants. The work of Jwanbot et al., (2013) examined the activity concentration of soil samples and consumable crops grown in Barkin Ladi Local Government Area, Plateau, North Central, Nigeria. Jwanbot and the other co-authors compared the activity concentration of the soil to that of the food crops and concluded that some percentage of the activity concentration of the soil were not absorbed by the crops.

Figure 4 and 5 revealed that the average absorbed dose rate for all food samples with the exception of garri gives almost the same values for all the four days of sampling. The drop in the ADR of garri follows the trend ADR D1>ADR D4>ADR D3>ADR D2. This may be as a result of the differences in the concentration of K-40 in each of the different four garri samples, G1, G2, G3 and G4. K-40 may be high in the sample purchased in day 1 and low in the sample purchased in day 2 due to respective high and low concentrations of the radionuclides in G-samples for the

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

two days. The determined absorbed dose rate values for the samples were shown in table 3. The minimum value was obtained from rice (8.03nGyh^{-1}) and the highest from garri (132.35nGyh^{-1}). The mean value of all absorbed dose rate was obtained to be 28.99nGyh^{-1}. It was observed that absorbed dose rate values for all the garri samples were higher than the worldwide limit of 55.0nGyh^{-1} (UNSCEAR, 2000) because of very high concentrations of K-40. A high concentration of K-40 in cassava tubers from which garri was produced may be responsible for the increase. This is also a pointer to high concentrations of K-40 in the soils where the tubers were cultivated. All other foodstuff samples gave values that were below the worldwide mean value. Similar work was done by Osanai et al. (2021). As a result of several types of naturally occurring radionuclides released into the environment due to hydrogen explosion in the eastern Japan, Osanai et al. (2021) compared the standard set for the values of NORMs in foodstuffs by the health ministry to the actual activity concentration and ADR of the NORMs in foodstuffs in Japan and concluded that the ACED for all the foodstuffs were under 1 mSv/yr which was the limit set by the health ministry. Osanai et al. (2021) however stated that the consumption of the considered foodstuffs posed no radioactive harm to the people of Japan. Akkurt and Gunoglu (2014) performed an adequate examination on the possible effects of natural radionuclides in sedimentary rocks located in Turkey. Assessment of sedimentary layers of rocks showed that they harbored some naturally occurring radioactive materials. They however concluded that the usage and mining of sedimentary rocks in Turkey posed no radioactive harm to people as the ADR of the NORMs in the rocks are less than the acceptable global limit. Measurement of the exhalation rate of radon was done by Kaliprasad et al. (2017). It was discovered that the ADR for radon in the study area was less than the global recommended limit. The related ADR of the radionuclide in the soil was determined and found to fall within the acceptable global range. The soil is used for various purposes such as farming and construction of buildings and bridges, therefore Kasiprasad et al. (2017) explained the need to make sure the soil is free of NORMs. Examination of the rate of the exhalation of radon showed no significant radiation hazard was posed to the inhabitants of the study area.

Table 5 showed the determined annual committed effective doses of the radionuclides to the consumers of the foodstuff samples. The lowest ACED of Th-232 was from corn with value 0.015mSvh^{-1} and the highest was from garri with value 1.136mSvh^{-1}. The average ACED value for Th-232 is 0.241 mSvh^{-1}. The ACED for U-238 recorded the lowest value from corn with value 0.003mSvh^{-1} and the highest

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

from garri with value 0.185mSvh^{-1}. The average ACED value for U-238 is 0.044 mSvh^{-1}. The lowest ACED value for K-40 was from corn with value 0.025mSvh^{-1} and the highest from garri with value 1.158mSvh^{-1}. The mean ACED value of K-40 is 0.180mSvh^{-1}. The values obtained were below the world limit of 1mSvh^{-1} (ICRP, 2007). Figure 6 revealed that the ACED for Th-232, U-238 and K-40 are less than the global limit. Van et al. (2019) compared the Annual Committed Effective Dose Rate (ACED) of foodstuffs consumed by the people of Red River Delta in Vietnam to the ACED of other countries and concluded that the foodstuffs in Vietnam are safe for consumption because the ACEDs estimated for all the NORMs were found to be below the Global Limit of 1 mSv/yr. Absar et al. (2021) examine the naturally occurring radioactive elements in tea leaves using Gamma ray spectrometer. The average annual effective dose rate was estimated and compared with the recommended limit of 1 mSv/yr. The ACED from tea leaves was found to be under the global limit. Drinking of tea from tea leaves was thereafter discovered not to be harmful for people in the study area. Isinkaye et al. (2021) showed the comparison between locally bred and natural river catfishes by assessing natural radionuclides like k-40, U-238, Ra-226, Th-232 and Ra-228 for the two breeds. Findings from the work of Isinkaye et al. (2021) revealed that the ACED obtained for the local and the natural rivers breeds were both within the acceptable global range and limit; therefore two considered breeds of fishes are safe for consumption (Isinkaye et al., 2021).

