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(RESEARCH ARTICLE)

Health risk assessment of radiation dose level in oranges and mangoes fruits from farms in Benue State, Nigeria

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Abstract

The health risk and radiation dose level in Oranges and Mangoes due to ingestion from farm locations in Benue State was assessed. A total of fifty (50) samples were collected in five different farm locations in Benue State, the samples were washed with distilled water to remove dirt, a radiation meter was placed 10cm from the fruits and measurements were taken for 30 seconds, background radiation levels and radiation dose level from the fruits were measured and calculated. The results showed that the radiation dose level for Oranges ranged from 1.489 to 2.365 mSv/hr and 1.122 to 1.899 mSv/hr for mangoes and the Annual Equivalent Doses (AED) for Oranges and Mangoes consumption was estimated to be 0.107 and 0.027 mSv/yr, respectively. Both values exceeded the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA) recommended limit of 1.0 mSv/yr. The high radiation levels could be attributed to naturally occurring radioactive materials in the soil or water, contamination from nearby sources. The Excess Lifetime Cancer Risk (ELCR) was calculated, with values of 0.2677 for Oranges and 0.683 for Mangoes, which are lower than the safe limit specified by WHO. While there is minimal risk associated with radiation exposure from consuming these fruits, further monitoring and investigation are necessary to ensure food safety and security in the study area.

Keywords: Radiation Dose level; Health risk; Excess Lifetime Cancer Risk (ELCR); Annual Effective Dose (AED)

1. Introduction

Natural radionuclides, such as 238U, 232Th, and 40K, are commonly found in the air, water, and soil. They enter plants through the absorption of nutrients and water from the soil by the roots and leaves. Consuming fruits is crucial as part of a balanced diet, as they are a significant source of essential nutrients. Living organisms are consistently exposed to ionizing radiation from Naturally Occurring Radioactive Materials (NORM), which can pose potential health risks when aided by natural processes such as weathering deposition and wind erosion (Wilson, 1993, Elles et al., 1997). These radionuclides, which are present almost everywhere, subject human beings to reasonable exposure. They can be found in soil, public water supplies, oil, and the atmosphere. Additionally, artificial sources of radionuclides, mainly from medical and industrial activities, contribute to human exposure. The accumulation of these radionuclides in the body can affect health conditions and may result in various diseases, weakening the immune system and contributing to an increase in mortality rate (Ali, 2008; Varier, 2009). Studies on radiation levels and radionuclide distribution in the environment are essential for estimating human exposure to natural and man-made sources of radiation. This information is necessary for establishing rules and regulations relating to radiation protection (Quindos et al., 1994). Radionuclides found in crops such as oranges and mangoes contribute to the radiation humans are exposed to, as these

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crops are an important part of the human diet and a source of essential nutrients. The ingested radionuclides could be concentrated in certain parts of the body for example ^{238}U accumulated in the human kidney and lungs, ^{232}Th in the liver, skeleton tissue, and lungs, and ^{40}K in muscles (Tawalbeh et al, 2012). The accumulation of these radionuclides in any organ in the body will affect the health condition which may result in inducing various forms of diseases, weakening the immune system, and also contributing to an increase in mortality rate. Natural sources of radiation are a combination of cosmic and terrestrial radiation representing the major part of radioactivity in the food chain. The radionuclides potassium-40, uranium-235, and -238 as well as products from these decay series such as radon-222, radium-226, and thorium-232 can be dated back to the beginning of the earth. Radionuclides such as ^{40}K, ^{and} ^{226}Ra that occur naturally in soil are incorporated metabolically into plants and ultimately find their way into food and water (Eisenbud & Gesell, 1997).

