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Radiological Impact Assessment of Farm Soils and Ofada rice (*Oryza sativa japonica*) from Three Areas in Nigeria

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Abstract:

Oryza sativa japonica (ofada rice) is largely grown in Aramoko, Abakaliki and Ofada communities and consumed by both the poor and rich in Nigeria. A total of twenty ofada rice farmlands were identified in each study area and rice samples were randomly collected, thoroughly mixed to make a representative sample from each farmland. Soil samples were collected in each farm to a depth of 5-15cm from at least eight different points and thoroughly mixed together to form a representative sample. The samples were thereafter taken to the laboratory for preparation and spectroscopic analysis. A well-calibrated NaI(Tl) gamma-ray detector was used in spectrometric analysis of the samples and descriptive statistics was used to analyze the results.

The respective mean ^{40}K, ^{238}U and ^{232}Th activity concentrations in the rice were 261.8±52.5Bq/kg, 9.6±1.2Bq/kg and 8.7±1.0Bq/kg (Ofada); 257.3±39.0Bq/kg, 9.3±1.1Bq/kg and 7.8±1.8Bq/kg (Abakaliki); and 248.2±54.8Bq/kg, 9.3±0.9Bq/kg and 7.6±1.5Bq/kg (Aramoko). The respective mean ^{40}K, ^{238}U and ^{232}Th activity concentrations in the soils were 333.9±62.8Bq/kg, 11.1±1.1Bq/kg and 11.0±1.4Bq/kg (Ofada); 306.8±36.0Bq/kg, 10.7±0.8Bq/kg and 9.4±1.8 Bq/kg (Abakaliki) and 321.8±42.4Bq/kg, 10.9±0.5Bq/kg and 9.5±0.6Bq/kg (Aramoko). The highest mean ingestion dose of 106.0±8.0µSv/y and outdoor effective dose of 32.4±3.40µSv/y were recorded in Ofada community. The highest mean ingestion cancer risk of (0.33±0.004) x10^{-3} was recorded in Aramoko. The results indicated significantly lower radionuclide ingestion dose than the world limit value of 290µSv/y and higher cancer risks than the UNSCEAR recommended limit of 0.29x10^{-3}, therefore consumption of ofada rice from the areas may not pose any serious health impact.

Keywords: Farm soils, Nigeria, Ofada rice, Producing areas, Radiological impact.

Introduction:

The formation of soil is due to the weathering of parent rocks in the earth crust that contains decay series ^{238}U and ^{232}Th and non-series ^{40}K radionuclides since the creation of the earth. Natural terrestrial radioactivity is linked to the activity concentrations of the series and non-series decay radionuclides in the earth crust and soils. Humans are exposed to the terrestrial radioactivity through direct and indirect pathways from radionuclides in the earth crust (1, 2). It is obvious to note that farmers repeatedly used and exhausted few available farmlands thereby caused soil infertility and consequently reduced the annual farm yields. The soil infertility motivated farmers to use various form of fertilizers to supplement the nutrients in farms to increase the annual food crop yields. Fertilizers contain uranium, thorium and radium radionuclides and their application especially those with phosphate rocks enhances the activity concentrations of natural radionuclides in the soil (3, 4). The radionuclides in the soil are transferred into food crops through plant-root uptake and the subsequent health impact when ingested by a human is continuously causing concern to scientists all over the world. These natural radionuclides in soil find their ways into the root system, in the same manner, the non-radioactive elements enter the plant roots and transferred to the edible parts of food crops (5) and the consumption or intake of radioactive contaminated foods is one of the sources of internal radiation exposure to human(6).

The United Nation's advocacy against the consumption of food contaminated with radionuclides has motivated various authors in the field of environmental radioactivity to continuously assess the health impact of radionuclides in various food matrices across the globe. In fact, the potential dangers envisaged in internal radiation exposure of human have encouraged many authors to study the radioactivity levels in various food items from different parts of the world (7-12). The estimated amounts of each radionuclide that are absorbed into the human body organs can be determined if the concentration of different radionuclides in a food item is measured and the consumption rates of the foodstuff by individuals are known. In other words, the level of radiation dose to man depends on the quantity of food consumed and the concentrations of the radionuclides in such foodstuffs.

Food in liquid or solid form is the foremost necessity among the needs for survival of human. It provides nourishment, energy and vitality. The food contains nutrients like carbohydrate, fat and oil for energy and heat; protein for body-building; minerals and vitamins for body protection and proper functioning of the body. In Nigeria, carbohydrate such as cereals and tubers constitute the most important food basket (13) and rice (cereal food crop) is commonly consumed by both the rich and poor. Although rice is grown in almost all the parts of the country the most popular areas that produce ofada rice varieties are Abakaliki in Ebonyi State, Ofada in Ogun State and Aramoko in Ekiti State. The geology of each of the study area is shown in Fig. 1.

