Asian Journal of Research and Reviews in Physics

5(3): 41-53, 2021; Article no.AJR2P.77873
ISSN: 2582-5992

Assessment of Radionuclides in Some Fruits from Niger Delta, Nigeria and Its Health Risks

C. J. Mgbemere [a*], C. P. Ononugbo [a] and G. O. Avwiri [a]

[a] *Department of Physics, University of Port Harcourt, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJR2P/2021/v5i330167

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/77873

Original Research Article

Received 21 October 2021
Accepted 25 December 2021
Published 26 December 2021

ABSTRACT

Determination of radionuclides' activity concentration in fruits is essential for the protection of human health. Fruits can be radioactive due to the present of naturally occurring radioactive materials (NORMs) and technically enhanced radioactive materials (TENORMs) in the environment. The Assessment of Radionuclide activity concentration in Some Fruits from Niger Delta, Nigeria and its Health Risks were carried out using gamma ray spectroscopy. The study measured the activity concentration of radionuclides in fruits and the results showed that the total activity concentration of ^{40}K, ^{232}Th and ^{226}Ra in fruits were 578.24 Bqkg^{-1}, 263.84 Bqkg^{-1} and 128.35 Bqkg^{-1} respectively. The study found out that ^{40}K has the highest value of activity concentration while apricot has the highest value of radionuclide concentration compared to other fruits. The statistical analysis of data was also done using statistical packages. The average estimated AED for Infants, Children and Adults due to the radioactivity in Avocado, Apricot, Guava and Pear were; 829.02 µSvy^{-1}, 565.865 µSvy^{-1}, and 838.725 µSvy^{-1}, 2737.665 µSvy^{-1}, 4361.4875 µSvy^{-1} and 2497.9025 µSvy^{-1}, 651.20833 µSvy^{-1}, 1202.6767 µSvy^{-1} and 813.22167 µSvy^{-1}, and 1164.7883 µSvy^{-1}, 1724.2933 µSvy^{-1} and 1088.8933 µSvy^{-1} respectively. The estimated AED due to the consumption of various fruits are above the world value. However, the estimated excess lifetime cancer risks for the various fruits are far below the world (WHO) limit. The study concluded that there is no cancer risk associated with the consumption of fruits in the study area and that the fruits that have tap root systems recorded highest value of radionuclides' activity concentration.

**Corresponding author: E-mail: jamesmgbemere@gmail.com;*

Keywords: Fruit; consumption; radionuclides; spectroscopy.

1. INTRODUCTION

Radiation is a form of energy that travels through space. Radiation is a kind of electromagnetic wave whose wavelengths are longer than those of red light. Radiation is present everywhere in our environment right from origin of earth. Hence radiation is as old as creation itself. World Nuclear association (2002) defined radiation as energy which moves in a form of wave or particle. Radiation can also be referred to as the emission and transmission of energy in the form of particles or wave from one place to another. It could be in the form of light, heat and sound or wave. Examples include: x-ray, γ-rays (gamma radiation) infrared, beta and alpha particles. In recent years radiation issues have become major concern to physicists in particular and scientists and environmentalists in general. Hence, both the type of radiation, sources of radiations, uses and their interactions with matter has been the most interesting and disturbing aspect in our day-to-day activities, ranging from the manufacturing, oil and gas and food industries. Radiation is important to man and other creatures in their activities. Man is exposed to different types of radiations at different levels, or dosage. Man is exposed to radiations that are emitted by radionuclides in the environment (i.e. air, water and soil), (UNSCEAR, 2009). The amount or quantity of radionuclides in a given environment is affected or dependent on the type of man-made and natural activities that are prominent in such locations or regions.

The global average natural dose of background ionizing radiation to humans is estimated to 2.401 $mSvy^{-1}$. Eighty percent (80%) of which comes from nature, while remaining 20% results from exposures to artificial radiation sources, primarily from medical imaging and industries [1]. The amount of radionuclide and radiations that man is exposed to is also a factor of the geological component of the bedrocks and other particles or minerals that are present within the environment, these in turn give rise to background radiation in that environment. The foods and fruits that we eat could contribute to a large extent, to the level or dosage of internal radiation that we could be exposed to, depending on the level of radionuclides that are present in such fruits or foods (UNSCEAR, 2013). Naturally, radiation is everywhere, even in our body. The average human body is composed of radionuclides at least in part, which include; Carbon-14 and Uranium [2]. Fruits as key means of vitamins and minerals that are cultivated in radiation polluted environment and consumed by humans could trigger radiation hazard like cancer, radiation sickness and organ failure. Hence, it becomes important to ascertain radionuclide levels and radiological risks that are associated with consuming these fruits.

Fruits represent an important aspect of our total diet and have high monetary value for citizens. Fruits as the sweet and fleshy product of a tree or plant that contains seeds are of different types. Thus, there are simple fruits (examples; Pears & Apples), aggregate fruits (example; strawberries) and multiple fruits (examples; breadfruits & pineapples). Generally, there are two main types of fruits based on rooting system, thus; Monocots and Dicots, (i.e. fruits that have fibrous roots & those that have tap root system). The rate of absorption and transportation of radionuclide from the environment to fruits is a factor of the type of rooting system, industrial (man-made) and natural activities that take place within the given environment (UNSCEAR, 2012), [3]. Radionuclide is conveyed in the environment and as such find their way into food crops and fruits. Some of the radionuclide is part and parcel of nutrients or minerals found in fruits. For instance; ^{40}K, is found in abundant in banana and other fruits and nuts (WHO, 2011). Radionuclides in the environment can be transferred to fruits through the roots, and leaves of the plants. Avwiri et al*,* [4] observed that naturally occurring radioactive materials (NORMs) are absorbed by food crops and fruits and this is possible because the NORMs are absorbed by the plants just like they absorb other plant nutrients in the soil or from other components of the environment (air & water). WHO (2011) opined that level of radionuclides in foods varies and depend on several factors such as type of food, fruit, and geographical region where the food is produced. The common radionuclides found in foods (cereals, tubers, etc), and fruits are; ^{40}K, ^{226}Ra and ^{238}U and their associated progeny. Hence, it becomes important to ascertain radionuclide activity levels that are available in fruits, investigate possible risks that are connected with consuming these fruits and the need to determine radiation exposure level in humans due to consuming these fruits from Niger Delta.

In addition, the objective of the study is as follows;

1. Ascertain activity concentration of radionuclides in fruits.
2. Estimate the radiological risk parameters to ascertain their risk level.
3. Estimate the Cancer risk associated with ingestion of these fruits.