CONCLUSION

In conclusion, this study so far shows that the foodstuff samples from Ode-Irele contain Potassium (K-40), Uranium (U-238) and Thorium (Th-232). The absorbed dose rate (ADR) values and annual committed effective dose (ACED) values determined were found to be within the global recommended limits and this implied that the frequently consumed foodstuffs by the people of the community will not pose any significant radiological health risk to them.

CONFLICT OF INTEREST

The authors declare no conflict of interest

ACKNOWLEDGEMENT

The authors wish to thank the Department of Physics, Federal University of Health Sciences, Otukpo, Benue State, Nigeria for making the departmental laboratory available for this research work.

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

REFERENCES

Abojassim, A.A., Al-Gazaly, H.H., & Kadhim, S.H. (2014). Estimated the Radiation Hazard Indices and Ingestion Effective Dose Rate in wheat flour Samples of Iraq Market. International journal of Food Contamination. 1: 2196 – 2804.

Absar, N., Abedin, J., Rahman, M.D.M., Miah, M.H., Siddique, N., Kamal, M., Chowdhury, M.I., Sulieman, A.A.M., Faruque, M.R.I., Khandaker, M.U., Bradley, D.A., & Alsubaie, A. (2021). Radionuclides Transfer from Soil to Tea Leaves and Estimation of Committed Effective Dose to the Bangladesh Populace. Life journal. 11:https://doi.org/10.3390/life11040282

Adedokun, M.B., Aweda, M.A., Maleka, P.P., Obed, R.I., Ogungbemi, K.I., & Ibitoye, Z.A. (2019). Natural Radioactivity Contents in Commonly Consumed Leafy Vegetables Cultivated Through Surface Water Irrigation in Lagos State, Nigeria. Journal of radiation Research and Applied sciences. 12: 147 – 156.

Adeleye, M.O., Musa, B., Oyebanjo, O., Gbenu, S.T., & Alayande, S.O. (2020). Activity concentration of Natural Radionuclides and Assessment of the associated Radiological Hazards in Marine Croaker (*Pseudotolitus Typus*) Fish from Two coastal areas of Nigeria. Science World Journal. 15: 1597 – 6343.

Akkurt, I., & Gunoglu, K. (2014). Natural Radioactivity measurements and Radiation Dose Estimation in Some Sedimentary Rock Samples in Turkey. Journal of Science and Technology of Nuclear Installation. 2014: 1 – 6.

Aryal, S. (2022). Gamma-Ray Spectroscopy- Definition, Principle, Parts, Uses. Microbe Notes. 1: 1 – 7.

Canbazoglu, C., & Dogru, M. (2013). A Preliminary Study on ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs Activity Concentrations of Elazig Region, Turkey. Journal of Analytical and Nuclear Chemistry. 295: 1245 – 1249.

Cengiz, G.B. (2020). Determination of Natural Radioactivity in Products of Animals Fed with Grass. A Case Study for Kars, Region Turkey. Scientific Reports. 10: 6939/https://doi.org/10.1038/s41598-020-63845-4.

Chandrashekara, K., & Somashekarappa, H.M. (2016). Estimation of Radionuclides Concentration and Average Annual Committed Effective Dose Due to Ingestion for Selected Medicinal Plants of South India. Journal of Radiation Research and Applied Sciences. 9: 68 – 77.

Chiozzi, P., De Felice, P., Fazio, A., Pasquale, V., & Verdoya, M. (2000). Laboratory Application of NaI (TI) γ–ray Spectrometry to Studies of Natural Radioactivity in Geophysics. Journal of Applied Radiation Isotope. 53:127 – 132.

El-Gamal, H., Hussien, M.T., & Saleh, E.E. (2019). Evaluation of Natural Radioactivity Levels in Soil and various Foodstuffs from Delta Abyan, Yemen. Journal of Radiation Research and applied Sciences. 12: 226 – 233.

Fathabadi, N., Salehi, A.A., Naddafi, K., Kardan, M.R., Yunessian, M., Nodehi, R.N., and Karimi, M. (2017). Radioactivity Levels in Mostly Local Foodstuff Consumed by Residents the High Level National Radiation Areas of Ramsar, Iran. Jouirnal of Environment Radioactivity. 169: 209 – 213.