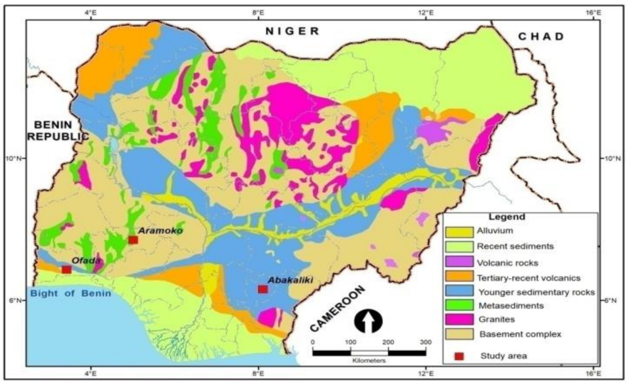

Figure1. Generalized geological map of Nigeria showing the study areas (14)

The three areas are characterized by different geological settings. The study is therefore aimed at measuring the natural radioactivity in the rice and farm soils from the three areas using gamma ray-spectrometer and determining the resulting health effect on human.

Omotayo *et al*. (15) reported that a farmer from each of the study areas produces as much as 136 metric tons of ofada rice per annum. Ofada rice is recently becoming famous and prominence among the species of rice because of its natural taste that inspired high demand for consumption (16). This is because the mode of preparation, serving and the emotional value obtained in eating ofada rice is traced to its originality that connects people to their cultural heritage and food habit (17). Osaretin *et al.* (18), reported that ofada rice contains higher protein, fat, and fiber than imported rice (aroso rice). However, there is a need to ensure compliance with the United Nation's advocacy for food free from contaminants by examining the radioactivity levels. The aim of the study, therefore, is to determine the radiological impact due to the soil and the ofada rice produced in the three communities, consumed by the people from the three communities and sell to other areas in Nigerian for consumption.

Materials and Methods:

Rice Sampling

Rice samples were collected from three study areas including Aramoko, Abakaliki and Ofada, in Ekiti, Ebonyi and Ogun States respectively. The three areas are known for the large production of ofada rice (*Oryza sativa japonica*) in Nigeria. Twenty ofada rice farmlands in each study area were identified and sampling was carried out in the farmlands during the harvesting period to facilitate and ensure site preciseness. Sampling was carried out randomly at different points and mixed to obtain a representative sample in each farmland. Thus, a total of twenty rice samples were collected in each study area. The samples collected in each farm were carefully packed in well-labeled polythene bags before being transported to a radiometric laboratory for preparation and spectroscopic measurements.

Soil Sampling

Soil samples were collected from the same twenty ofada rice farmlands. Soil samples were collected at eight or ten points and the same spots where the rice samples were taken. Thereafter, the soil samples were thoroughly mixed to obtain a representative sample. This gave a total number of twenty soil samples each collected for Aramoko, Abakaliki and Ofada communities. The soil samples from farms were carefully packed in black polythene bags and properly labeled. Thereafter, all the soil samples were transported to a radiometric laboratory for preparation and spectroscopic measurement.

Food sample preparation

The study focuses on human ingestion of rice grown and consumed hence only the edible portions of the rice samples were prepared for spectrometric analysis. The rice shafts were removed and the edible parts were thereafter oven-dried at $110\,^{o}C$ to attain constant mass. The rice samples were then milled and sieved with a 2.0mm mesh sieve to attain the same matrix as the standard food sample before homogenized. 200g each of the rice sample was packed into uncontaminated geometry sample containers of uniform sizes. The containers were then sealed for about 28 days (4 weeks) to allow for secular equilibrium between ^{226}Ra and ^{228}Ra and their respective progenies before gamma spectroscopy.

Soil sample preparation

The soil samples were crushed, grounded and sieved with a 2.0mm mesh sieve, after drying for about twenty days at room temperature. Thereafter the soil samples were oven-dried at 110 ^{o}C to attain constant mass. 200g of each sample was transferred into uncontaminated empty cylindrical plastic containers of uniform sizes and then sealed for about four weeks like the food samples. This was to allow secular equilibrium between ^{226}Ra and ^{228}Ra and their respective progenies before gamma spectroscopy.