2. MATERIALS AND METHODS

2.1 Study Area

The Niger Delta is a densely populated region that is sometimes called "the Oil Rivers" because it was once a major producer of palm oil. The region presently consists of nine states and one hundred & eighty-five (185) Local Government Areas. The States that make up the Niger Delta are: Abia, Akwa-Ibom, Bayelsa, Cross-River, Delta, Edo, Imo, Ondo and Rivers State.

The Niger Delta is a tropical rain climate with a mean high annual rainfall which varies within the region. It is located at longitude 50°E to 80°E, latitude 4°N-10°N of the equator and at an altitude below 1000 meters, (NGIA; Opafunso, 2007).

The Niger Delta region is also known as the Oil producing region in Nigeria, because it is where almost 100% of Nigeria's crude oil is gotten from. The region occupies 75,000km^2 (7.5%) of the total land area of Nigeria, and is home to approximately 30 million people (Asanebi, 2016).

The local communities in Niger Delta have being experiencing environmental hazards and degradation of agricultural land due to oil spills during crude oil exploration (extraction and refining).

2.2 Sample Collection

The method of data collection is observation method. Total samples of ten (10) fruits were collected from the Niger Delta Region. The samples were collected from major markets in the region within a given location based on sample collection plan that covered the study area effectively.

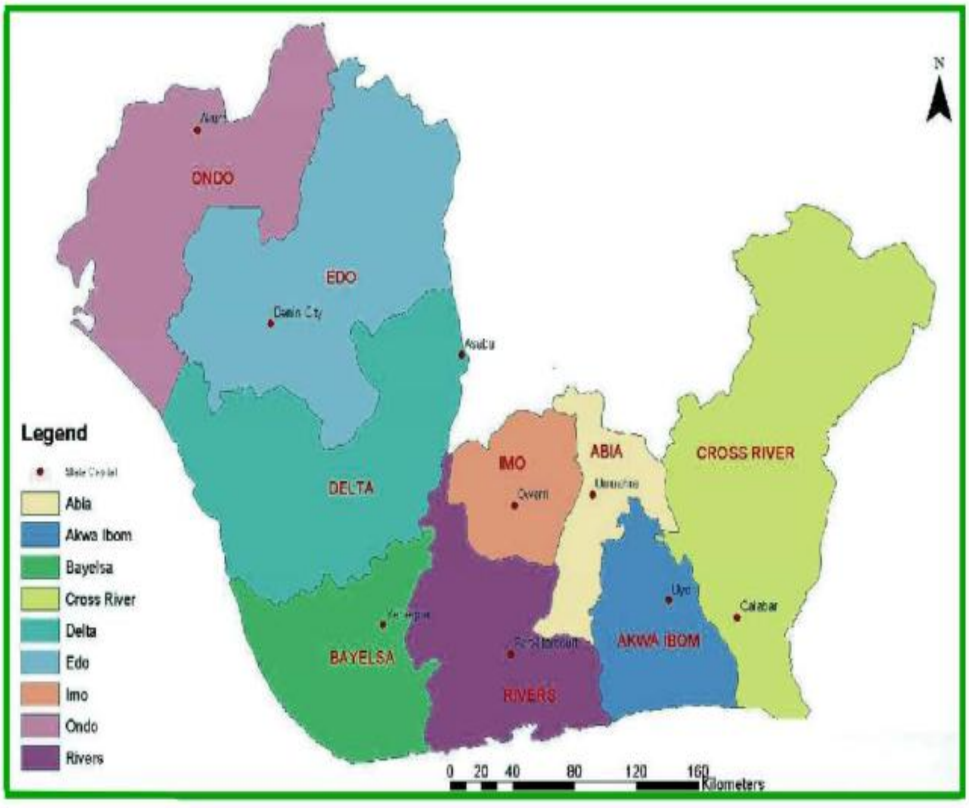

Fig. 1. Map of the study area (Niger Delta) (NDP, 2006)

Table 1. Sample collection area

S/N	Sample Name	Sample Area	Number of Samples
1	Apricot	Abia State	1
2	Avocado Pear	Imo State	1
3	Guava	Abia State	1
4	Guava	Cross-River State	1
5	Guava	Delta State	1
6	Guava	Rivers State	1
7	Pear	Bayelsa State	1
8	Pear	Edo State	1
9	Pear	Imo State	1
10	Pear	Rivers State	1
Total			**10**

2.3 Sample Preparation

After collection, samples were cut into pieces, air dried for three (3) weeks, grinded and passed through a 2 mm mesh size sieve. Afterwards, the air dried and ground samples were weighed using a weighing balance. Then the samples were packed in special air tight polyethylene plastic containers (PVC), closed and tightly sealed using cello tape for 30 days so as to allow for ^{238}U and its short-lived progenies to reach secular radioactive equilibrium (Veiga et al, 2006) before gamma counting. The sealed sample containers were labelled appropriately. Using equation 3.1, dried samples were measured and calculated as follows:

$$W_3Kg = (W_2 - W_1)Kg \qquad (1.1)$$

The weight of the empty container was recorded (W_1kg), the pulverized sample packed into the container and weighed (W_2kg) and the final weight (W_3kg) was calculated by subtracting the weight of the empty plastic container (W_1kg) from the weight of the sample plus the container (W_2kg).

After this period all the decay products in the ^{232}Th series and ^{226}Ra sub-series were in radioactive equilibrium with their daughters.

2.4 Quality Assurance/Quality Control

The prepared samples were analyzed by inserting them inside the detector which was connected to a computer program MAESTRO window that matched gamma energies to a library of possible isotopes [5].

The detector was shielded by 15cm thick lead all round and 10cm thick on top. The energy resolution of 2.0 kev and relative efficiency of 33% at 1.33Mev was achieved in the system with the counting time of 10,800 seconds to reduce statistical uncertainty. The configuration and geometry were maintained throughout the analysis, as previously characterized based on well established protocol of the laboratory.

2.5 Validation of the Analytical Technique

The standard International Atomic Energy Agency (IAEA) sources were used for calibration (IAEA, 2003: [6]). From the counting spectra, the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K was determined using computer program. The peak corresponds to 1460 kev (^{40}K) for ^{40}K, 1764.5 Kev (Bi-214) for ^{226}Ra and 2614.5 kev (Ti-208) for ^{232}Th were considered in arriving at the activity levels (Bqkg^{-1}).

