

Original Research Article

EVALUATION OF NATURAL RADIOACTIVE DOSE LEVELS AND ASSOCIATED ANNUAL DOSE RATES OF HUMAN EXPOSURE TO CONTAMINANTS IN FOODS IN ABUJA, NIGERIA

ABSTRACT

Measurement of radioactive contamination in some commonly consumed food samples within the six area councils of Abuja, Nigeria were conducted in this study by means of a very sensitive and portable 3M/3-X Geiger Müller counter-based environmental radiation dosimeter. Eight (8) different food samples were randomly selected in each of the sample locations making a total of forty-eight (48) food samples surveyed across the six area councils. The results obtained shows that, the range of radiation dose levels in the analyzed samples varies from 0.0159 ± 0.0001 to $0.3407 \pm 0.0002 \mu\text{Svy}^{-1}$ at Bwari; 0.1490 ± 0.0001 to $0.3902 \pm 0.0002 \mu\text{Svy}^{-1}$ at AMAC; 0.0095 ± 0.0001 to $0.0209 \pm 0.0001 \mu\text{Svy}^{-1}$ at Gwagwalada; 0.0057 ± 0.0001 to $0.0133 \pm 0.0002 \mu\text{Svy}^{-1}$ at Kuje; 0.0274 ± 0.0001 to $0.2271 \pm 0.0002 \mu\text{Svy}^{-1}$ at Abaji; and at Kwali it was between 0.0182 ± 0.0001 and $0.3503 \pm 0.0002 \mu\text{Svy}^{-1}$, and their corresponding arithmetic mean are $0.1690 \pm 0.0001 \mu\text{Svy}^{-1}$, $0.2256 \pm 0.0001 \mu\text{Svy}^{-1}$, $0.0133 \pm 0.0001 \mu\text{Svy}^{-1}$, $0.0088 \pm 0.0001 \mu\text{Svy}^{-1}$, $0.1360 \pm 0.0001 \mu\text{Svy}^{-1}$, and $0.1237 \pm 0.0001 \mu\text{Svy}^{-1}$, which gives estimated annual dose rates of $0.1885 \pm 0.0003 \text{mSvy}^{-1}$, $0.2576 \pm 0.0001 \text{mSvy}^{-1}$, $0.1170 \pm 0.0001 \text{mSvy}^{-1}$, $0.0771 \pm 0.0001 \text{mSvy}^{-1}$, $0.1553 \pm 0.0002 \text{mSvy}^{-1}$, and $0.1412 \pm 0.0001 \text{mSvy}^{-1}$. This findings reveals that, the obtained values were sufficiently less than the maximum recommended global average exposure dose limit for environmental background (2.4mSvy^{-1}) [7] and public dose limit (1.0mSvy^{-1}) [19], hence radiation dose levels and dose rates associated with the intake of contaminated food in this work are generally relatively low and will not pose any immediate radiological health hazard to the populace, deterministic radiation effects may occur only in extreme cases.

Keywords: Natural radioactivity, Food, Radiation, Annual dose rates, Geiger Müller counter.

1. INTRODUCTION

Human body is permanently irradiated from external and internal ionizing radiation sources. External radiation sources can either be natural (cosmic, earth) or artificial, which are of equal peril to man [1]. The radionuclides of interest in the case of contaminating events are almost all present now in foods in measurable quantities. 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 radioactive elements (^{40}K , ^{210}Po , ^{222}Rn , ^{228}Ra , ^{240}Pu , ^{241}Am , ^{90}Sr , ^{131}I , ^{238}U , ^{232}Th , ^{210}Pb , ^{137}Cs , ^{14}C etc.) found in food products differ greatly [2-

5]. Contamination of the food chain occur 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 erithemia, leukemia, malignancy, eye cataracts, hematological depression and incidence of chromosome aberrations. At low doses connected with the consumption of contaminated food, the most relevant health effect of ionizing radiation presently is assumed to be an increased risks 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]. ^{40}K normally gives the largest radiation dose from food to the most population. ^{210}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. The presence of ^{222}Rn in drinking water from wells drilled in bedrock is unevenly distributed, being based on the type of supply and geographical variations, resulting to great differences in exposure among the population. Population sub-groups with specific food 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, 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 in reducing radioactivity concentration levels in local food, and significant amounts of food products have been saved for the food market [2-4, 10-13, 20]. Our target in this work is to evaluate the possible effect of radiation doses levels from human cooked foods in restaurants and the consequent annual dose rates across the six area councils of Federal Capital Territory, Abuja, Nigeria. The dose criterion of 1.0mSvyr^{-1} was considered as annual dose limit to fulfill radiation protection of the public and workers. This work is so 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. MATERIAL AND METHODS

2.1 Study Area

The Federal Capital Territory, Abuja lies between the latitude of $8^{\circ}25'N$ to $9^{\circ}25'N$ of the equator and longitude $6^{\circ}45'E$ to $7^{\circ}45'E$ of Greenwich Meridian, and at an elevation of 2760ft above sea-level, bounded by Kaduna State to the North, Kogi State to the South, Niger State to the West, and Nasarawa State to the East (Figure 1). Abuja has six local area councils, which includes: Bwari, Abuja Municipal Area Council (AMAC), Gwagwalada, Kuje, Abaji, and Kwali and land area of about 7315km^2 , nearly 0.79% of Nigeria total area, and it is situated within the savannah region with moderate climate conditions [14].