IAEA. (1989). International Atomic Energy Agency. Natural Analogues of Bitumen and Bituminized Radioactive Waste. A Guide Book. A.A. E985-06482. Finland.

ICRP. (2007). International Commission on Radiological Protection. Recommendations of the ICRP Publication, Annuals ICRP Conference, Tokyo. 37: 2 – 4.

Ilori, A.O., Oluwafisoye, P.A., & Sordum, B. (2018). Estimation of Natural Radionuclide Concentrations and Heavy Metals Contents Due to Bitumen Exploitation at Gbeleju-Loda, Ode_Irele, Ondo-Sate, Southwestern Nigeria. Asian Journal of Physical and Chemical Sciences. 6: 1 – 10.

Inoue, K., Fukushi, M., Le, T.V., Tsuruoka, H., Kasahara, S., & Nimelan, V. (2020). Distribution of Gamma Ray Dose Rate Related with Natural Radionuclides in All of Vietnam and Radiological

Risk assessment of the Built-Up Environment. Scientific Reports. 10: doi.org/10./038/s41598-020-69003-0.
Isinkaye, M.O., Ajilu, F.S., & Ajayi, O.S. (2021). Committed Effective Dose from Natural Radionuclides in Farm-Raised and Wild Catfish in Ibadan, Nigeria. Radiation Protection Dosimetry. 193: 1 – 7.
Jibiri, N.N., & Abiodun, T.H. (2012). Effects of Food Diet Preparation Techniques on Radionuclides Intake and Implications for Individual Ingestion Effective Dose in Abeokuta, Southwestern Nigeria. World Journal of Nuclear Science and Technology. 2: 1 – 8.
Jodlowki, P., Wachniew, P., & Nowak, J. (2016). Determination of the Self-Attenuation Based on the Sample Composition in Gamma-Ray Spectrometry of 210Pb: Requirements for the Scope of Chemical Analyses. Journal of Radioanalytical and Nuclear Chemistry. 311: 1588 – 2780.
Joel, E.S., De, D.K., Omeje, M., Adewoyin, O., Olawole, O.C., Akinwumi, A., Erubami, S., & Adeyemi, G.A. (2020). Assessment of Background Radionuclides and Gamma Dose Rate Distribution in Urban-Setting and its Radiological Significance. Scientific African. 8: doi/ 10.1016/j.sciaf.2020.e00377.
Jwanbot, D.J., Izam, M.M.,nyam, G.G., & John, H.N. (2013). Radionuclides Analysis of some soils and Food Crops in Barkin Ladi LGA, Plateau State-Nigeria. Journal of Environment and Earth Science. 3: 2224 – 3216.
Kaliprasad, C.S., Vinutha, P.R., & Narayana,Y. (2017). Natural Radionuclides and Radon Exhalation rate in the Soils of Cauvery River Basin. SAGE Journals. 1: https://doi.org/10.1177/117862211.
Khan, I.U., Sun, W., & Lewis, E. (2020). Review of Low-Level Background Radioactivity Studies Conducted from 2000 to Date in People Republic of China. Journal of Radiation Research and Applied Sciences. 13: 406 – 415.
Lai, T.P., Stauffer, K.A., Murthi, A., Shaheen, H.H., Peng, G., Martin, N.C., & Hopper, A.K. (2009). Mechanism and a Peptide Motif for Targeting Peripheral Proteins to the Yeast Inner Nuclear Membrane. Traffic. 1: 10(9):1243-56.
Lordford, T., Emmanuel, O. D., Cyril, S., & Alfred, A. A. (2013). Natural Radioactivity Levels of Some Medicinal Plants Commonly Used in Ghana. Springer Plus. 2: 157 – 168.
McMahon, D.M., Vdovenko, V.Y., Stepanova, Y.I., Karmaus, W., Zhang, H., Inving, E., & Svendsen, E.R. (2015). Dietary Supplementation with Radionuclide Free Food Improves Children's Health Following Community Exposure to ^{137}Cesium: A Prospective Study. 94: https://doi.org/10.1186/s12940-015-0084-x.
Merli, I.D., DaSilveira, M.A.G., & Medina, N.H. (2015). Traces of Natural Radionuclides in Animal Food. American Institute of Physics Conference Proceedings1625. 111:https//doi.org/10.1063/1.4901774.
Moore, H.B. (1957). The Meaning of Food. American Journal of Clinical Nutrition. 5: 77 – 82.
Mukami, M., & Oki, T. (2014). Estimated Dietary Intake of Radionuclides and Health Risks for the Citizens of Fukushima City Tokyo, and Osaka after the 2011 Nuclear Accident. PLoS ONE. 9: e112791.doi: 10.1371/journal.pone.0112791.
Nicolov, V.P., Georgescu, P.L., Iticescu, C., Moraru, D.I., & pintilie, A.G. (2020). The Assessment of the annual Effective Dose Due to Ingestion of Radionuclides from Drinking Water Consumption: Calculation Methods. Journal of Radioanalytical and Nuclear Chemistry. 327: 49 – 58.
Omosule, S. (2011). Educational Development in Irele and Its Patrons. Ikale Voice.1: 1 – 9.
Orosun, M.M., Adisa, A.A., Akinyose, F.C., Amaechi, E.C., Ige, O.S., Ibrahim, B.M.,Martins, G., Adebanjo, G.D., Oduh, O.V., & Ademola, O.J. (2018). Measurement of Natural Radionuclide Concentrations and Radiological Impact Assessment of Fish samples from Dadin Kowa Dam, Gombe State Nigeria. African Journal of Medical Physics. 1: 25 – 35.