The background counts were determined by counting an empty container of the same dimension as those containing the samples and subtracting from the gross count. The activity concentrations of the samples were determined using the net area under the photopeak's using:

$$A_c = \frac{C_n}{P_\gamma M \varepsilon} \qquad (1.2)$$

Where A_c is the activity concentration of the radionuclide in the sample given in Bqkg^{-1}, C_n is the net count rate under the corresponding peak, P_γ is the absolute transition probability of the specific γ-ray, M is the mass of the sample (kg) and ε is the detector efficiency at the specific γ-ray energy.

The collected data was statistically analyzed using statistical packages such as SPSS, excel, and statistical tools like histogram, frequency.

The possible radiological risks associated with the recorded values were analyzed using equations.

2.6 Instrumental Operation and Analysis

A Sodium Iodide Thallium activated [NaI (TI)] detector connected to ORTEC 456 amplifier is used in measuring the activity concentration of the radionuclides ^{232}Th, ^{226}Ra and ^{40}K in the collected fruit samples. The NaI (TI) detector is used to detect ionizing radiation emitters (radionuclides) in a given material [7].

The detector converts the ionization and excitation produced by radiation into light pulse or scintillation and the amount of this light that is produced is proportional to the amount of energy deposited by the radiation (particle or photon) (Vlado, 2019). The process is such that a small light pulse is then converted into an electric pulse by an electric component (a photomultiplier tube). The size of the amplified electric pulse is proportional to the energy deposited by the radiation.

The proportionality of the output pulses (light) to the deposited radiation energy enables the output to be used as input pulses for a gamma spectrometer and thereby discriminate between different types and energies of radiations (radiation emitters). This process is repeated each time gamma radiation hits the crystal. The role of Ti is strictly to enable the detector to operate properly. Thus, when ionizing radiation enters the crystal, it produces electron-hole pairs. The thallium-doped NaI converts the energy from the incident gamma radiation into light in the visible spectrum which is then detected with the photomultiplier tube. Basically, the principle of gamma spectroscopy is that every gamma emitting radionuclide always emits a gamma ray with specific energies.

2.7 Radiological Parameters

2.7.1 Radium Equivalent (Ra_{eq})

In order to effectively estimate the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, an index known as radium equivalent activity (Ra_{eq}) has been presented. This is to enable a single index to define the radiation hazards associated with mixture of the radionuclides. Ra_{eq} can be calculated from equation (2.8) with an assumption that 370 $Bqkg^{-1}$ of ^{226}Ra, 259 $Bqkg^{-1}$ of ^{232}Th and 4810 $Bqkg^{-1}$ of ^{40}K produce the same gamma-ray dose rate (NEA-OECD, 1979;Ravisankar et al*.,* 2014; Kolo et al., 2015).

$$Ra_{eq} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \qquad (1.3)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively.

Both external and internal gamma dose from exposure to radon and its daughter nuclides are related to Radium equivalent (Ravisankar et al*.,* 2015) [8]

2.7.2 Annual Effective Dose

The ingestion dose (annual effective dose) due to radionuclides in fruits can be calculated using the following formula;

$$AED = A \times R \times C \qquad (1.4)$$

Where A is the activity concentration of the radionuclide, R, is the radionuclide ingestion dose convection factor in (Sv/kg) and C is the annual intake of fruits. The world value for the radionuclide ingestion dose convection factor and the annual intake of fruits for different age categories is given in Table 1.

2.7.3 Annual Committed Effective Dose (ACED)

This is a measure of total effective dose of radiation delivered to an individual due to exposure to internal radiation, that is the dose that measures the stochastic health risk due to an intake of radioactive material (Cumhur, 2019) [9]. The annual committed effective dose can be calculated by using the equation below;

$$ACED = AED_T \times C_r \qquad (1.5)$$

Where D_T is the total effective dose, C_r is the total intake of radionuclide.

Hereditary effect; the hereditary effect due to ingestion of radionuclides can be calculated by using the formulae;

$$H_{eff} = AED_T \times 0.2 \times 10^{-3} \qquad (1.6)$$

Annual Gonadal equivalent dose: The annual Gonad equivalent dose (H) due to the ingestion of fruits can be calculated by using the following formulae:

$$H = w_t \times D_T \qquad (1.7)$$

Where; w_t is the gonad weighted value (0.08) given by ICRP, 2012 and D_T is the total effective dose due to the ingestion of radionuclides.

2.7.4 Excess Lifetime Cancer Risk (ELCR)

The probability of occurrence of cancer in any given population for a given lifetime exposure is measured by excess lifetime cancer risk (ELCR). ELCR was calculated from the estimated annual effective dose D using equation 2.13 (Qureshi et al*.,* 2014): [10]

$$\text{ELCR} = D_T \times DL \times RF \quad (1.8)$$

Where D_T is the total ingestion of radionuclide, DL is the life expectancy of 70 years for adult and 50 years for Children and Infants, and RF is risk factor given to be 5×10^{-5} mSv^{-1} for stochastic effects (ICRP 2012: Priharti et al*.,* 2016). Thus ELCR =D_T x Average duration of life (DL) x Risk factors (RF).

2.8 Radiation Hazard Indices

Radiation hazard indices are used to estimate radiation effects associated with radionuclides in a given media. Thus, gamma and alpha representative indices are used to estimate the level of alpha and gamma radiation hazards that are associated with the natural radionuclides in specific samples [11]. The indices are regarded as screening tools.

Gamma and Alpha absorbed representative index value (I_γ and I_α) can be calculated by;

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (1.9)$$

$$I_\alpha = \frac{A_{Ra}}{200} \quad (1.10)$$

Table 2. The Annual Ingestion C and Ingestion dose R Conversion Factor for Radionuclides and different age categories. (WHO 2011: Priharti, 2016)

Age Category	Fruit Ingestion (kg/y)	Radionuclides ($\times10^{-8}$ Sv/Bq)		
		^{40}K	^{226}Ra	^{232}Th
Infants (1-6 years)	23.01	4.20	96	45
Children (7-13 years)	46.02	1.30	80	29
Adults (>18 years)	69.03	0.62	28	23

3. RESULTS

Table 3. Specific activity concentration of radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in fruit samples and their associated radiological parameters