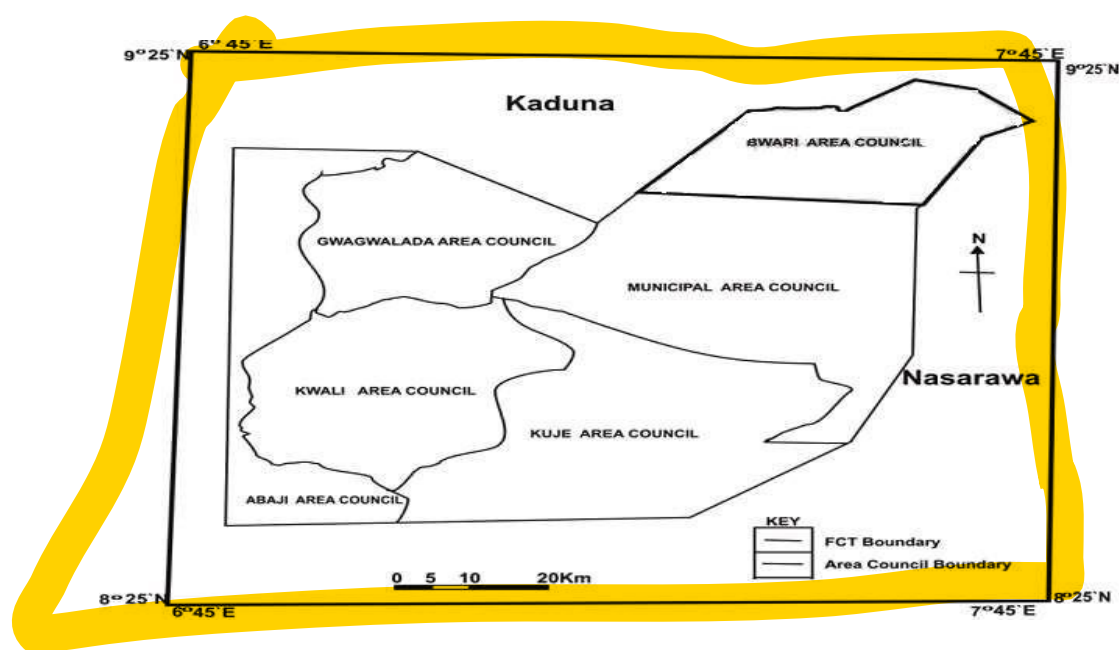


Fig. 1. The map of Abuja indicating the six local area councils [14-15].

2.2 Samples Collections and Preparation

Since Fukushima accident, much interest has been developed in the application of checking food and water for possible radiation contamination, but a very slight studies of radioactivity in human cooked foods in restaurants have been carried out in Abuja, Nigeria. Therefore, an approximate amount of forty-eight (48) different kinds of human cooked foods samples were randomly selected from the six area councils for analysis and the average value of five replicas of their respective radiation dose levels and annual dose rates were computed. The samples were detected for radiations when hot and were kept for some time to cool down, thereafter, they were detected for radiations again when cold. 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. 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. Each samples were then collected on an equal sized paper that could fit in the tube and immediately, a sensitive electric weighing balance was used to determine their weight before inserting them into the tube and 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 for 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 contaminant food samples were estimated with the following formula:

$$\text{Net counts} = \text{Raw count rate (cpm)} - \text{Background count rate (cpm)} \quad (1)$$

$$RE_D = \sum_{j=1}^N \left(\frac{C_L \times CR_j \times E_F}{B_M} \right) \quad (2)$$

Where, RE_D is the radiation exposure dose, CR_j is the consumption rate of food group (g/day), C_L is the contaminant concentration (mg/g), 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 dose rate was computed using the relation [7, 16]:

$$A_{DR} = E_{DR} \times 1.21 \times 10^{-3} (\text{mSvy}^{-1}) \quad (3)$$

Where, A_{DR} is the annual dose rates (mSvy^{-1}), and E_{DR} radiation absorbed dose rates (ηGyhr^{-1}).

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 characterization of the detector in the forty-eight (48) different food samples chosen from the six area councils and the obtained value were tabulated in Tables (1) – (6).

Table 1. Radiation dose levels of the samples at Bwari

Sample locations	Food samples	Radiation dose ($\mu\text{Sv} \cdot \text{hr}^{-1}$)
Kubwa	Semovita + egusi soup	0.1880 ± 0.0001
Simape	Eba (cassava) + okro soup	0.0159 ± 0.0001
Katampe	Jolloff rice	0.2867 ± 0.0002
Barapa	Rice + stew	0.2146 ± 0.0001
Kawu	Adalu	0.1382 ± 0.0001
Ushafa	Fufu + vegetable soup	0.3407 ± 0.0002
Panunuki	Tuwo sinkafa	0.0622 ± 0.0001
Dutse Alhaji	Wheat + oha soup	0.1058 ± 0.0001
	Average	0.1690 ± 0.0001
	Annual dose	$(0.1885 \pm 0.0003) \text{mSvy}^{-1}$