Radioactivity determination

The sample analysis was carried out using a single crystal 5.0cm × 5.0cm NaI(Tl) detector, manufactured by Scintitech Instrument, USA, coupled with a Hamamatsa (R1306NSV3068) photomultiplier tube and a Multichannel Analyzer, MCA (2100R:01) manufactured by Price gamma Technology, USA that required no inbuilt PC memory for operation. The MCA with attached Quantum MCA software is capable of performing automatic adjustment of the detector bias and amplifier gain. All calibration functions were made through the software. The detector has adequate energy resolution (FWHM) of about 8.0% in 0.662MeV (^{137}Cs) to distinguish the gamma-ray energies of radionuclides in each sample. The ^{214}Bi with peak gamma-ray energy of 1.760MeV was selected to provide an estimate of ^{226}Ra (^{238}U) in the sample, the radionuclide ^{208}Tl with gamma-ray energy 2.615MeV was selected for estimating ^{232}Th. The ^{40}K radionuclide was determined by measuring the 1.460MeV gamma-ray emitted during its decay. Each sample was counted for 36000 seconds. The expression for activity concentration is given by (19)

$$A(Bq/kg) = \frac{N}{\varepsilon \times I_{\gamma} \times t \times m_s} \quad 1$$

where *A* represents activity concentration in Bq/Kg; N, is a number representing the count rate under the photo peak, ε in cps/Bq represents the efficiency of radionuclide at the specific γ-ray energy, I_γ is a number representing the gamma yield, m_s represents the mass of the sample in kg and t is representing time.

Effective dose due to ingestion of food crop

According to Jibiri *et al.* (20), the effective dose due to ingestion of food is given by:

$$H_{T,r} = \sum\left(U^{i} \times C_{r}^{i}\right) \times g_{T.r} \quad 2$$

Where the coefficients U^i and C^i_r denote the consumption rate (kg/yr) and activity concentration of the radionuclide (Bq/kg) respectively and $g_{T\,r}$ is the dose coefficient for ingestion of radionuclide *r* (Sv Bq^{-1}). The values of $g_{T\,r}$ for ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs are 5.9 x 10^{-9}Sv Bq^{-1}, 4.8 x 10^{-8}Sv Bq^{-1}, 2.3 x 10^{-7}Sv Bq^{-1} and 1.3 x 10^{-8}Sv Bq^{-1} respectively for members of the public (adult) (21). These conversion factors were used to determine the effective doses due to dietary intake of radionuclides contained in ofada rice from the study areas. The rice consumption rate (U^i) value of 26.35 kg/Person in Nigeria (22) was used in the study.

Absorbed and outdoor effective dose rates

The absorbed gamma dose rates D_R in the air at 1m above the ground level were calculated using (4):

$$D_R = 0.427CRa + 0.623CTh + 0.043CK \quad 3$$

where D_R is the dose rate in nGy/h and C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq/kg) of radium (^{226}Ra), thorium (^{232}Th), and potassium (^{40}K), respectively.

The determination of absorbed gamma dose exposure of human is not sufficient to quantify the radiological health effect. However, the better feature in quantifying the radiological health impact from the soil is by determining the effective dose rates. The effective dose rate due to soil samples from the farmlands in each site was calculated using (7):

$$H_R = D_R \times 0.2 \times 0.7 \times 8760 \quad 4$$

Where D is the absorbed gamma dose rate in (nGy/h); 0.2 is the occupancy factor; 0.7 Sv/Gy is the conversion factor and 8760 h/y as recommended by UNSCEAR and reported in (4).

Lifetime cancer risks due to ingestion of ofada and background radiation exposure from farm

The irregular cells growth either due to the action of carcinogens or likely exposure to gamma-rays may end up in the creation of tumor and later develops to cancerous cells. The cancerous cells can attack the adjoining body system and later spread to different organs of the body. A lifetime cancer risk is defined as the probability of a member of a population dying from cancer at a lifetime due to internal or external radiation exposures (23). The lifetime cancer risks associated with intake of rice in the study was determined from the cancer risk coefficients for ingestion of radionuclides and per-capita intake of the radionuclides given by (24):

$$R_F = \sum r_i I_i \qquad 5$$

and

$$I_i = A_i CT \qquad 6$$

r_i is the cancer risk coefficient for ith radionuclide, I_i is the per-capital activity intake of the radionuclide, A_i is the activity concentration of the ith radionuclide, C is the food consumption rate and T is the average lifetime expectancy. The average lifetime expectancy at birth in Nigeria is 45.5 years (24) and the values of risk coefficients, r for ^{226}Ra, ^{232}Th and ^{40}K are 9.56x10^{-9} Bq^{-1}, 2.45x10^{-9} Bq^{-1} and 5.89x10^{-10} Bq^{-1}(25).