S/N	Sample				Activity (Bqkg^{-1})				
	Scientific Name	Trade Name	Sample Code	Area Code	^{40}K	^{226}Ra	^{232}Th	Ra_{eq} (Bqkg^{-1})	H_{in}
1	*Persea Americana*	AVOCADO Pear	AP	API	38.17±4.59	7.85±2.18	18.75±5.15	37.6	0.16
2	*Prunus armeniaca*	APRICOT	AT	ATA	69.55±4.30	19.70±5.63	15.70±5.36	47.63	0.17
3				GAA	84.73±4.86	16.29±5.76	21.60±5.88	53.7	0.19
4				GAC	59.51±5.21	19.80±4.68	25.67±5.39	61.09	0.22
5	*Psidium guajava*	GAUVA	GA	GAD	90.55±5.10	13.36±4.29	25.26±5.17	56.45	0.19
6				GAR	148.74±5.19	151.23±3.37	26.08±6.52	199.98	0.95
7	*Pyrus communis*	PEAR	PR	PRB	210.81±4.87	43.70±2.89	14.89±5.09	81.23	0.33
8				PRE	195.30±4.02	11.27±5.28	20.59±5.48	55.75	0.18
9				PRI	111.89±2.11	4.10±2.95	24.04±4.15	47.09	0.13
10				PRR	76.97±5.48	146.92±4.10	16.92±3.80	177.04	0.88

Table 4. Gamma and Alpha Representative Index Level in the Fruit Samples (Avocado Pear, Apricot, Guava and Pear)

S/N	Activity (Bqkg^{-1})					
	Sample Code	^{40}K	^{226}Ra	^{232}Th	I_γ (Bqkg^{-1})	I_α (Bqkg^{-1})
1	AP	54.66	25.78	19.98	0.408	0.129
2	AT	113.91	108.51	22.01	1.021	0.543
3	GA	89.82	46.75	23.97	0.612	0.234
4	PR	135.49	37.24	20.42	0.543	0.186
Total		**393.88**	**218.28**	**86.38**	**2.584**	**1.092**

Table 5. Estimated radiological risk parameters for different age categories

S/N	Sample Area Code	Age Category	^{40}K	^{226}Ra	^{232}Th	Radiological Parameters		
						AED_T (μSvy^{-1})	AGED (μSvy^{-1})	ELCR $\times 10^{-3}$
1	API	Infant	36.89	173.4	194.2	404.44	32.36	0.010
		Children	22.84	289.01	250.2	562.08	44.97	0.014
		Adult	16.34	151.73	297.7	465.76	37.26	0.012
2	ATA	Infant	67.21	435.17	162.6	664.95	53.19	0.017
		Children	41.61	725.28	209.5	976.42	78.11	0.0 24
		Adult	29.77	380.77	249.3	659.81	52.78	0. 023
3	GAA	Infant	81.88	359.39	223.7	664.93	53.19	0.017
		Children	50.69	599.73	288.3	938.69	75.09	0.023
		Adult	36.26	314.86	342.9	694.06	55.52	0.024
4	GAC	Infant	57.51	437.37	265.8	760.68	60.85	0.019
		Children	35.02	728.98	342.6	1106.6	88.52	0.028
		Adult	25.47	382.7	407.6	815.73	65.26	0.029
5	GAD	Infant	86.5	295.11	261.6	643.16	51.45	0.016
		Children	54.17	491.86	337.1	883.14	70.65	0.022
		Adult	38.75	258.22	401.1	698.02	55.84	0.024
6	GAR	Infant	143.74	3340.6	270	3754.4	300.35	0.049
		Children	88.99	5567.7	348.1	6004.7	480.38	0.15
		Adult	63.66	2923	414.1	3400.8	272.06	0.012
7	PRB	Infant	203.73	965.31	154.18	1323.22	105.86	0.033
		Children	126.12	1608.86	198.72	1933.7	154.69	0.052
		Adult	90.22	844.65	236.41	1171.28	93.7	0.041
8	PRE	Infant	188.74	248.94	213.19	650.87	52.07	0.022
		Children	116.84	414.92	274.79	806.55	64.52	0.020
		Adult	83.59	217.83	326.91	628.33	50.27	0.022
9	PRI	Infant	108.13	90.57	248.92	447.62	35.81	0.011
		Children	66.94	150.94	320.83	538.71	43.09	0.035
		Adult	47.89	79.25	381.68	508.82	40.71	0.018
10	PRR	Infant	74.39	3245.4	175.19	3494.98	279.59	0.087
		Children	46.05	5409.01	225.81	5680.87	454.47	0.142
		Adult	32.94	2762.42	268.64	3064	245.12	0.011