Table 2. Radiation dose levels of the samples at AMAC

Sample locations	Food samples	Radiation dose ($\mu\text{Sv} \cdot \text{hr}^{-1}$)
Gwarinpa	Poundo-cocoyam + oha soup	0.2767 ± 0.0001
Maitama	Jolloff rice	0.3902 ± 0.0002
Utako	Semovita + vegetable soup	0.2271 ± 0.0002
Garki	Abacha + Ugba	0.1958 ± 0.0001
Lugbe	Eba (cassava) + bitterleaf soup	0.2008 ± 0.0001
Jabi	Starch + banga soup	0.1490 ± 0.0001
Orozo	Fried rice	0.1660 ± 0.0001
Gwagwa	Beans porridge	0.1995 ± 0.0001
	Average	0.2256 ± 0.0001
	Annual dose	$(0.2576 \pm 0.0001) \text{mSvy}^{-1}$

Table 3. Radiation dose levels of the samples at Gwagwalada

Sample locations	Food samples	Radiation dose ($\mu\text{Sv} \cdot \text{hr}^{-1}$)
Kutunku	Rice + beans + stew	0.0095 ± 0.0001
Zuba	Semovita + egusi soup	0.0114 ± 0.0001
Dobi	Moin-moin	0.0095 ± 0.0001
Paiko	Jolloff rice	0.0095 ± 0.0001
Tsudna	Suya	0.0152 ± 0.0001
Goi	Tuwo sinkafa	0.0152 ± 0.0001
Gwako	Beans porridge	0.0152 ± 0.0001
Sabo	Fufu + okro soup	0.0209 ± 0.0001
	Average	0.0133 ± 0.0001
	Annual dose	$(0.1170 \pm 0.0001) \text{mSvy}^{-1}$

Table 4. Radiation dose levels of the samples at Kuje

Sample locations	Food samples	Radiation dose ($\mu\text{Sv h}^{-1}$)
Chukuku	Boli + groundnut	0.0057 ± 0.0001
Tunbwa	Fried rice	0.0133 ± 0.0002
Duriya	Asun goat meat	0.0076 ± 0.0001
Chibiri	Rice + stew	0.0076 ± 0.0001
Wumi	Indomie noodles	0.0114 ± 0.0001
Gwari	Poundo-cocoyam + black soup	0.0057 ± 0.0001
Sauka	Moin-moin	0.0076 ± 0.0001
Kiyi	Agidi + ewedu soup	0.0114 ± 0.0001
Average		0.0088 ± 0.0001
Annual dose		$(0.0771 \pm 0.0001) \text{mSv y}^{-1}$

Table 5. Radiation dose levels of the samples at Abaji

Sample locations	Food samples	Radiation dose ($\mu\text{Sv h}^{-1}$)
Agyana	Nkwobi	0.2271 ± 0.0002
Nuku	Semovita + egusi soup	0.1667 ± 0.0001
Kebba	Ewa aganyin	0.0833 ± 0.0001
Rimba	Akpu + Ogbolo soup	0.2095 ± 0.0002
Ebagi	Akara + pap	0.1592 ± 0.0001
Panagana	Rice + beans +stew	0.0274 ± 0.0001
Uboshenu	Kilishi	0.0323 ± 0.0001
Dapala	Ofada rice	0.1826 ± 0.0001
Average		0.1360 ± 0.0001
Annual dose		$(0.1553 \pm 0.0002) \text{mSv y}^{-1}$

Table 6. Radiation dose levels of the samples at Kwali

Sample locations	Food samples	Radiation dose ($\mu\text{Sv h}^{-1}$)
Dafa	Moin-moin	0.0261 ± 0.0001
Yebu	Fried rice	0.3503 ± 0.0002
Ashara	Wheat + okro soup	0.0588 ± 0.0001
Pai	Rice + beans + stew	0.1749 ± 0.0001
Kilankwa	Tuwo sinkafa	0.0336 ± 0.0001
Gumbo	Amala + ewedu soup	0.0575 ± 0.0001
Wako	Ewa aganyin	0.0182 ± 0.0001
Yangoji	Akara + pap	0.2703 ± 0.0002
Average		0.1237 ± 0.0001
Annual dose		$(0.1412 \pm 0.0001) \text{mSv y}^{-1}$

The graphical representation of the measured radiation dose levels found in the food samples are illustrated in figures (2 - 7). The average radiation dose levels and annual effective doses rate for all the samples locations are indicated in figures (8 - 10) with their error bar denoting one standard deviation of the average.