The cancer risks due to the external radiation exposure from farm soils were evaluated using the activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th radionuclides in the farm soils and carcinogenicity radionuclide slope factors for environmental exposure to radionuclides by the United States Environmental Protection Agency and the average life expectancy (25):

$$R_S = \sum r_i AT \qquad 7$$

Where A is the activity concentration in Bq/kg, r_i is the cancer mortality risk coefficient for ith radionuclide and T is the average life expectancy. The value of r for ^{226}Ra, ^{232}Th and ^{40}K are 1.33 x 10^{-17}kg/Bq-s, 1.97x10^{-19}kg/Bq-s and 4.66 x 10^{-16}kg/Bq-s respectively.

The total cancer risk, R_T was evaluated by summation of the cancer risks due to the ingestion of ofada rice and the radiation exposure from farm soils:

$$R_T = R_S + R_F \qquad 8$$

where R_S is the mean cancer risks due to radioactivity in soils and R_F is the mean cancer risks due to radioactivity in food ingestion.

Radiological hazard indices

Radiological hazard index isa concept used to assess the radiation hazard associated with natural radionuclides in environmental matrices. The hazard indices are useful tools in determining the radiological suitability of soil or other environmental substances for building construction. The radiological parameters including radium equivalent activity (Ra_{eq}), internal hazard index (H_{in}), external hazard index (H_{ex})and gamma index (I_γ) are determined to appraise the radiological health risks due to radiation exposure from soils.

Radium equivalent activity

Radium equivalent activity is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg in materials used in building and it is determined on the assumption that 10 BqKg^{-1} of ^{226}Ra, 7 BqKg^{-1}for ^{232}Th and 130 Bq/kg for ^{40}K produce the same gamma-ray dose rate (26). The radium equivalent activity was calculated using (7):

$$Ra_{aq} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \qquad 9$$

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

External hazard index

The external hazard index (H_{ex}) is a radiation criterion used to evaluate hazard level from natural gamma radiation due to exposure to radon and its decay progeny (27) and it was calculated using (7):

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad 10$$

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

Internal hazard index

The internal hazard index is also a radiation criterion due to exposure to radon and its decay progeny (27) and it was using (7):

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad 11$$

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

Gamma index

The gamma index (I_γ) is a hazard parameter used to correlate the annual dose rate due to external gamma radiation. It is used only as screening tool for identifying materials that might pose health risk when used as construction materials (28). The gamma index was calculated using the model from European Commission (29).

$$I_\gamma = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \qquad 12$$

where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) respectively

Results and discussion:

Activity concentrations in rice from the study areas

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th were calculated using Eq. 1 and the results are presented in Table1. The results indicated that the natural radionuclides were present in the rice samples and no trace of artificial radionuclide was detected. It was observed that ^{40}K exhibited the highest activity concentration in each rice sample investigated in the study. Similar findings of ^{40}K exhibiting the highest concentration in radioactivity were reported (6). The radioactivity levels obtained in the ofada rice from Ofada community were slightly higher than any of the other two communities. However, the ^{226}Ra and ^{232}Th activity concentrations obtained in rice from Abakaliki and Aramoko were very similar. This is assumed to be due to the radionuclide absorption capability of the ofada rice irrespective of the geological formations of the different communities. The mean activity concentrations of 89.3±6.2Bq/kg for ^{40}K, 2.8±0.7Bq/kg for ^{226}Ra and 7.5±2.7Bq/kg for ^{232}Th reported for paddy rice from Kampung Permatang TokLabu in Malaysia (30) were lower than the values obtained for ofada rice from all the three study areas. The average activity concentration of^{40}K reported as 109.9Bq/kg in rice (Siam species) (31) was about one-half less than the values obtained from each of the three study areas. The respective values of ^{226}Ra and ^{232}Th concentrations reported for rice (White glutinous species) (31) were higher than the values in the present study. Mlwilo et al., (8), reported radioactivity levels in rice from Tanzania as24.7Bq/kg for ^{40}K, 5.02Bq/kg for ^{226}Ra and 3.8Bq/kg for ^{232}Th. These values were lower than the corresponding values in the present study.

