Evaluation of Natural Radioactive Dose Levels and Associated Annual Effective Dose Rates in Ingested Foodstuffs at Abuja, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author DOS designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Authors DOS and AFA managed the analyses of the study. Authors DOS and AFA managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Measurement of radioactive contamination in some commonly consumed foodstuffs within the six area councils of Abuja, Nigeria was conducted in this study by means of a very sensitive and portable 3M/3-X Geiger Müller counter-based environmental radiation dosimeter. Eight different food samples were randomly selected in each of the sample locations making a total of 48 foodstuffs samples surveyed across the six area councils. The results obtained show that, the range of radiation dose levels in the analyzed samples varied from 0.0159 ± 0.0001 to 0.3407 ± 0.0002 μSv y⁻¹ at Bwari; 0.1490 ± 0.0001 to 0.3902 ± 0.0002 μSv y⁻¹ at AMAC; 0.0095 ± 0.0001 to 0.0209 ± 0.0001 μSv y⁻¹ at Gwagwalada; 0.0057 ± 0.0001 to 0.0133 ± 0.0002 μSv y⁻¹ at Kuje; 0.0274 ± 0.0001 to 0.2271 ± 0.0002 μSv y⁻¹ at Abaji; Kwali was between 0.0182 ± 0.0001 and 0.3503 ± 0.0002 μSv y⁻¹, and their corresponding arithmetic mean are 0.1690 ± 0.0001 μSv y⁻¹, 0.2256 ± 0.0001 μSv y⁻¹, 0.0133 ± 0.0001 μSv y⁻¹, 0.0088 ± 0.0001 μSv y⁻¹.

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1. INTRODUCTION

Human body is permanently irradiated from external and internal ionising radiation sources. External radiation sources can either be natural (cosmic, earth) or artificial, which are of equal peril to man [1]. Currently, almost all the radionuclides of interest in the case of contaminating events are substantially present in foods. Natural radioactive elements are transferred and recycled through natural processes and between the various environmental compartments by entering into ecosystems and human food chains. The levels at which naturally occurring radionuclides \( ^{40}\text{K}, {}^{210}\text{Po}, {}^{222}\text{Rn}, {}^{228}\text{Ra}, {}^{240}\text{Pu}, {}^{261}\text{Am}, {}^{89}\text{Sr}, {}^{131}\text{I}, {}^{238}\text{U}, {}^{232}\text{Th}, {}^{210}\text{Pb}, {}^{137}\text{Cs}, {}^{14}\text{C} \) etc.) found in food products differ greatly [2-5]. Contamination of the food chain occurs due to direct deposition of these radioactive elements on plants leaves, fruits, tubers, root uptake from contaminated soil or water, and animals ingesting contaminated plants, soil or water. The more radiation dose a person receives, the greater the chance of developing erythema, leukaemia, malignancy, eye cataracts, haematological depression and incidence of chromosome aberrations [6]. At low doses connected with the consumption of contaminated food, the most relevant health effect of ionising radiation presently is assumed to be an increased risk of malignancy [6]. It has been estimated that at least one-eighth of the average annual effective dose due to natural sources is caused by the consumption of foods [7]. Potassium \( ^{40}\text{K} \) normally gives the largest radiation dose from food to the most population. Polonium \( ^{210}\text{Po} \) is the second most important contributor to the radiation dose from food to the average population, which occur in relatively high concentrations in seafood [6]. Population subgroups with specific foodstuffs consumption patterns may also have higher exposure to radioactive elements. The deleterious radiological health hazards posed by human activities, especially in the production of energy, research, the medical application of nuclear facilities and oil and gas extraction and production have attracted great concern and tremendous interest over the years in the field of radiation protection [8-9]. Several studies have reported various efficient ways of reducing radioactivity concentration levels in local food, and significant amounts of food products have, therefore, been saved for the food market [2-4, 10-13,14]. Our target in this work is to evaluate the possible effect of radiation dose levels from human cooked foods in restaurants and the consequent annual dose rates across the six area councils of the Federal Capital Territory, Abuja, Nigeria. The dose criterion of 1.0 mSvyr\(^{-1} \) was considered as annual dose limit to fulfil radiation protection of the general public and workers. This work is relevant because it presents a pioneering radioactive data that could also be used as baseline data for radiation impact for the estimation of internal radiation dose within the study area.