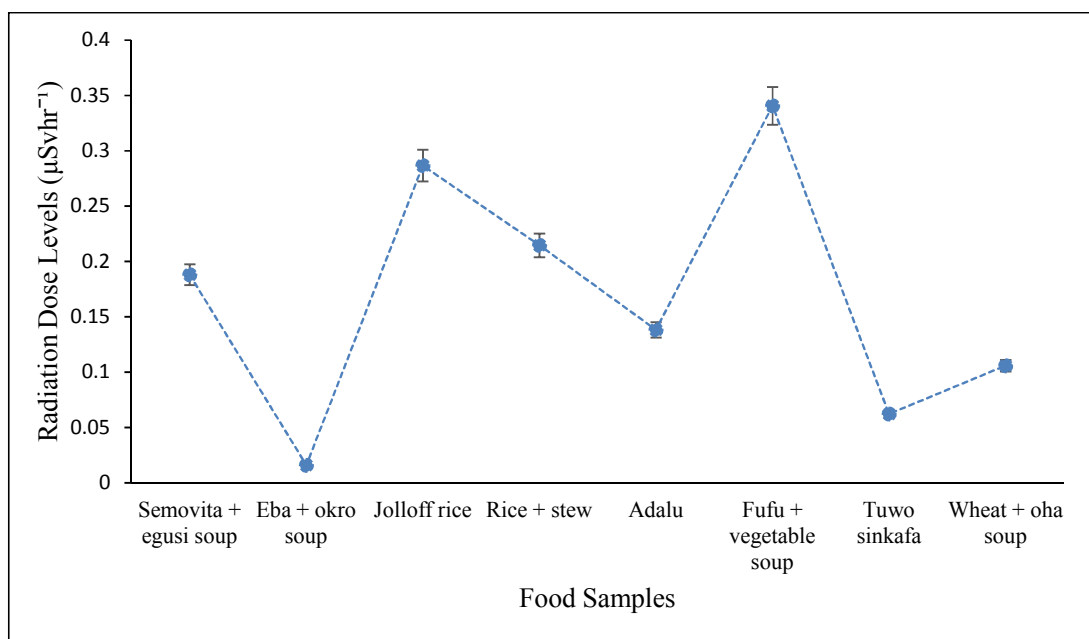


Fig. 2. Radiation Dose Levels of the food samples at Bwari.

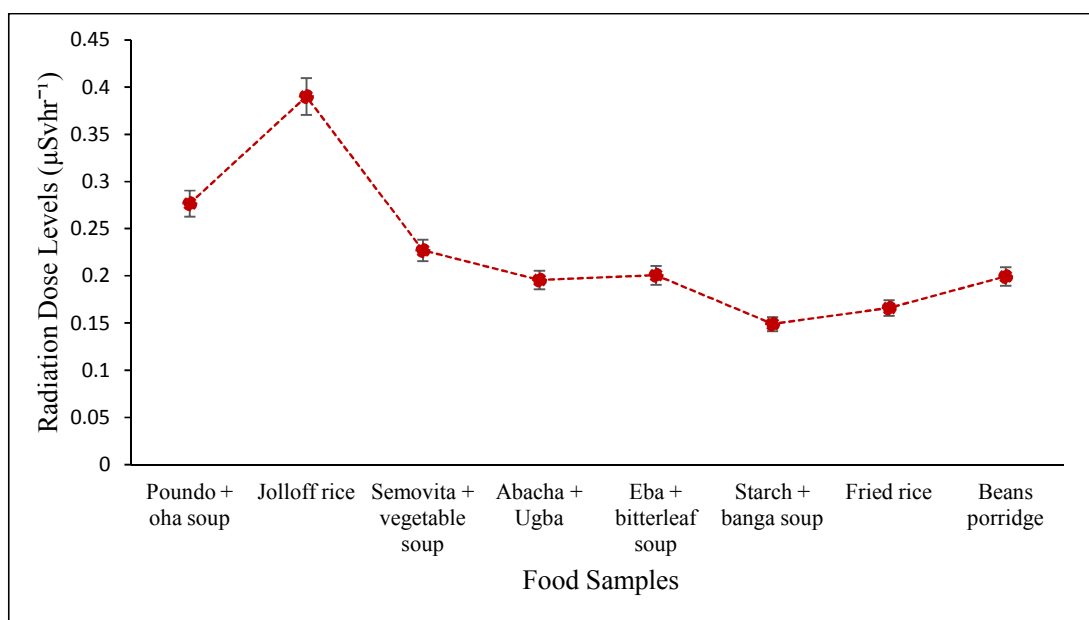


Fig. 3. Radiation Dose Levels of the food samples at AMAC.