Activity concentrations in farm soil from the study areas

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the farm soils in the study areas shown in Table 2 varied from238.5Bq/kg (Abakaliki) to 450.5Bq/kg (Ofada); 8.7Bq/kg (Aramoko) to 12.9Bq/kg (Ofada) and 6.2Bq/kg (Abakaliki) to 13.0Bq/kg (Abakalilki) respectively. Generally, the radioactivity levels in soils reported in studies from other countries were higher than the values obtained in the present study. For instance, the activity concentrations in the soils around the proposed site of Lambapur Peddagattu and Serpally India were 807.08±255.87Bq/kg, 48.07±22.30 Bq/kg and 230.77±89.26 Bq/kg for ^{40}K, ^{226}Ra(^{238}U)and^{232}Th respectively (32). Also the ^{40}K, ^{226}Ra and ^{232}Th activity concentrations in the agricultural soils from the State of Kedah, North of Malaysia were 325±9.83Bq/kg, 102.08±3.96Bq/kg and 133.96±2.92Bq/kg respectively (4) while the ^{40}K, ^{226}Ra (^{238}U) and ^{232}Th activity concentrations in the soil samples from the historical city Panipat India were 291.06±0.57Bq/kg, 30.24±0.53Bq/kg and 29.89±0.61Bq/kg respectively (33). The activity concentrations in the soils from Chikun Kaduna Metropolis were 459.56 Bq/kg for ^{40}K, 62.28 Bq/kg for^{226}Ra and 155.34 Bq/kg for^{232}Th (34). The activity concentrations in the soils of few areas in Nigeria were reported as 180.5±16.0 Bq/kg for ^{40}K, 22.5±3.8Bq/kg for ^{226}Ra and 38.5±6.1Bq/kg (35); 180.5219.8Bq/kg for ^{40}K, 20.3 Bq/kg for ^{226}Ra and 21.1 Bq/kg for ^{232}Th (36) and 352.34±18.67Bq/kg for ^{40}K, 19.86±2.56Bq/kgfor^{226}Raand 14.2±0.87Bq/kg for ^{232}Th (37) were all higher than the values obtained in the present study.

Table 1. Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th (Bq/kg), effective dose rates (μSvy^{-1}) and cancer risks in ingestion of rice from the three communities

Community	No of farmlands		^{40}K	^{226}Ra	^{232}Th	Effective dose rates	Cancer risk (x10^{-3})
Ofada	20	Range	201.1-330.5	8.2-11.3	7.2-10.2	93.7-118.4	0.28-0.38
		Mean± σ	261.8±37.9	9.6±1.0	8.7±0.9	105.6±8.2	0.32±0.03
Abakaliki	20	Range	208.5-321.5	7.5-11.8	5.0-10.3	83.0-118.0	0.27-0.37
		Mean± σ	257.2±35.5	9.3±0.9	7.8±1.5	98.1±10.2	0.31±0.03
Aramoko	20	Range	201.3-340.1	6.8-11.2	5.6-8.9	77.4-114.0	0.24-0.36
		Mean± σ	248.2±40.1	9.2±1.1	7.6±0.8	96.2±8.5	0.30±0.03

*σ is the standard deviations

Effective dose rates due to the consumption of ofada rice

Eq. 2 was used to determine the effective dose in ingestion of ofada rice from the study areas. The mean effective doses obtained in the study indicated that Abakaliki and Aramoko have very close values of 98.1±10.2μSv/y and 96.2±8.5μSv/y respectively and the highest value of 105.60±8.2μSv/y was obtained in rice from Ofada community.

The effective dose of 294.3±49.8µSv/y due to the ingestion of rice reported for Kampung Peratang Malaysia (30) was about three times higher in magnitude than the value got in ofada rice from Ofada Community. The respective effective doses of 153.4±332.2µSv/y and 236.1±26.8µSv/y were reported for rice from other two areas, Sungai Besar and Kampung Sakan in Malaysia (30). The effective dose from each of the two reported areas in Malaysia was higher than the values reported in the present study. The estimated effective dose obtained in the study was higher than 64.23µSv/y (12) reported for Bangladesh but lower than the world average value of 290µSv/y (7).

Although the effective dose of the rice from the Ofada community was higher than the values obtained in Abakaliki and Aramoko, the radiological impact may depend on the frequency and quantity of the rice consumed. Ofada rice constitutes the major food types of nutritive importance in Nigeria and is consumed mostly during ceremonies and festivals. Therefore expected radiological effects due to ingestion of rice from the study areas depend largely and directly on the reality of dietary habits and the food choices of individuals.