Agricultural practices, such as excessive use of fertilizers, can add radioactive elements to the soil, leading to the spread of radionuclides within the soil. Exposure to ionizing radiation from crops such as yams and cassava is a continuous and inevitable occurrence on Earth but can be minimized. It's important to note that there is a background of natural radiation everywhere in our environment, which comes from space (cosmic rays) and naturally occurring radioactive materials contained in the earth and living things (Hughes, 1997, Johns & Cunningham, 1983). Fasanmi et al. (2021) conducted a radiological assessment of fruits, vegetables, grains, and tuber crops in Okemesi township, Ekiti State, revealing mean activity concentrations of radionuclides in food samples and their associated annual effective dose. The study highlighted the importance of establishing rules and regulations related to radiation protection based on such information. Sowole et al. (2018) determined the concentrations of natural radionuclides in fruits from major markets in Ijebu-Ode town, Nigeria. The study found that the annual committed effective dose from consuming these fruits was below the globally recommended limit, indicating no radiological health hazard to consumers. Babatunde Ibikunle (2022) estimated the activity concentration of natural radionuclides in soil, leaf, and fruit samples of mango plants from Akure, Nigeria. The study concluded that while the mean radium equivalent and hazard indices were below the world average, the mean annual effective dose equivalent for different age groups from radionuclide ingestion through mango consumption was above the world average. Abojassim et al. (2016) measured the specific activity and annual effective dose of vegetables and fruits from the local market in Najaf governorate. The results showed that the specific activities and annual effective doses in all samples were lower than worldwide median values, indicating that the values are safe, these studies emphasize the need for regular radiological monitoring of food crops to ensure public health and safety.

Oranges and mangoes are some of the most consumed fruits in almost every household in Benue State of Nigeria, despite their potential health risk, little is known about the radiation levels in these fruits. Therefore, it is important to monitor and assess their radiation levels to avoid potential public health risks and inform policy and regulatory decisions regarding radiation exposure in agriculture to ensure the safety of the food supply. This work will serve as baseline data on the assessment of radiation levels in oranges and mangoes fruits to avoid the detriments and associated health risks from the resultant influence of soil radioactivity on fruits, thereby determining the safety of consumers of these particular fruits. It will also lay a foundation through which further investigation on the concentration of radionuclides present in oranges and mangoes can be determined. Necessary authorities can also take advantage of the findings for proactive measures to ensure the safety of these fruits.

1.1. Radioactive materials in the Earth and the body

Uranium, thorium, potassium etc. naturally found on the earth are called radioactive sources and are the source of terrestrial radiation. Trace amounts of uranium, thorium, and their decay products can be found everywhere. Terrestrial radiation levels vary by location, but areas with higher concentrations of uranium and thorium in surface soils generally have higher dose levels. Traces of radioactive materials can be found in the body, mainly naturally occurring potassium-40. Potassium-40 is found in the food, soil, and water we ingest. Our bodies contain small amounts of radiation because the body metabolizes the non-radioactive and radioactive forms of potassium and other elements in the same way (Groot, 2009).

1.1.1. Radiation doses

Radiation dose is a measurement of how much energy is deposited into a material from a source of radiation. Radiation dose is divided into three (3) namely; Absorb, effective and equivalent dose (Harb and El-Kamel., et al, 2008).

1.1.2. Absorbed dose (D)

Absorbed dose Is the energy (ΔE) deposited by ionizing radiation per unit mass of material (Δm). Its unit of measurement is grey (Gy). Mathematically, the absorbed dose is expressed as, Dose = $\frac{\Delta E}{\Delta m}$………………………………….. (1)

Where ΔE = is the change in energy and Δm = is the change in mass.

1.1.3. Equivalent dose (H)

Equivalent dose is defined as the product of the absorbed dose(D) and the radiation weighting factor. Mathematically, it is expressed as,

$H = D \times W_R$……………………….. (2)

Where D = is the absorbed dose and W_R = is the weighting factor. The unit of measurement is the sievert (Sv).

1.1.4. Effective dose (E)

Effective dose is defined as the sum of the products of the equivalent dose to each organ or tissue irradiated (H_T) and the "Corresponding weighting factor (W_T) for that organ or tissue.

$E\ (Sv) = \sum_T W_T H_T$ ………………………… (3)

Where W_T is the weighting factor and H_T is the target organ.

2. Materials and method

2.1. Study Area

Benue State is situated in the Benue Valley in the North Central region of Nigeria, it is inhabited by many tribes, with a population of 597,398 consisting of 357,295 males and 240,103 females (FGN, 2017). These tribes include Tiv, Idoma, Etilo, Jukun, Egede, Hausa, Yoruba, and Ibo, with the Tiv(s) being the dominant tribe. The population is largely engaged in civil service duties, commercial activities, and agrarian peasantry Farming and a built-up area with the highest concentration of people in Makurdi with annual rainfall between (150 -180) m and temperature of 26 °C-40 °C.