2. MATERIALS AND METHODS

2.1 Study Area

The Federal Capital Territory, Abuja, Nigeria lies between the latitude of 8°25’N to 9°25’N of the equator and longitude 6°45’E to 7°45’E of the Greenwich Meridian, and at an elevation of 2760ft above sea-level. The area is bounded by Kaduna State to the North, Kogi State to the South, Niger State to the West, and Nasarawa State to the East (Fig. 1). Abuja has six local area councils, which includes: Bwari, Abuja Municipal Area Council (AMAC), Gwagwalada, Kuje, Abaji, and Kwali. The area has a land area of about 7315 km\(^2 \), which is nearly 0.79% of Nigeria total land area, and it is situated within the savannah region with moderate climate conditions [15].
2.2 Samples Collections and Preparation

An approximate amount of 48 different kinds of human cooked foodstuffs samples were collected from the six area councils for analysis and the average value of five replicas of their respective radiation dose levels and annual effective dose rates were computed. Each sampled material of 0.5 kg – 2 kg was transferred into a Marinelli beakers with the content tightly sealed using adhesive tape after collection. This is done to prevent the effect of atmospheric humidity as well as control elevated emissions of radionuclides. The samples were tested for radiations when hot (50°C-80°C), and kept for some time to cool down, and thereafter; then tested for radiations again when cold (23°C-26°C). The radioactive contamination detector (3M/3-X Geiger Müller counter) was used to ascertain the radiation exposure dose levels in the collected food samples by applying the direct measurement technique of concentrations (i.e., measurement of radioactivity in which the radioactivity from a relatively large sample can be placed close to the detector). Background counts of the system were observed and the average of the counts was taken as the background counts without inserting any radioactive source in the tube holder. About 0.5 kg each, of fresh samples, were then collected on an equal sized paper that fits in the tube. The weight of these samples, to the nearest 0.001 kg, were determined using a sensitive electric weighing balance before inserting them into the tube. Measurement of the detected radiation dose acquired after a time of 60 seconds was displayed on the digital display visual readout. The counting was repeated five times. The gross
counts per minute (cpm) observed with the source were deducted from the mean value of the background counts to arrive at the counts per minute (cpm). The net counts and exposure doses of each foodstuffs samples were estimated using equations (1) and (2):

\[
\text{Net counts} = \text{Raw count rate (cpm)} - \text{Background count rate (cpm)}
\]

(1)

\[
\text{RE}_D = \sum_{i=1}^{N} \left( \frac{C_i \times CR_j \times E_F}{B_M} \right)
\]

(2)

Where, \( \text{RE}_D \) is the radiation exposure dose, \( CR_j \) is the consumption rate of food group (gday\(^{-1}\)), \( C_i \) is the concentration level (mgg\(^{-1}\)), \( B_M \) is the body mass (kg), \( E_F \) is the exposure factor (dimensionless), and \( N \) is the total number of food samples. The annual effective dose rate was computed using the relation [7,17]:

\[
A_{DR} = E_{DR} \times 1.21 \times 10^{-3} \text{ (mSv y}^{-1})
\]

(3)

Where, \( A_{DR} \) is the annual effective dose rates (mSv y\(^{-1}\)), and \( E_{DR} \) radiation absorbed dose rates (\( \mu \text{Gy hr}^{-1} \)). Radiation doses ingested are obtained by measuring radionuclide activity in foodstuffs and multiplying these by the masses of food consumed over a period of time. Hence, doses from each ingested radionuclide and foodstuffs were estimated using the following equation:

\[
D_{\text{ing}} = DC_{\text{ing}} \times A_{i} \times TF_{F} \times D_{d}
\]

(4)

Where, \( D_{\text{ing}} \) is the dose from each ingested radionuclide and foodstuffs (Sv y\(^{-1}\)), \( DC_{\text{ing}} \) is the dose coefficient for ingestion for the radionuclide (Sv Bq\(^{-1}\)), \( A_{i} \) is the average annual intake of the foodstuffs (kg y\(^{-1}\)), \( TF_{F} \) is the transfer factors for the foodstuffs (m\(^2\) kg\(^{-1}\)), and \( D_{d} \) is the deposition density (Bq m\(^{-2}\)).

3. RESULTS AND DISCUSSION

The computed results of determined radiation dose levels and annual effective doses rate evaluated from this study were based on the characterisation of the detector in the 48 different foodstuffs samples chosen from the six area councils. The graphical representation of the measured radiation dose levels found in the food samples is illustrated in Figs. 2-7. The average radiation dose levels and annual effective doses rate for all the samples locations were indicated in Figs. 8 - 10 with their error bar denoting the standard deviation of the average.