Absorbed and outdoor effective doses in farm soils

Eqs.3 and 4 were respectively used to determine the gamma absorbed dose and effective dose rates in the farm soils from the study areas.
The mean absorbed dose rates (nGy/h) in the air at 1.0 m above the ground determined in farm soils at each study area are shown in Table2. The mean absorbed dose in the soil samples obtained in Ofada community was about 4.0 nGy/h greater than the value obtained in Aramoko and almost 2.0nGy/h higher than the value obtained in Abakaliki. However, the absorbed dose value in the soil samples in each of the study areas was far below the world average value of 59.0nGy/h (7).
The effective dose rate was 0.032±0.003mSv/y at Ofada, 0.029±0.002mSv/y at Abakaliki and 0.030±0.002mSv/y at Aramoko. Each of these values was ten times lower in magnitude than the world average value of 0.30 mSv/y (38). The outdoor effective doses received from farm soils by the local population in each of the study areas were low and insignificant radiological health burden could only be expected.

The degree of the association between the outdoor effective dose due to the farm soils and effective dose due to ingestion of the rice from the study areas was determined using statistical analysis (Pearson's rank correlation).Fig. 2 shows the regression lines and the correlation coefficients of 0.61 for Ofada, 0.42 for Abakalilki and 0.22 for Aramoko. The statistical analysis indicated that the correlation between the outdoor effective dose and effective dose due to ingestion of ofada rice at Ofada community showed a significant coefficient while the two others indicated low coefficients.

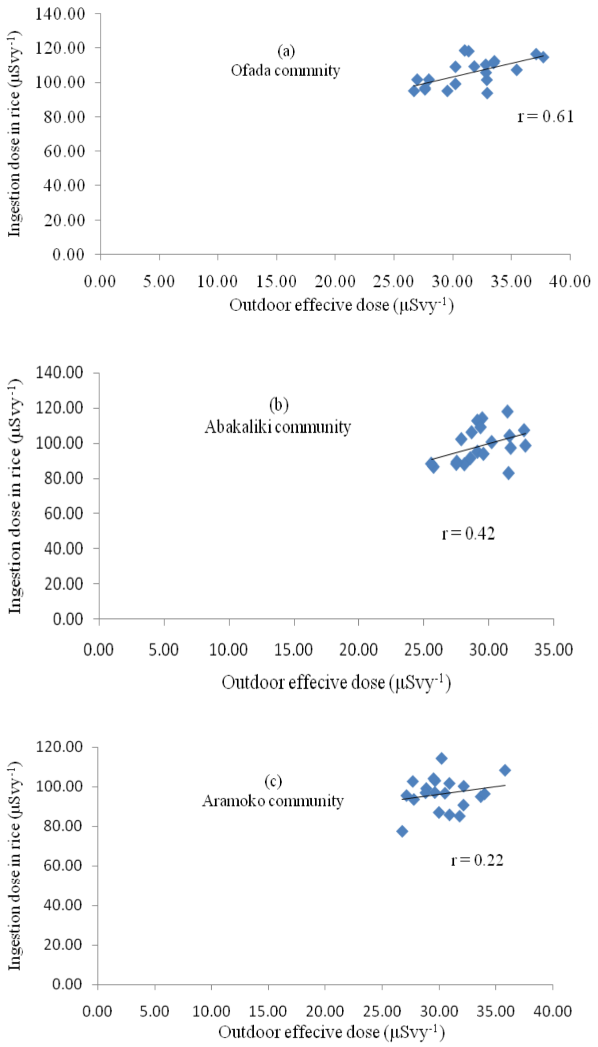

Figure 2.Correlation between outdoor effective and ingestion doses in (a) Ofada (b) Abakaliki (c) Aramoko communities

Lifetime cancer risks due to ingestion of rice and exposure from farm soils

Using eqs. 5 and6, the cancer risks due to ingestion of rice were evaluated and the results are presented in Table 1 for Ofada, Abakaliki and Aramoko communities as (0.32±0.03) x10^{-3}, (0.31±0.03) x10^{-3} and (0.30±0.03) x10^{-3} respectively. The cancer risks resulting from the ingestion of ofada rice from the study areas were almost the same. However, the cancer risk due to ingestion of the ofada rice from each community was slightly higher than the value of 0.29×10^{-3} reported by (12).

Eq.7 was used to determine the cancer risks due to background radiation exposure of individuals from each of the study areas and the results are presented in Table 2 as (0.22±0.04) x10^{-3}, (0.20±0.02) x10^{-3} and (0.22±0.03) x$10^{-3}$for Ofada, Abakaliki and Aramoko communities respectively. The cancer risk value obtained in each study area is lower than the UNSCEAR recommended value of 0.29 x 10^{-3} reported by (7, 39).