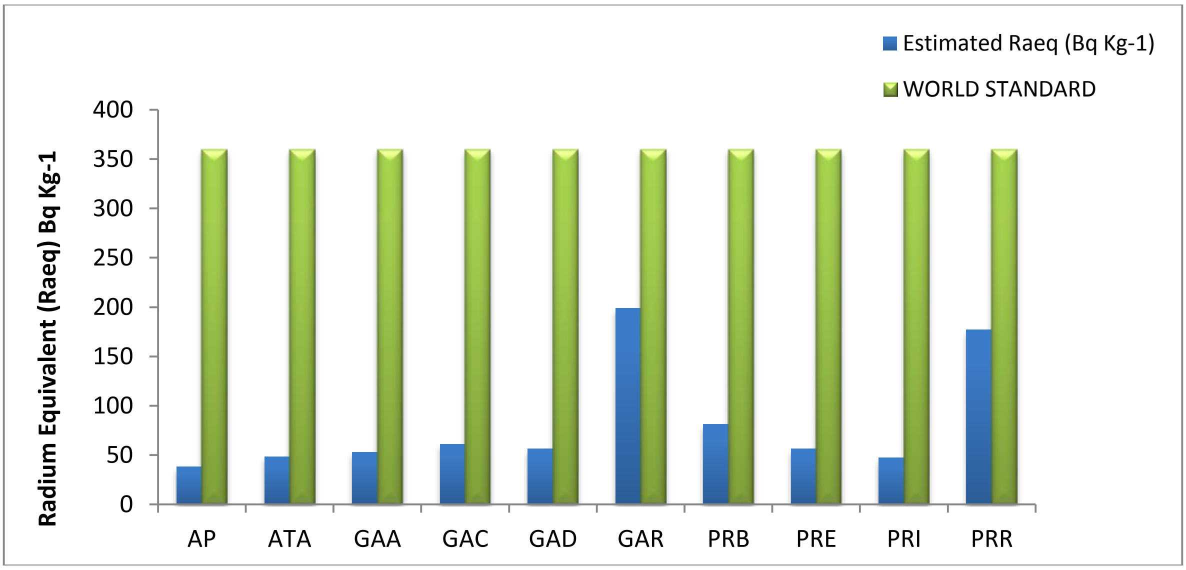

Fig. 2. Comparison of estimated radium equivalent (Ra_{eq}) with world standard

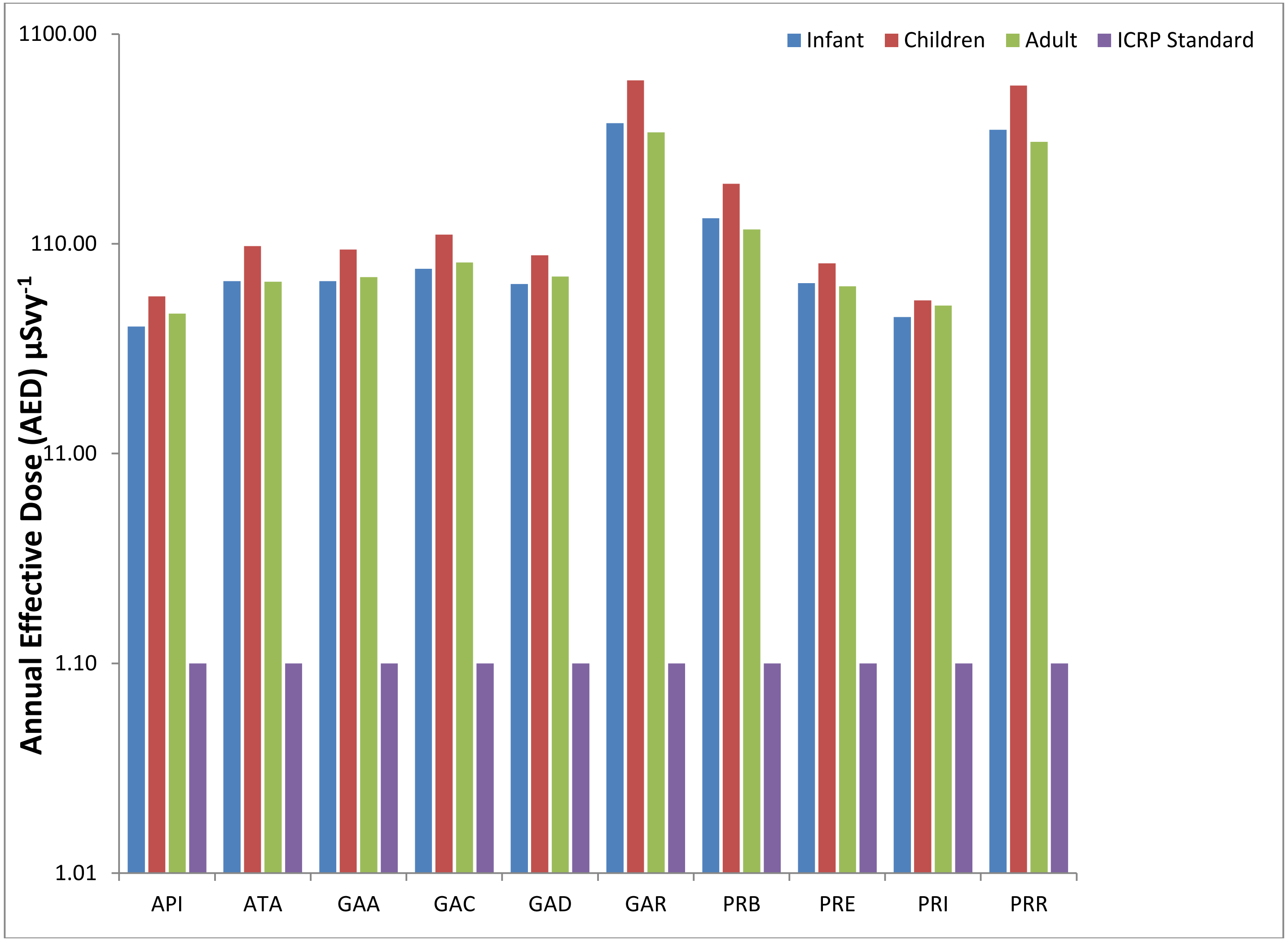

Fig. 3. Comparison of estimated annual effective dose of infants, children and adults with world standard

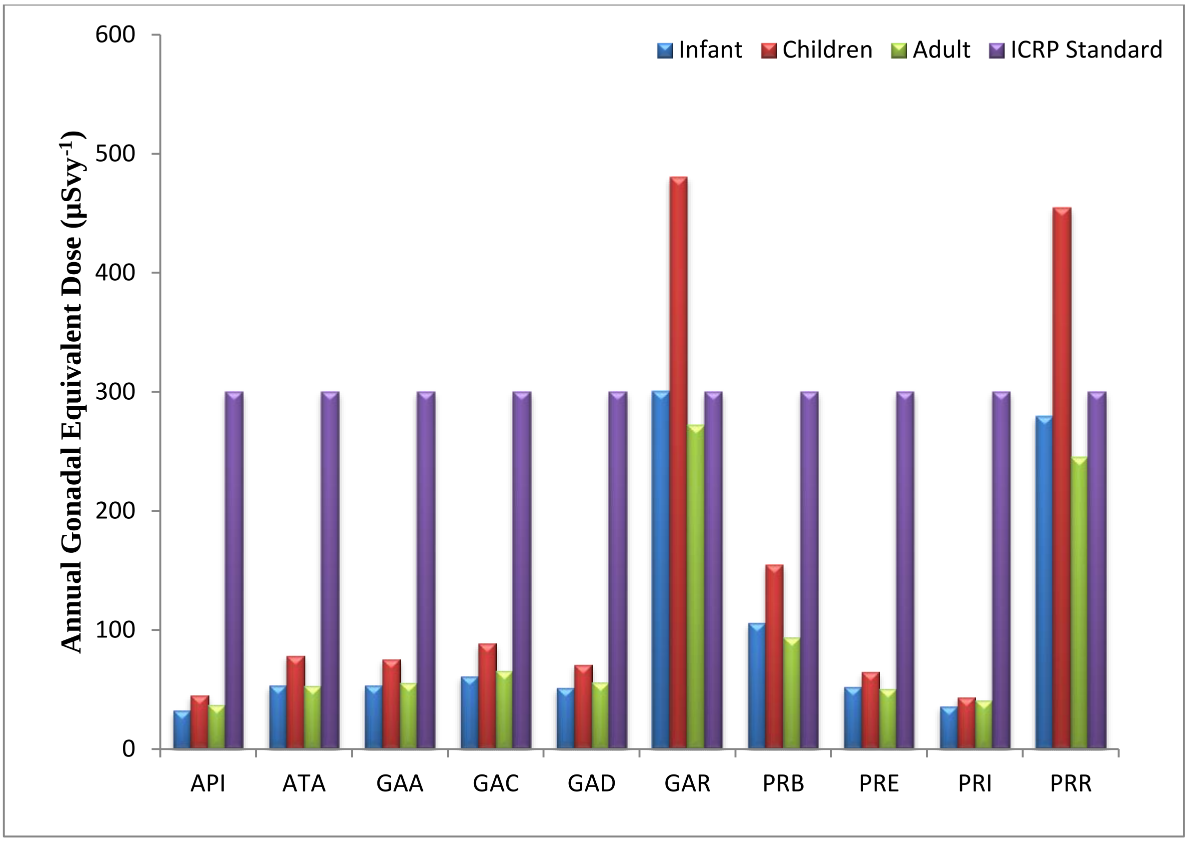

Fig. 4. Comparison of estimated annual gonadal equivalent dose of infants, children and adults with world standard