**Fig. 2. Radiation dose levels of the food samples at Bwari**
Figs. 2 - 8 present the human radiation exposure dose levels from food samples in this study. The range of the radiation dose levels for each of the sample location is estimated to range from $0.0159 \pm 0.0001$ to $0.3407 \pm 0.0002 \ \mu$Sv/hr⁻¹ with arithmetic mean of $0.1690 \pm 0.0001 \ \mu$Sv/hr⁻¹ for Bwari; $0.1490 \pm 0.0001$ to $0.3902 \pm 0.0002 \ \mu$Sv/hr⁻¹ with an arithmetic mean of $0.2256 \pm 0.0001 \ \mu$Sv/hr⁻¹ for AMAC; $0.0095 \pm 0.0001$ to $0.0209 \pm 0.0001 \ \mu$Sv/hr⁻¹ with an arithmetic mean of $0.0133 \pm 0.0001 \ \mu$Sv/hr⁻¹ for Gwagwalada; $0.0057 \pm 0.0001$ to $0.0133 \pm 0.0002 \ \mu$Sv/hr⁻¹ with an arithmetic mean of $0.0088 \pm 0.0001 \ \mu$Sv/hr⁻¹ for Kuje; $0.0274 \pm 0.0001$ to $0.2271 \pm 0.0002 \ \mu$Sv/hr⁻¹ with an arithmetic mean of $0.1360 \pm 0.0001 \ \mu$Sv/hr⁻¹ for Abaji; and for Kwali it was between
0.0182±0.0001 and 0.3503±0.0002 μSv·y⁻¹ with an arithmetic mean of 0.1237±0.0001 μSv·y⁻¹. The corresponding estimated annual effective dose rates for each sample locations were 0.1885±0.0003 mSv·y⁻¹, 0.2576±0.0001 mSv·y⁻¹, 0.1170±0.0001 mSv·y⁻¹, 0.0771±0.0001 mSv·y⁻¹, 0.1553±0.0002 mSv·y⁻¹, and 0.1412±0.0001 mSv·y⁻¹ respectively. The result revealed that the foodstuffs samples in AMAC have the higher radiation exposure dose levels, which was caused as a result of the high dose concentration level in Jollof rice (0.3902±0.0002 μSv·y⁻¹) in this location. Jollof rice at AMAC was followed by Bwari, Abaji and Kwali, with

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**Fig. 5. Radiation dose levels of the food samples at Kuje**

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**Fig. 6. Radiation dose levels of the food samples at Abaji**

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Gwagwalada and Kuje having the least radiation dose levels. The values of the radiation dose levels of all the food samples in each of the samples locations indicated that all foodstuffs samples selected and analysed are within the region of accepted limit for food samples of 2.4 mSv\(^{-1}\) set by UNSCEAR [7] and general public dose limit of 1.0 mSv\(^{-1}\) [8,18-20]. The highest associated annual dose rates were observed in descending order on sample locations at AMAC (28%), Bwari (20%), Abaji (17%), Kwali (15%), Gwagwalada (12%), and Kuje (8%) (Figs. 9-10). The high radiation dose levels and associated annual effective dose rates recorded from the
food samples obtained from AMAC might be due to the high concentration of radioactive elements in the food samples as a result of the presence of abundance radioactive minerals such as kaolinite, feldspars, zircon, thorianite, monazite, carnottite, torbernite, uraninite etc. It is worth noting that AMAC is an industrial location, where most activities in the Federal Capital Territory, Abuja, Nigeria are carried out and the majority of the restaurants are located. The radioactive dose levels concentration order recorded in Bwari, Abaji, Kwali, and Gwagwalada, followed by Kuje with the least radioactive dose concentration could be due to the application of potassium ($^{40}$K)

![Fig. 9. Annual dose rates of the food samples for all the sample locations](image1)

![Fig. 10. Percentage Annual Dose Rates of the food samples for all the sample locations](image2)
based fertiliser for the improvement of food crop, soil type and irrigation pattern. The obtained values were, however, sufficiently low, compared to the maximum recommended global average exposure dose limit for environmental background (2.4 mSv y⁻¹) [7] and general public dose limit (1.0 mSv y⁻¹) [20]. Thus, no radiological hazard is envisaged to the populace of this sample locations. The food samples are, therefore, safe and generally acceptable for consumption.

4. CONCLUSION

The radioactive doses in human foodstuffs samples in some major selected restaurants across the six area councils of the Federal Capital Territory, Abuja, Nigeria have been estimated in this study and the associated annual effective dose rates were computed. The results indicate that all the foodstuffs samples across the study area are not harmful, as they are not acted upon by the radiation exposure dose levels and annual effective dose rates. This is because the computed values are sufficient falls within the recommended global average exposure dose limit for environmental background (2.4 mSv y⁻¹) and general public dose limit (1.0 mSv y⁻¹). The intake of foodstuffs in the sample locations, therefore, does not pose any immediate radiological health hazard to the populace. The data obtained can, therefore, be used as a baseline for radiation impact for the estimation of internal radiation dose within the study area.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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