Eq. 8 was used to determine the total cancer risks, R_T due to ingestion of rice and gamma exposure from the farm soils in the three study areas and the results were 0.54 x 10^{-3}, 0.51 x 10^{-3} and 0.52 x 10^{-3} for Ofada, Abakaliki and Aramoko communities respectively.

Table2. Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides, gamma absorbed and outdoor effective doses in farm soil and cancer risks from the three communities

Community	No of farmlands		^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Gamma dose (nGy/h)	Effective dose(mSv /y)	Cancer risk (x10^{-3})
Ofada	20	Range	243.7-450.5	9.0-12.9	8.2-11.2	21.7-30.7	0.027-0.038	0.16-0.30
		Mean± σ	333.9±56.0	11.1±1.0	9.9±0.9	25.6±2.6	0.032±0.003	0.22±0.04
Abakaliki	20	Range	238.5-350.1	8.9-11.9	6.2-13.0	20.8-26.7	0.026-0.033	0.16-0.23
		Mean± σ	306.9±30.7	10.7±0.9	9.4±1.4	24.0±16.9	0.029±0.002	0.20±0.02
Aramoko	20	Range	265.3-420.5	8.7-12.2	8.3-10.7	21.8-29.1	0.027-0.036	0.18-0.28
		Mean± σ	321.8±43.7	10.8±0.9	9.5±0.7	24.8±1.9	0.030±0.002	0.22±0.03

* σ is the standard deviations

Radiological hazard indices due to radionuclides in the farm soils

Eqs. 9, 10, 11 and 12 were respectively used to determine the radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}) and gamma index (I_γ) in the farm soils from Ofada, Abakaliki and Aramoko and the results are presented in Table 3. From a radiological and safety perspective, the radium equivalent activity in any material for building construction must be less than or equal to 370Bq/kg i.e. $Ra_{eq} \leq 370$ Bq/kg (2).The mean radium equivalent activity of farm soils from each of the communities was lower than 370Bq/kg, thus the use of the farm soils for construction of human dwellings is not expected to pose any serious radiological effect.

From a radiological point of view, the external hazard index, internal hazard index and gamma index of any building material must respectively be less than one(2). The values of H_{ex}, H_{in}, and I_γ in the farm soils from each study area were less than one, therefore no radiological health effect is expected when the soils are used for construction of human dwellings. The profile of Ra_{eq}, H_{ex}, H_{in}, and I_γ with reference to farm land number in Ofada, Abakaliki and Aramoko are respectively shown in Figs. 3, 4 and 5. The shaded area in each Figure showed the standard deviation (departure) from the mean and the line at the middle of the shaded area indicated the mean

Table 3.Radiological hazard indices due to activity concentrations of the farm soils

Community	No of farmlands		Ra_{eq} (Bq/kg)	H_{in}	H_{ex}	I_γ
Ofada	20	Range	43.46-60.24	0.14-0.20	0.12-0.16	0.17-0.24
		Mean± σ	50.95±4.87	0.17±0.01	0.14±0.01	0.20±0.02
Abakaliki	20	Range	42.02-52.12	0.14-0.17	0.11-0.14	0.16-0.20
		Mean± σ	47.54±2.86	0.16±0.01	0.13±0.01	0.18±0.01
Aramoko	20	Range	43.76-57.07	0.15-0.18	0.12-0.15	0.17-0.22
		Mean± σ	49.20±3.51	0.16±0.01	0.13±0.01	0.19±0.01