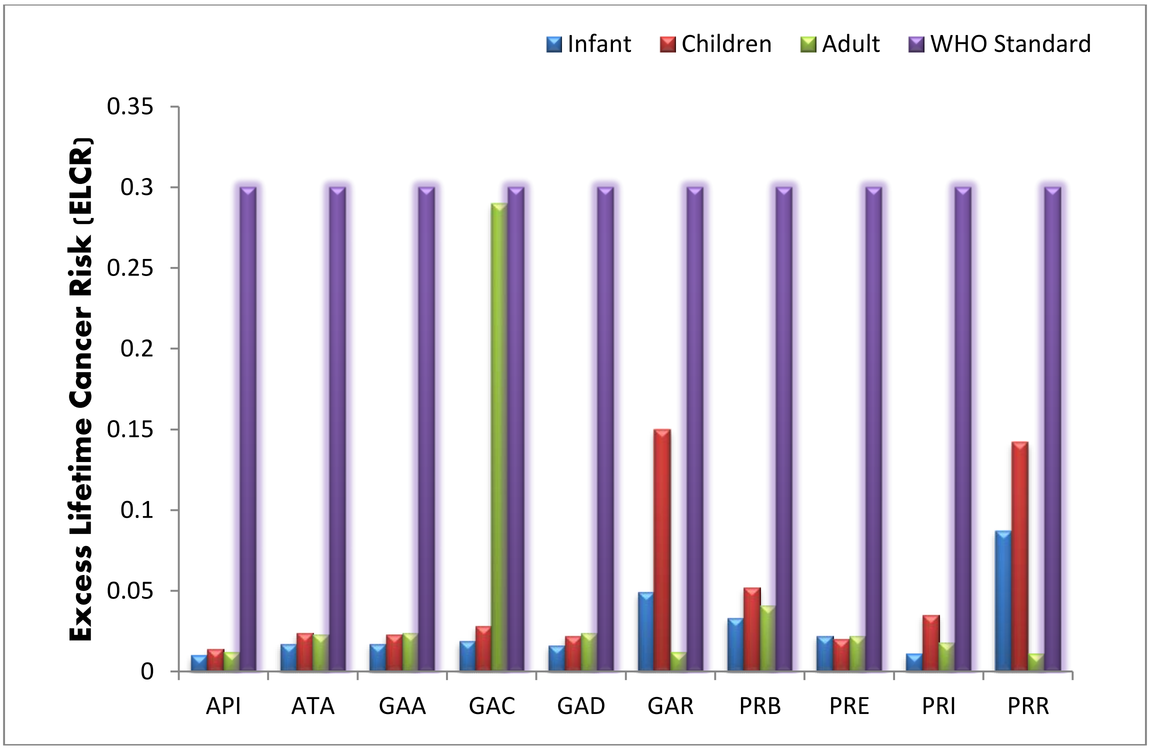

Fig. 5. Comparison of Estimated Excess Lifetime Cancer Risk (ELCR) of infants, children and adults with world standard

4. DISCUSSION

Table 3. showed the radionuclides that are present in fruits, and they are ^{40}K, ^{226}Ra and ^{232}Th, and the activity concentration of the identified radionuclides in various fruit samples. The highest activity concentration value of ^{40}K, ^{226}Ra and ^{232}Th in Avocado Pear is: 71.15±4.52 $Bqkg^{-1}$ for ^{40}K, 43.70±3.44 $Bqkg^{-1}$ for ^{226}Ra and 21.20±5.75 $Bqkg^{-1}$ for ^{232}Th respectively. In Apricot, the highest activity concentrations for the various radionuclides (^{40}K, ^{226}Ra and ^{232}Th) are: 212.75±3.64 $Bqkg^{-1}$ for ^{40}K, 291.20±3.15 $Bqkg^{-1}$ for ^{226}Ra, and 26.69±6.24 $Bqkg^{-1}$ for ^{232}Th. The radionuclide activity concentration in Guava due to ^{40}K, ^{226}Ra and ^{232}Th are 148.74±5.15 $Bqkg^{-1}$, 151.23±3.37 $Bqkg^{-1}$ and 26.08±6.52 $Bqkg^{-1}$ respectively.

Table 3. further showed that the activity of ^{40}K in Avocado and Gauva, ^{226}Ra activity in Avocado and Pear, and ^{232}Th activity in Avocado and Gauva from Rivers state has the highest concentration value compared to the same fruits from other parts (states) of Niger Delta. Thus the table showed that the activity concentration of ^{226}Ra was also highest in Apricot, followed by Guava, and Pear. This high activity of ^{226}Ra in the above sampled fruits is due to the rooting system of the fruits and the industrial activities in the region that uses radiation sources in their operations, Avwiri G. O. et al, [12].

The Apricot, Pear and Guava that has highest value of internal hazard index are those that are got from Rivers state, followed by the Guava sample from Edo state. And this is due to the high value of radionuclide activity concentration in these fruits. The table also showed that the estimated internal Hazard index (H_{in}) values ranges from 0.22 to 0.7 with a total value of 2.06 and Radium equivalent (Ra_{eq}) ranges between 58.55 and 148.78 and a total value of 491.85.

Table 4. showed the average activity concentration of radionuclides, Gamma representative index level and Alpha representative index level in the sampled fruits. The average activity concentration for ^{40}K ranges between 54.66 $Bqkg^{-1}$ and 135.49 $Bqkg^{-1}$, ^{226}Ra ranges from 108.51 $Bqkg^{-1}$ to 21.77 $Bqkg^{-1}$ and ^{232}Th ranges from 23.97 $Bqkg^{-1}$ to 18.90 $Bqkg^{-1}$. While the total values of the radionuclides ranges from 21.40 $Bqkg^{-1}$ for ^{232}Th to 96.32 $Bqkg^{-1}$ for ^{40}K, the average activity concentration of ^{226}Ra is lower than ^{40}K but higher than ^{232}Th in the sampled fruits.