Osanai, M., Hirano, D., Mitsuhahashi, S., Kudo, K., Hosokawa, S., Tsushima, M., Iwaoka, K., Yamaguchi, I., Tsujiguchi, T., Hosoda, M., Hosokawa, Y., & Saito, Y. (2021). Estimation of Effect

EDITOR-IN-CHIEF
Prof. E. McLenna [Austrilia]

of Radiation Dose Reduction for Internal Exposure by Food Regulations under the Current Criteria for Radionuclides in Foodstuff in Japan Using Monitoring Results. Food Safety: Food Assessment methodology and Decision-Making Criteria. 10: 2304 – 8158.

Paatero, S.S., & Paatero, J. (2021). Transfer of Natural Radionuclides in Terrestrial Food Chains – A Review of Investigation in Finland. International Journal of Environmental Research and Public Health. 18: 1 – 10.

Pearson, A., Gaw, S., Hermansphn, N., & Glover, C.N. (2016). Natural and Anthropogenic Radionuclide Activity Concentration in the New Zealand Diet. Journal of Environmental Radioactivity. 151: 601 – 608.

Shooshtari, M.G., Deevband, M.R., Kardan, M.R., Fathabadi, M., Salehi, A.A., Naddafi, K., Yunesian, M., Nodehi, R.N., Karimi, M., & Hosseini, S.S. (2017). Analytical Study of ^{226}Ra Activity Concentration in Market Consuming Foodstuffs of Ramsar, Iran. Journal of Environmental Health Science and Engineering. 15: https://doi.org/10.1186/s40201-017-0281-3.

Sowole, O.E., & Amodu, F.R. (2019). Determination of Annual Dose Rate of Natural Radionuclides in Man from Fishes in Victoria Island Lagoon, Southwest of Nigeria. International Journal of Ocean Oceanography. 13: 57 – 64.

Tawalbeh, A.A., Samat, S.B., & Omar, M. (2012). Radiological impact of Drinks Intake of Naturally Occurring Radionuclides on Adults of Central Zone of Malaysia. Malaysian Journal of Analytical Sciences. 16: 187 – 193.

Tzortzis, M., Svoukis, E., & Tsertos, H. (2003). A Comprehensive Study of Natural Gamma Radioactivity Levels and Associated Dose Rates. Cyprus University Journal. doi: 10.1093/rpd/nch300.

UNSCEAR. (1993). United Nation Scientific Committee on Effect of Atomic Radiation. Exposure from Natural Sources of Radiation. United Nations, New York.

UNSCEAR. (2000). United Nation Scientific Committee on Effect of Atomic Radiation. Ionizing Radiation Sources and Biological Effect Report to the General Assembly, New York.

Van, T.T., Bat, L.T., Nhan, D.D., Quang, N.H., Cam, B.D., & Hung, L.V. (2019). Estimation of Radionuclide Concentrations and Average Annual Effective Dose Due to Ingestion for the Population in the Red River Delta, Vietnam. 63: 444 – 454.

Yablokov, A.V., Nesterenko, V.B., & Nesterenko, A.V. (2009). Atmospheric, Water and Soil Contamination after Chernobyl. Ann N Y Academic Science. 1181: 223 – 236.

Zagatto, V.A.B., Medina, N.H., Okuno, E., & Umisedo, N.K. (2008). Natural Radioactivity in Bananas. United State. American Institute of Physics. 1: 94 – 243.

Zehringer, M. (2016). Radioactivity in Food: Experiences of the Food Control Authority of Basel-City since the Chernobyl Accident. 1: https/doi:10.5772/62460.

EDITOR-IN-CHIEF

Prof. E. McLenna [Austrilia]