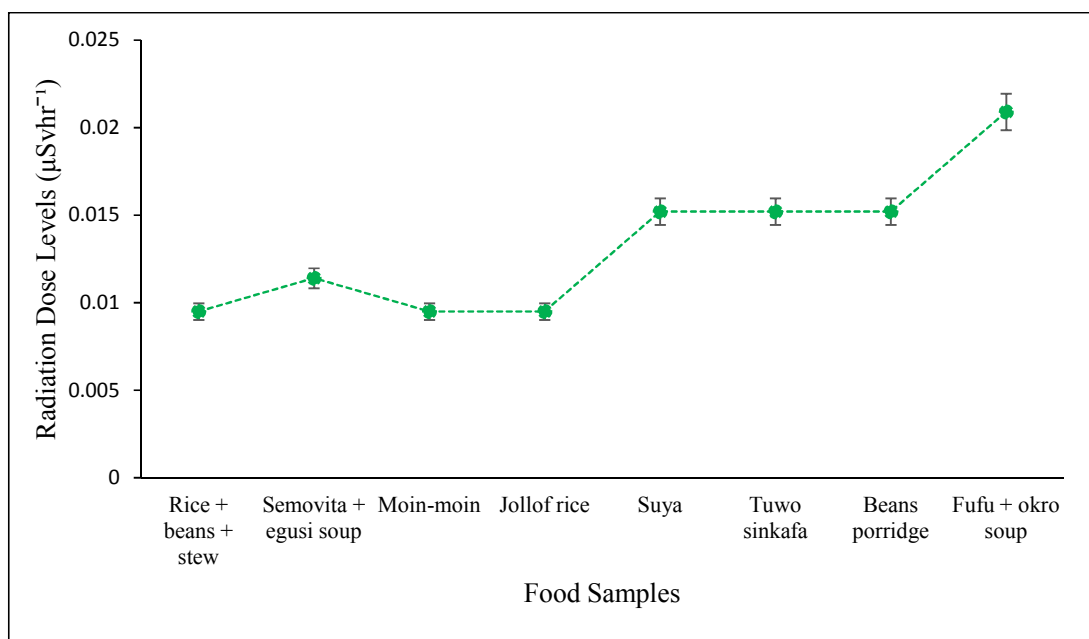


Fig. 4. Radiation Dose Levels of the food samples at Gwagwalada.

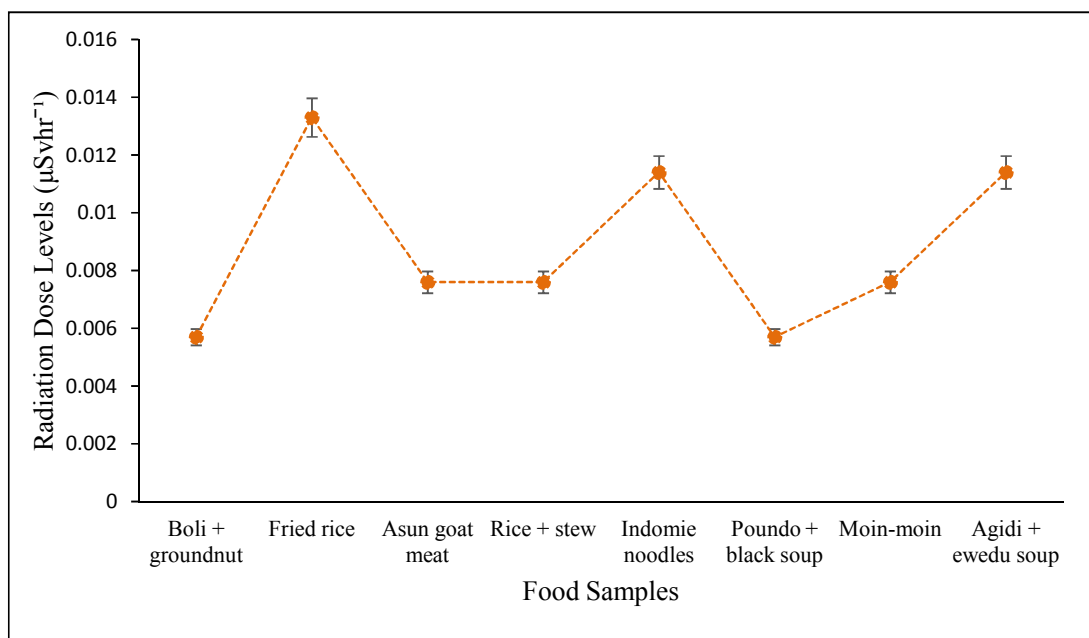


Fig. 5. Radiation Dose Levels of the food samples at Kuje.

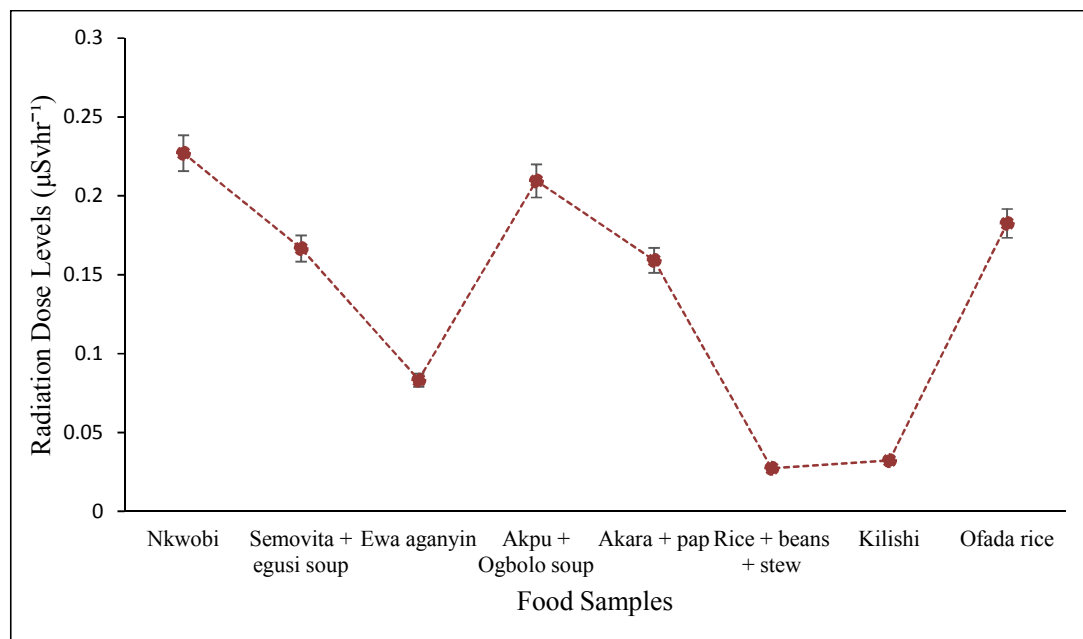


Fig. 6. Radiation Dose Levels of the food samples at Abaji.