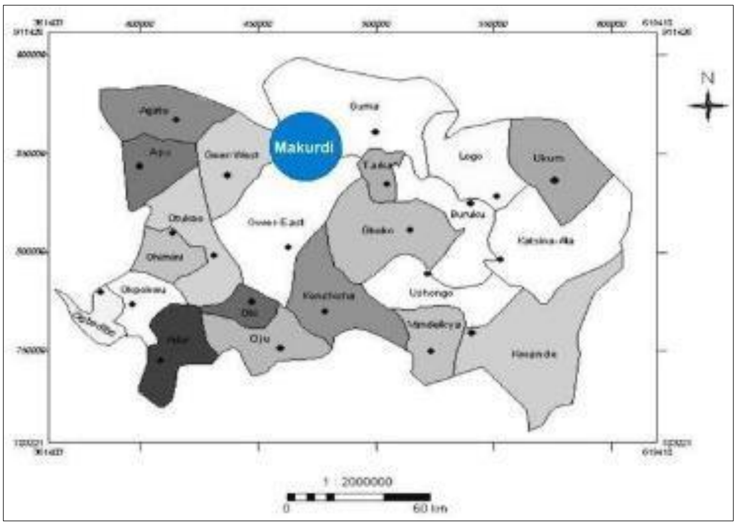

Figure 1 Map of Benue State (Retrieved from Research gate)

2.2. Parameter Experimental Procedure

The experimental procedures that were perform in this study are explained below step by step

2.2.1. Sample preparation and Analysis

The samples of different species of both oranges and mangoes, were collected from various Farm Locations in Vandiekya, Ushongo, Konshisha, Buruku and Gbok Local Government Area of Benue State. A total of fifty (50) samples were collected and brought to the physics laboratory of the Faculty of Science at Benue State University (BSU) in Makurdi. After collection, the samples were washed with distilled water to remove dirt and subsequently, the radiation level of the samples was measured using a radiation meter alert. The radiation meter was placed 10cm from the sample and the values were taken and recorded in every 30 seconds for each of the samples, and averages were calculated to get the values of background radiation from the samples. The difference between the background radiation and the radiation from the sample was calculated to give the radiation level of the sample in the study area.

3. Results

3.1. **Conversion of the measured radiation**

The values obtained for the assessment of radiation in milliroentgen per hour (mR/hr) were converted to micro-Sievert per hour (μSv/hr)

ZμSv/hr = Z mR/hr x 10 ……………………………… (4)

Where Z is the value of the measured radiation in mR/hr on the sample and 10 is the calibration factor for the radiation alert meter used.

3.2. Determination of Radiation dose Level (D) in mSv/hr and Background Radiation Level of Oranges and Mangos at different Farm Locations.

Since radiation rate measurements were made in μSv/hr by the survey meter, the dose level (D) was obtained by making proper unit conversions. To obtain radiation dose level (D) in mSv/yr, conversion was made as shown in the equation below

$$D\left(\frac{mSv}{y}\right) = \frac{D\left(\frac{\mu Sv}{h}\right)\left(\frac{24hrs}{d}\right)\left(\frac{365}{y}\right)}{10^3\left(\frac{\mu Sv}{mSv}\right)} \quad \text{………………………… (5)}$$

Table 1 Radiation Dose level of Oranges

Sample ID	Farm Locations	mR/hr	μSv/hr	Dose (mSv/yr)	USNRC (mSv/yr)
Org 1	Vandiekya	0.010	0.100	0.876	1.000
Org 2	Ushongo	0.008	0.080	0.701	1.000
Org 3	Konshisha	0.009	0.090	0.788	1.000
Org 4	Buruku	0.017	0.170	1.489	1.000
Org 5	Gboko	0.027	0.270	2.365	1.000

Table 2 Radiation Dose Level of Mangoes

Sample ID	Farm Location's	mR/hr	μSv/hr	Dose (mSv/yr)	USNRC (mSv/yr)
Man 1	Vandiekya	0.016	0.16	1.402	1.000
Man 2	Ushongo	0.011	0.11	0.964	1.000
Man 3	Konshisha	0.012	0.12	1.051	1.000
Man 4	Buruku	0.018	0.18	1.577	1.000
Man 5	Gboko	0.013	0.13	1.139	1.000

3.2.1. Assessment of Annual Effective Dose (AED) due to ingestion of Oranges and Mangoes, and the Excess Lifetime Cancer Risk (ELCR) to assess the potential health risks associated with consuming these fruits annually.

The effective dose is a useful concept in the radioactivity measurement that enables the summation of all radiations absorbed by different organs. The annual effective dose due to the ingestion of food contaminated with radiation was obtained from Equation 6 below.