The Gamma representative index value is highest in Apricot and lowest in Avocado and has the total value of 3.431 $Bqkg^{-1}$. The Alpha representative index is greater in Apricot, followed thus; Gauva, pear, Avocado. However, the estimated total Alpha representative index value is above the recommended value of 0.1 $Bqkg^{-1}$ by World Health Organization (WHO).

Table 5. showed the estimated radiological parameters; Annual Effective Dose (AED), annual gonadal equivalent dose (AGED) and excess lifetime cancer risk (ELCR) for different age categories from various fruit samples. In more than 60% of the sampled fruits, AED is greater in Infants. Also, the total value of the AED is 2.2341 μSvy^{-1} this means that when all the sampled fruits from different states are consumed, the Annual effective dose value will be above the permissible value of $1mSvy^{-1}$ (1000 μSvy^{-1}) set by ICRP [13]. The Excess Lifetime Cancer Risk (ELCR) for Infants, Children and Adults in the study area is presented in the above table. The ELCR due to ingestion of Avocado by Infants, Children and Adults is very low compared to Pear, Guava and Apricot respectively. Variations in the values of the ELCR due to ingestion of fruits are due to the different conversion factors for different age category. This is in agreement with Priharti, et al [14-30]. Also the internal hazard index for all the fruits from different states in Niger Delta showed that the internal hazard due to Apricot is very high.

Figs. 2 to 5 showed the comparison of the estimated radiological parameters with standards.

Fig. 2 showed the comparison of estimated radium equivalent value with world standard and all the estimated radium equivalent values for the sampled fruits are below the acceptable limit. That is, they are within the acceptable world value recommended by UNSCEAR.

The comparison of estimated annual effective dose (AED) for different age categories with world standard is shown in Fig. 3. The AED due to ingestion of Avocado from Imo, Guava from Bayelsa, Delta, and Akwa-Ibom, Pear from Abia, Cross-River, Edo and Imo states are within the world acceptable standard of $1mSvy^{-1}$ (1000 μSvy^{-1}) set by ICRP. However, the AED due to the ingestion of Apricot from Edo and Rivers, Guava from Edo and Rivers, and Pear from Rivers states are very high compared to the world standard. The values are above the world standard and as such could cause internal radiation exposure if consumed unwittingly. Generally, the average annual effective dose due to ingestion of Apricot, Guava and Pear are above world acceptable limit of 0.29 $mSvy^{-1}$. These comparisons are necessary in order to show the true radiological conditions (dangers or benefits) associated with the sampled fruits from the Niger Delta. From this result, the consumption of Apricot, Guava and Pear, mostly, by children should be minimized to avoid over-exposure.

Figs. 4 showed the comparison of estimated average annual gonadal equivalent dose (AGED) for different age categories with world standard. In all the sampled fruits, the AGED for infants and adults are within (below) the world acceptable limit. But the average AGED value in Children due to ingestion of Apricot is above the world standard. This high level of annual gonadal equivalent dose in children is due to the high level of activity of radionuclides (Potassium-40, Radium-226 and Thorium-232) in Apricot. However, this further implies that children should avoid excessive consumption of Apricot to avoid internal exposure.

Fig. 5 showed the comparison between estimated excess lifetime cancer risk (ELCR) due to the radionuclide concentration in the fruits with world standard. All the estimated excess lifetime cancer risk ELCR due to the ingestion of various sampled fruits are lower than the acceptable limits with comparison to WHO standard of 0.3.

However, the estimated radiological parameters from the activity concentration of the radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in sampled fruits are compared with the world standards and the results indicates that the value of radiological parameters due to ingestion of various fruits from Niger Delta by different age categories are affected by the age and type of fruit consumed. The radionuclide activity concentration in Apricot is very high, then followed by Guava and Pear. These high values of activity concentration of the radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in Apricot, Guava and Pear are attributed to their rooting system and to technically enhanced naturally occurring radionuclides (TENORMs) released into the Niger Delta environment by the oil and gas industries and fertilizer companies in the region. Thus, the activities of these industries in one way or the other increase the concentration of radionuclides in the environment by increasing background radiation. The overall results of estimated radiation hazard indices and associated potential radiological risk of some fruits that are produced in Niger Delta are higher than the permissible world standard. Hence there is need to safeguard the Niger Delta environment from further degradation.

5. CONCLUSION

The Assessment of radionuclides in some fruits from Niger Delta Nigeria was investigated and the result showed as follows:

1. The natural radionuclides (^{40}K, ^{226}Ra and ^{232}Th) are present in the fruits that are produced in the Niger Delta of Nigeria.
2. The activity concentration of ^{40}K is higher than ^{226}Ra and ^{232}Th in fruits that are produced in Niger Delta.
3. Apricot, also commonly called monkey kolanut has a very high activity concentration, thus its annual gonadal equivalent dose, internal hazard index, Alpha representative index and annual effective dose for various age categories are much higher than the world acceptable limits for fruits according to UNSCEAR, WHO and other radiation regulatory agencies.
4. The annual gonadal effective dose in different age categories due to ingestion of Apricot, Guava and Pear produced in Edo and Rivers states are higher than the world recommended acceptable limit. While the annual gonadal effective dose of other fruits such as Avocado for different age categories, from the Niger Delta are lower than acceptable limit for fruits.
5. The annual effective doses of some sampled fruits are below the world acceptable limit. Also, the estimated values of excess lifetime cancer risk for different age categories due to ingestion of fruits from Niger Delta are below (within) the acceptable limit.
6. The activity concentration of ^{232}Th in each fruit is lowest. That is, the activity concentration of ^{232}Th is low when compared with the activity concentration and radiological parameters of ^{226}Ra and ^{40}K in each fruit.
7. The estimated average of the radiological parameters for all the sampled fruits is

lower than the world standard in each case. The implication is that if all the fruits from the Niger Delta are consumed by an individual the value of the excess lifetime cancer risk is very small compared to the world standard. Also, the radium equivalent is below the world standard.

8. The activity concentrations of the identified radionuclides ^{40}K, ^{226}Ra and ^{232}Th in Apricot, Guava and Pear that are produced in the Niger Delta, Nigeria are very high.