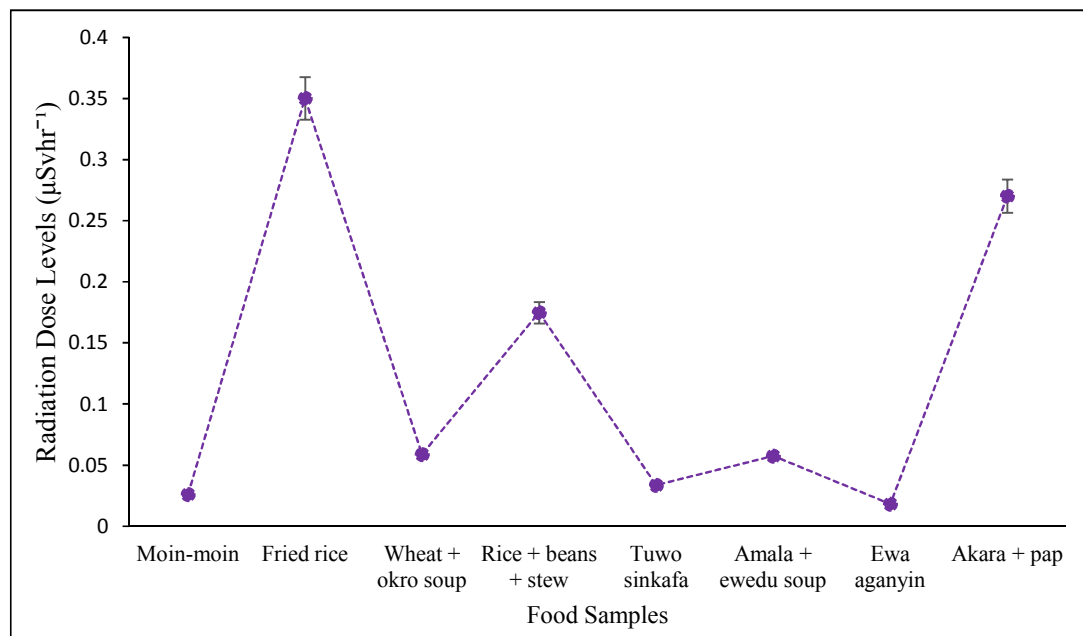


Fig. 7. Radiation Dose Levels of the food samples at Kwali.

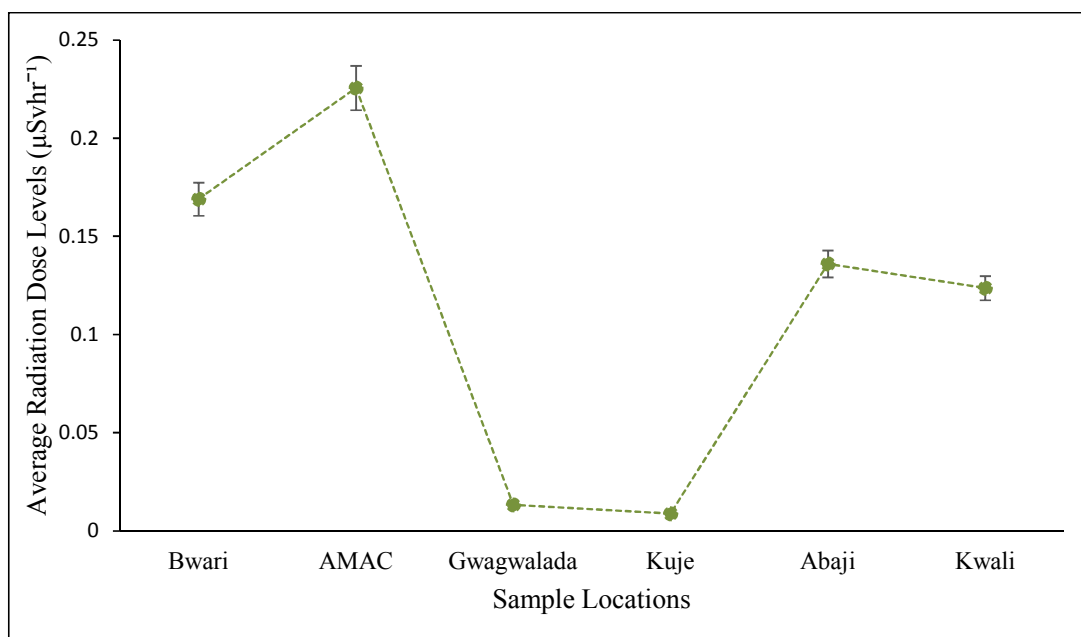


Fig. 8. Average Radiation Dose Levels of the food samples for all the sample locations.