$HT,r = \sum(U^i \times C_r^i) \times g_{Tr}$ ……………………………..(6)

Where i is the food group. U^i is the food consumption rate (kg/yr), C_r^i is the radiation concentration (Bq/kg), and g_{Tr} is the Dose coefficient ($5.9x10^{-9}$ $SvBq^{-1}$).

The U^i statistics used for the different crops in Nigeria were obtained from the Food Agricultural Organization (FAO). The U^i used for the different crops in Nigeria were 10 and 10kg/person/yr for Orange and Mango respectively.

3.2.2. Excess Life Cancer Risk (ELCR)

The excess lifetime cancer risk (ELCR) was calculated using the equation below:

ELCR = D_{ing} x D_L x R…………………………………. (7)

Where D_{ing} is the annual effective dose due to ingestion, D_L is the duration of life (50 years) (WHO 2018) and Risk factor R is $0.05Sv^{-1}$ which is fatal cancer risk per Sievert.

Table 3 Annual Effective Dose (AED) for Oranges and the Excess Lifetime Cancer Risk (ELCR)

Sample ID	Farm Locations	mR/hr	µSv/hr	Dose (mSv/yr)	AED (mSv/yr)	WHO (mSv/yr)	ELCR (mSv/yr)
Org 1	Vandiekya	0.010	0.100	0.876	0.096	1.000	0.2400
Org 2	Ushongo	0.008	0.080	0.701	0.0077	1.000	0.0193
Org 3	Konshisha	0.009	0.090	0.788	0.0086	1.000	0.0215
Org 4	Buruku	0.017	0.170	1.489	0.1630	1.000	0.4075
Org 5	Gboko	0.027	0.270	2.365	0.2600	1.000	0.6500

Table 4 Annual Effective Dose (AED) for Mangoes and the Excess Lifetime Cancer Risk (ELCR)

Sample ID	Farm Locations	mR/hr	µSv/hr	Dose (mSv/yr)	AED (mSv/yr)	WHO (mSv/yr)	ELCR (mSv/yr)
Man 1	Vandiekya	0.016	0.16	1.402	0.0123	1.000	0.0305
Man 2	Ushongo	0.011	0.11	0.964	0.0085	1.000	0.0215
Man 3	Konshisha	0.012	0.12	1.051	0.0920	1.000	0.2300
Man 4	Buruku	0.018	0.18	1.577	0.0138	1.000	0.0345
Man 5	Gboko	0.013	0.13	1.139	0.0100	1.000	0.0250

4. Discussion

4.1. Measured Radiation Dose Level in mSv/hr and Background Radiation Level of Oranges and Mangoes at different Farm Locations.

From Figure 2 and 3 below, it is evident that the assessment radiation dose levels in oranges and mangoes at various sample locations show variability. The radiation dose levels ranged from 1.489 to 2.365 mSv/hr, with doses in certain Farm locations exceeding the recommended limit of 1.0 mSv/yr set by the United States Environmental Protection Agency (USEPA) and Nigeria Nuclear Regulatory Authority (NNRA). This indicates potential health concerns for individuals consuming these fruits. The elevated radiation levels in the fruits may be attributed to the presence of naturally occurring radioactive materials in the soil or water, and possible contamination from nearby sources of radioactive materials. It is plausible that the high background radiation is linked to mineral deposits within the sample locations, as studies have shown that background radiation stems from natural mineral resources and, to a lesser extent, man-made activities.

4.2. Measured Annual Effective Dose (AED) due to ingestion of Oranges and Mangoes, and the Excess Lifetime Cancer Risk (ELCR) to assess the potential health risks associated with consuming these fruits annually.

Furthermore, from Figure 4 and 5, the annual effective dose for both oranges and mangoes was calculated, resulting in mean values of 0.107 and 0.027 mSv/yr, respectively. Comparing these values with the World Health Organization's (WHO) recommended limit of 1.0 mSv/yr, it is evident that the effective doses for both fruits are within safe limits. The excess lifetime cancer risk (ELCR) was also calculated for oranges and mangoes, yielding values of 0.2677 and 0.683, respectively. These values are lower than the recommended safe limit set by WHO. Consequently, while there is a minimal risk associated with radiation exposure from consuming these fruits, it is also important for consumers to be conscious of contamination from nearby sources of radioactive materials and improper storage or handling of the fruits.