Therefore, further studies should be carried out on the Radionuclide content of the soil where those fruits were collected.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. UNSCEAR. Sources and effects of ionizing radiation, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, with scientific annexes, United Nations, New York; 2008.
2. Zakariya NI, Kahn M. Benefits and Biological effect of ionizing. Radiation Scholars Academic Jounl of Biosciences (SASIS). 2014;2(9):583-591.
3. Abojassim AA, Al-Gazaly HH Kadhim SH. Estimated radiation hazard indices and ingestion effective dose in wheat flour samples of Iraq markets. International Journal of Food Contamination, 2014;1(6):1-5.
4. Avwiri GO, Osaralube E, Alao A. Adewumi. Assessment of norm-containing food crops/stuffs in OML 58 & OML 61 within the Niger delta region of Nigeria. Indian J. Innovations Dev. 2012;1 (1).
5. Carini F, Brambilla M, Mitchell NG, Tsukada H. Radionuclides Behavior in Fruit Plants. T. Takahashi (ed.), Radiological Issues for Fukushima's Revitalized Future; 2016. DOI:10.1007/978-4-431-55848-4_14.
6. Desideri D, Meli M, Roselli C, Forini N, Rongoni A, Feduzi L. Natural radionuclides in Italian diet and their annual intake. Journal of Radioanalytical and Nuclear Chemistry. 2014;299(3):1461-1467.
7. Askari M. Advantages of gamma radiation in science and industry. Journal advanced physical American scientific publishers United State of America. 2014;3:1-7.
8. Islam A, Begum A, Yeasmin S, Sultana MS. Assessment of dose due to natural radio-nuclides in vegetables of high background radiation area in south-eastern part of Bangladesh. International Journal of Radiation Research. 2014;12(3):271-275.
9. Cumhur C, Mahmut D. A preliminary study on ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs activity concentrations in vegetables and fruits frequently consumed by inhabitants of elazıgˇ region, turkey. Journal of Radioanalytical and Nuclear Chemistry, 2013;295(2):1245-1249.
10. Sowole O, Olaniyi OE. Assessment of Radioactivity Concentrations and Effective of Radionuclides inSelected Fruits from Major Markets at Ijebu – Ode in Ogun State, Southwest of Nigeria. J. Appl. Sci. Environ. Management. 2018;22 (1):95-98.
11. Muhammad R, Saeed UR, Muhammad B, Wajid A, Iftikhar A, Khursheed AL, Khali AM, Matiullah. Evaluation of Excess lifetime cancer risk from gamma dose rates in jhelim valley. Journal of radiation research and Applied Sciences. 2014;7: 29-35).
12. Avwiri GO, Osarolube E, Alao AA. Assessment of Natural Radionuclide Content in Some Commonly Consumed Vegetables and Fruits in Oil Mining Lease (OML) 58 and 61, Oil and Gas Producing Areas in the Niger Delta Region of Nigeria Using Gamma-Ray. International Journal of Scientific Research. 2013;2(2).
13. Annals of the ICRP. PUBLICATION 103. The Recommendations of the International Commission on Radiological Protection. Elsevier; 2007.
14. Priharti W, Samat SB. Radiological risk assessment from the intake of vegetables and fruits in malaysia. Malaysian Journal of Analytical Sciences. 2016;20(6):1247–1253.
15. Abojassim AA, Hady HN, Mohammed ZB. Natural radioactivity levels in some vegetables and fruits commonly used in Najaf Governorate, Iraq. J. Bioen. Food Sci. 2016;3(3):113-123.
16. Avwiri OG, Agbalagba EO. Assessment of Natural radioactivity associated radiological health hazards indices and soil-to-crop transfer factors in cultivated area. Environmental Earth Sciences. 2014;71(4):1541-1549.

17. Choi MS, Lin XJ, Lee SA, Kim W, Kang HD, Doh SH, Kim DS, Lee DM. Daily intakes of naturally occurring radioisotopes in typical Korean foods. Journal of Environmental Radioactivity. 2008;99(8): 1319-1323.
18. Giri S, Singh G, Jha VN, Tripathi RM. Ingestion Of ^{238}U(nat), ^{226}Ra, ^{230Th} and ^{210}Po in Vegetables by adult inhabitants of Bagjata uranium mining area, Jharkhand, India. Journal of Radioprotection. 2010;45(2):P183-199.
19. Harb S. Natural Radioactivity Concentration and Annual Effective Dose in Selected Vegetables and Fruits. Journal of Nuclear and Particle Physics. 2015;5(3):70-73.
20. ICRP. Compendium of Dose Coefficients based on ICRP Publication 60: ICRP Publication 119. Oxford: Pergamon Press: 2012:71 - 86.
21. ICRP. Age-dependent doses to the members of the public from intake of radionuclides –Part 5. Compilation of ingestion and inhalation coefficients. ICRP Publication 72. Ann. ICRP 199; 26(1).
22. International Commission on Radiological Protection Age-dependent doses to members of the public from intake of radionuclides: part 5. Compilation of ingestion and inhalation dose coefficients. Annals of the ICRP 26(1). ICRP Publication 72. Pergamon Press, Oxford; 1996.
23. Ononugbo CP, Mgbemere CJ . Dose Rate and Annual Effective Dose Assessment of Terrestrial Gamma Radiation in Notre Fertilizer Plant. International Journal of Emerging Research in Management &Technology. 2016;5 (9).
24. Rumman M, Jannatul F, Aleya B, Aminul I. Natural Radionuclides Concentrations and Annual Effective Dose in Seasonal Fruits of Bangladesh. Nuclear Science. 2018;3(3):28-35.
25. Saeed MA, Zainal NJ, Hossain I, Javed MA, Mubarak AA. Measurements of natural radionuclides in vegetables by gamma spectrometry. Journal of Applied Spectroscopy. 2014;81(3):541 - 545.
26. Shanthi G, Maniyan CG, Allan Gnana Raj G, Thampi Thanka KJ. Radioactivity in food crops from high-background radiation area in southwest India, Current science. 2009;97(9):1331-1335.
27. UNSCEAR. Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly, with Scientific Annexes. United Nations. New York; 2016.
28. UNSCEAR. Report from 59th session May 2012, to UN General Assembly, November, 2012; Effects of ionizing Radiation; 2012.
29. Velasco H, Cid AS, Anjos RM, Zamboni CB, Rizzotto M, Valladares DL, Juri Ayub J. Variability of ^{137}Cs and ^{40}K soil-to-fruit transfer factor in tropical lemon trees during the fruit development period. Journal of Environmental Radioactivity. 2012;104; 64-70.
30. Avaialble:www.unscear.or/docs/reports/2008/09-86753_report_2008_Ga-Report_corr2.pdf.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/77873