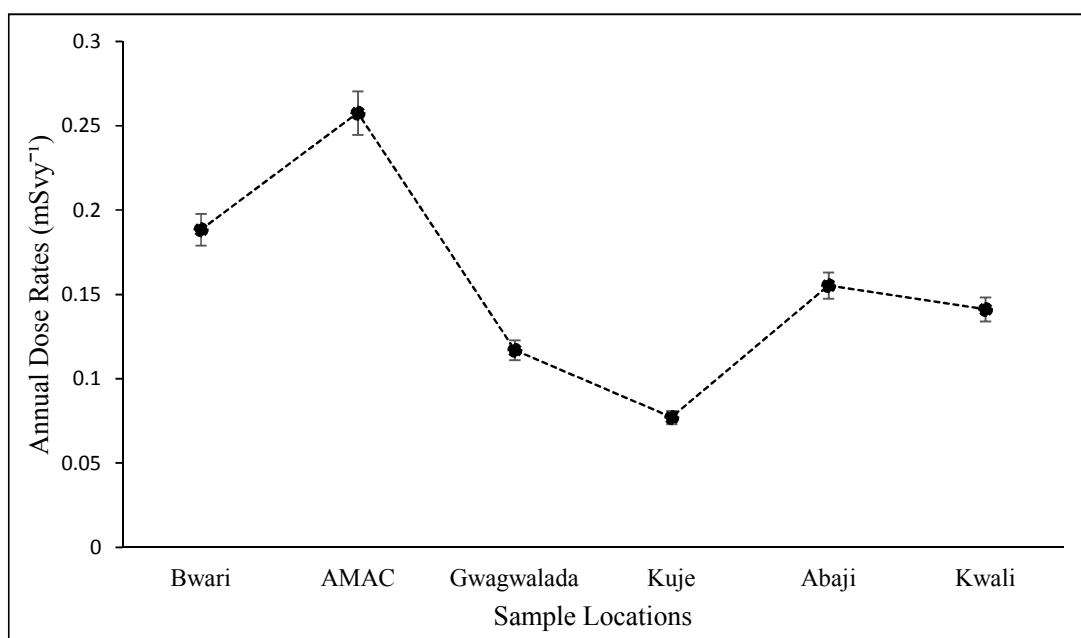


Fig. 9. Annual Dose Rates of the food samples for all the sample locations.

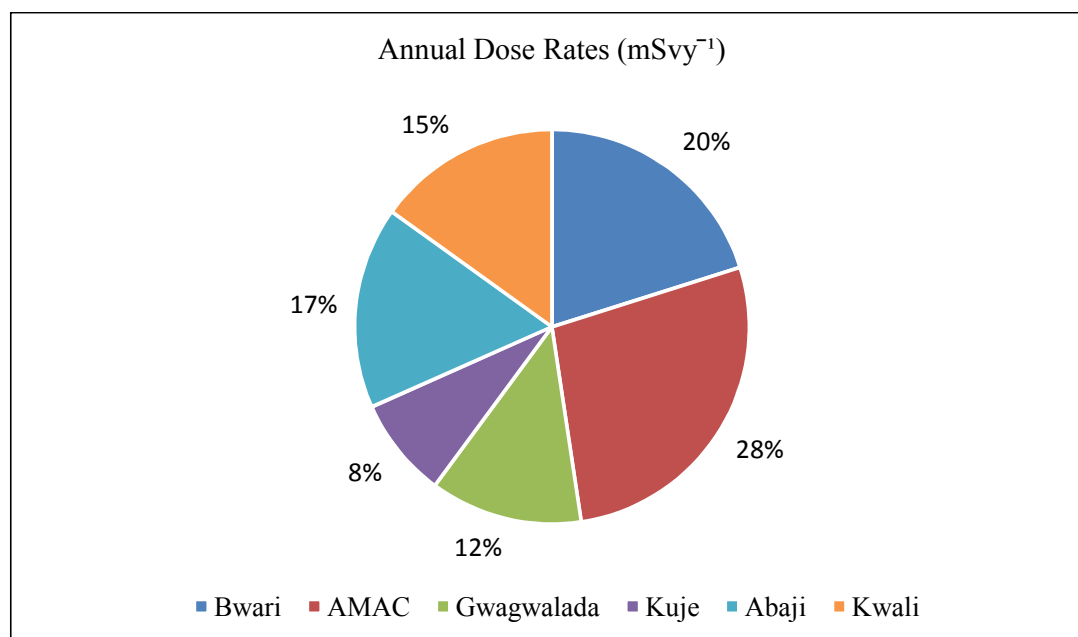


Fig. 10. Percentage Annual Dose Rates of the food samples for all the sample locations.