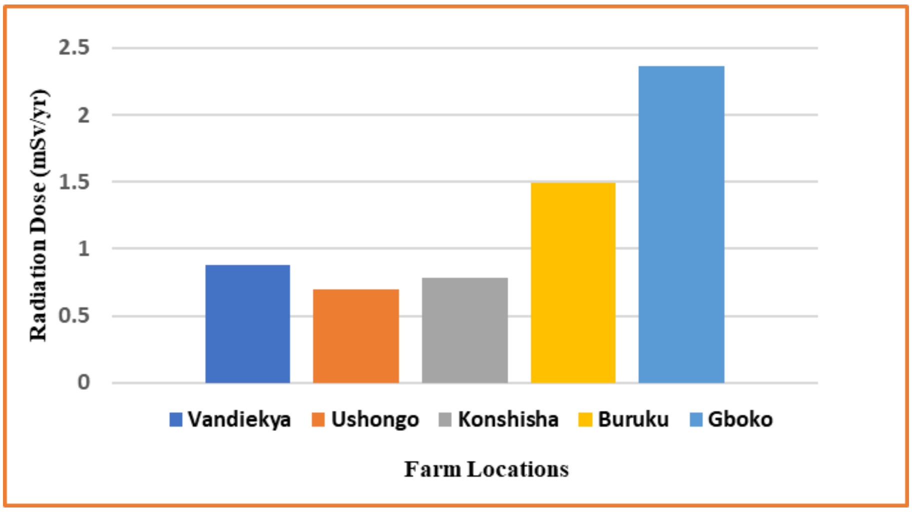

Figure 2 Radiation Dose Level of Oranges in µSv/yr with Farm Locations

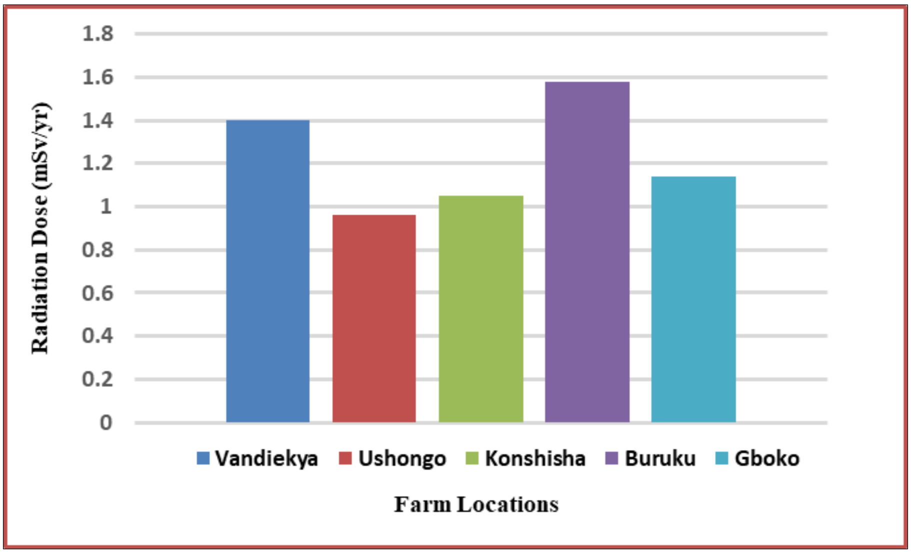

Figure 3 Radiation Dose Level of Mangoes in µSv/yr with Farm Locations

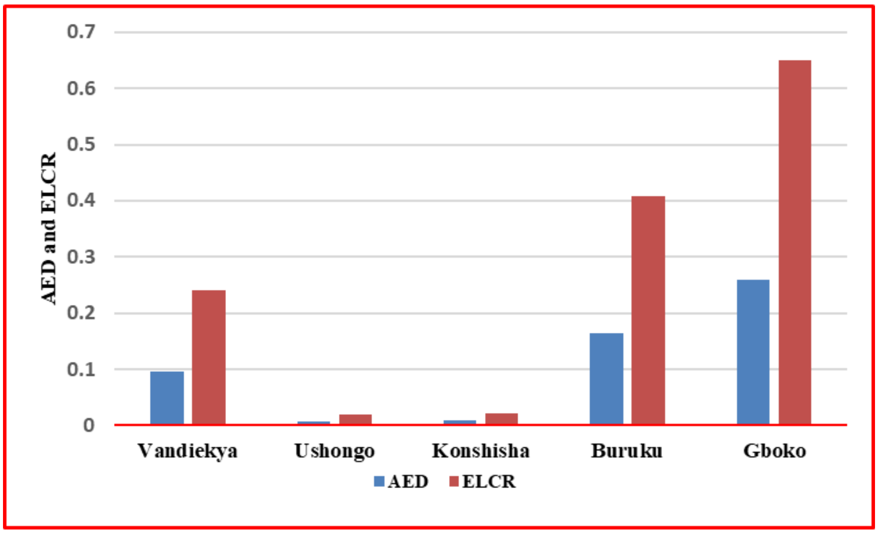

Figure 4 Annual Effective Dose (AED) and the Excess Lifetime Cancer Risk (ELCR) of Oranges with Farm Locations

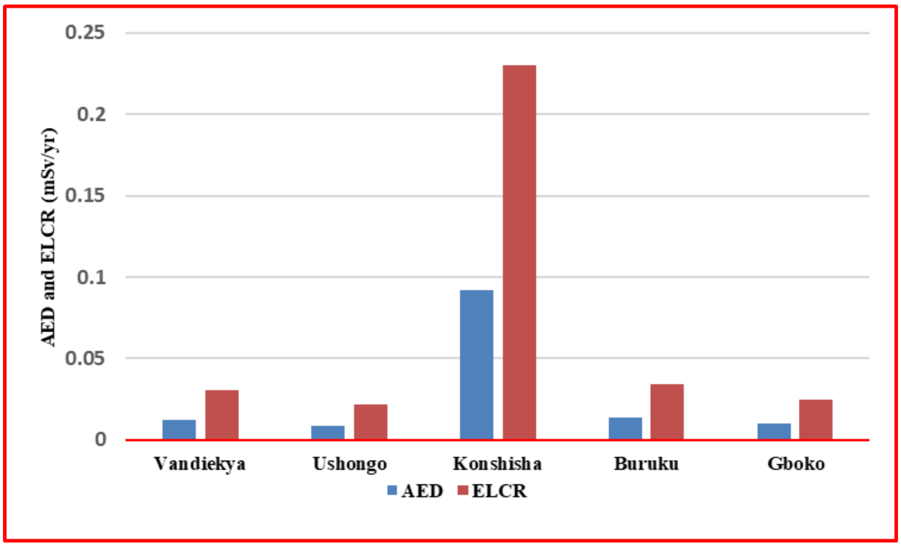

Figure 5 Annual Effective Dose (AED) and the Excess Lifetime Cancer Risk (ELCR) of Mangoes with Farm Locations

5. Conclusion

The investigation of the radiation dose levels of Oranges and Mangoes fruits was carried out using a radiation meter alert to measure the natural radiation dose present in the fruits and to evaluate the associated health risks. The findings revealed that the radiation dose levels in both oranges and mangoes fruits ranged from 1.489 to 2.365 mSv/hr in certain farm locations exceeding the recommended limit of 1.0 mSv/yr set for food safety as stipulated by established standard organizations. As a result, it is advisable to exercise caution when consuming these fruits due to the potential detrimental effects of prolonged radiation exposure on human health, including an increased risk of cancer. It is noteworthy that the Excess Lifetime Cancer Risk (ELCR) values calculated for both Orange and Mango fruits were 0.2677 and 0.683 respectively which comparatively is small for the risks associated with radiation dose level, which is estimated at approximately 2.4mSv/yr according to the International Commission on Radiological Protection (ICRP).

By the standards set by national and international Organizations such as the World Health Organization (WHO), the U.S. Nuclear Regulatory Commission (USNRC), and the U.S. Environmental Protection Agency (USEPA), it was observed that the radiation level of oranges is generally lower, while that of mangoes is higher. Despite the relatively small ELCR values calculated for both fruits, it is essential to consider the cumulative effects of radiation exposure over time. In scenarios where individuals consume multiple fruits with similar radiation levels, there exists the potential for an increase in total radiation exposure, the study highlights the importance of assessing the radiation levels in fruits and the potential health implications associated with their consumption, it also, emphasizes the need for vigilance in regulating the intake of these fruits, especially in light of their radiation levels exceeding recommended safety limits and the potential cumulative effects of radiation exposure over time.

Compliance with ethical standards

Disclosure of conflict of interest

Authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in collaboration among all authors. Author RMA, PEO and OSO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MIA, EA, EEO and FEW managed the research analyses and the literature searches. All authors read and approved the final manuscript.

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