The above figures (2 - 8) presents the human radiation exposure dose levels from contaminated food samples in this study. The range of the radiation dose levels for each of the sample locations is estimated to be 0.0159 ± 0.0001 to $0.3407 \pm 0.0002 \mu\text{Svy}^{-1}$ with arithmetic mean of $0.1690 \pm 0.0001 \mu\text{Svy}^{-1}$ for Bwari; 0.1490 ± 0.0001 to $0.3902 \pm 0.0002 \mu\text{Svy}^{-1}$ with an arithmetic mean of $0.2256 \pm 0.0001 \mu\text{Svy}^{-1}$ for AMAC; 0.0095 ± 0.0001 to $0.0209 \pm 0.0001 \mu\text{Svy}^{-1}$ with an arithmetic mean of $0.0133 \pm 0.0001 \mu\text{Svy}^{-1}$ for Gwagwalada; 0.0057 ± 0.0001 to $0.0133 \pm 0.0002 \mu\text{Svy}^{-1}$ with an arithmetic mean of $0.0088 \pm 0.0001 \mu\text{Svy}^{-1}$ for Kuje; 0.0274 ± 0.0001 to $0.2271 \pm 0.0002 \mu\text{Svy}^{-1}$ with an arithmetic mean of $0.1360 \pm 0.0001 \mu\text{Svy}^{-1}$ for Abaji; and for Kwali it was between 0.0182 ± 0.0001 and $0.3503 \pm 0.0002 \mu\text{Svy}^{-1}$ with an arithmetic mean of $0.1237 \pm 0.0001 \mu\text{Svy}^{-1}$. The corresponding estimated annual dose rates for each sample locations were $0.1885 \pm 0.0003 \text{mSvy}^{-1}$, $0.2576 \pm 0.0001 \text{mSvy}^{-1}$, $0.1170 \pm 0.0001 \text{mSvy}^{-1}$, $0.0771 \pm 0.0001 \text{mSvy}^{-1}$, $0.1553 \pm 0.0002 \text{mSvy}^{-1}$, and $0.1412 \pm 0.0001 \text{mSvy}^{-1}$ respectively. This revealed that the food 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 ($0.3902 \pm 0.0002 \mu\text{Svy}^{-1}$) in this location. The dose levels was followed by Bwari, Abaji and Kwali, with Gwagwalada and Kuje having the least radiation dose levels although it is within the accepted limit for food samples of 2.4mSvy^{-1} set by [7] and general public dose limit of 1.0mSvy^{-1} [19]. The values of the radiation dose levels of all the food samples in each of the samples locations indicated that all food samples selected and analyzed are within the region [8, 17-18]. The highest associated annual dose rates is observed in ascending order on sample locations at AMAC (28%), Bwari (20%), Abaji (17%), Kwali (15%), and Gwagwalada (12%) respectively, while the lowest annual dose rates is recorded on food samples analyzed at Kuje (8%) (Figure 9 - 10). The high radiation dose levels and associated annual 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, been an industrial location, as most activities in the Federal Capital Territory,

Abuja is done in this location and majority of the restaurants are deep inside the town. 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 ^{40}K based fertilizer in improving of food crop, soil type and irrigation pattern, resulting to the presence of abundance radioactive minerals such as kaolinite and feldspars and so on in the sample locations. This might be as a result of high water content of tubers, which tend to accumulate soluble radioactive elements, because majority of populace in this sample locations are farmer. It could also be due to presence of uranium and thorium minerals in the soil such as zircon, thorianite, monazite, uraninite etc. as a result of some of this sample locations are closed to mining sites. The obtained values were sufficiently low, compared to the maximum recommended global average exposure dose limit for environmental background (2.4mSvy^{-1}) [7] and public dose limit (1.0mSvy^{-1}) [19]. Thus, no radiological hazard is envisaged to the populace of this sample locations and therefore, the food samples are safe and can be generally acceptable for consumption.

4. CONCLUSION

The radioactive contamination in human food samples in some major selected restaurants across the six area councils of the Federal Capital Territory, Abuja, Nigeria has been undertaken in this study and the associated annual dose rates were computed. The range of the mean radiation dose levels obtained for each of the sample locations is estimated to be $0.1690 \pm 0.0001 \mu\text{Svy}^{-1}$ for Bwari; $0.2256 \pm 0.0001 \mu\text{Svy}^{-1}$ for AMAC; $0.0133 \pm 0.0001 \mu\text{Svy}^{-1}$ for Gwagwalada; $0.0088 \pm 0.0001 \mu\text{Svy}^{-1}$ for Kuje; $0.1360 \pm 0.0001 \mu\text{Svy}^{-1}$ for Abaji; and $0.1237 \pm 0.0001 \mu\text{Svy}^{-1}$ for Kwali. The highest associated annual dose rates is observed in ascending order on sample locations at AMAC ($0.2576 \pm 0.0001 \text{mSvy}^{-1}$, 28%), Bwari ($0.1885 \pm 0.0003 \text{mSvy}^{-1}$, 20%), Abaji ($0.1553 \pm 0.0002 \text{mSvy}^{-1}$, 17%), Kwali ($0.1412 \pm 0.0001 \text{mSvy}^{-1}$, 15%), and Gwagwalada ($0.1170 \pm 0.0001 \text{mSvy}^{-1}$, 12%), while the lowest annual dose rates is recorded on food samples analyzed at Kuje ($0.0771 \pm 0.0001 \text{mSvy}^{-1}$, 8%). The obtained results confirmed that all the food samples across the study area are not harmful and not affected by the radiation exposure dose levels and annual dose rates because the values are sufficiently falls within the recommended global average exposure dose limit for environmental background (2.4mSvy^{-1}) and general public dose limit (1.0mSvy^{-1}). Therefore, the intake of contaminated food in the sample locations posed no any immediate radiological health hazard to the populace. The obtained data can be used as baseline data for radiation impact for the estimation of internal radiation dose within the study area.

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