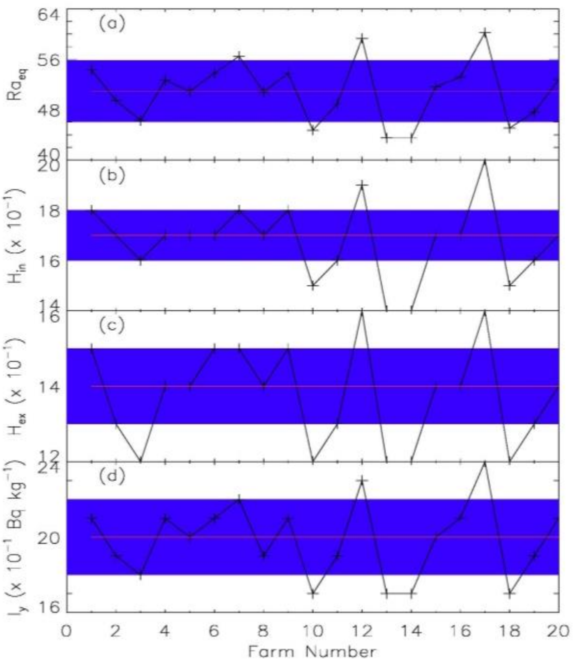

Figure 3. Ra_{eq}, H_{in}, H_{ex} and I_{γ} of farm soils from Ofada Community

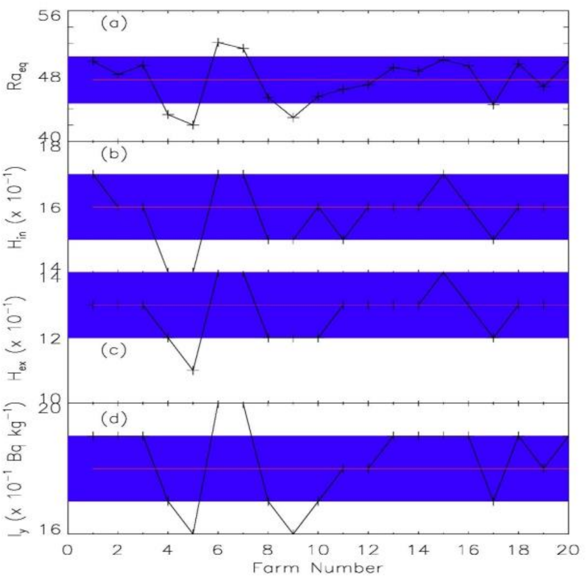

Figure 4: Ra_{eq}, H_{in}, H_{ex} and I_{γ} of farm soils from Abakalilki Community

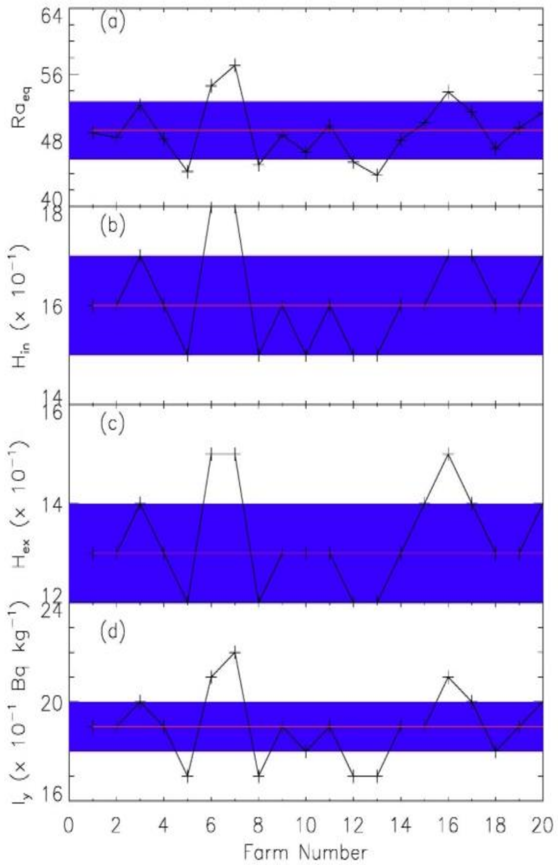

Figure 5. Ra_{eq}, H_{in}, H_{ex} and I_{γ} of farm soils from Aramoko Community

Conclusion:

The activity concentrations of natural radionuclides ^{40}K, ^{226}Ra and ^{232}Th in rice and the farm soil samples from Ofada, Abakaliki and Aramoko Communities have been measured using gamma-ray spectrometry method. The effective dose rates are estimated from the activity concentrations of the three natural radionuclides in the ofada rice. The gamma absorbed dose and effective dose rates due to external exposure from farm soil radioactivity are calculated. From the results, the mean radioactivity levels in the rice appear very close and this is attributed to the absorption pattern of the ofada rice irrespective of the geological setting of the areas. The radiological impact in the study is insignificant as the cancer risks due to ingestion of the ofada rice and the farm soils in the study are low when compared to the United Nations Scientific Committee on the Effects Atomic Radiation (UNSCEAR) recommended value of 0.29 $x10^{-3}$.

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Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Besides, the Figures and images, which are not ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Olabisi Onabanjo University.

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تقييم التأثير الإشعاعي للتربة الزراعية للرز أوفادا(الرز الاسيوي الياباني)من ثلاثة مناطق في نيجيريا

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الخلاصة:

يزرع الارز الاسيوي والمسمى ب (ارز اوفادا)في مجتمعات المسماة (أراموكو ، وأباكاليكي وأوفادا) ويستهلكها كل من الفقراء والأغنياء في نيجيريا على حد سواء . تم تحديد ما مجموعه عشرين مزرعة من أراضي الأرز في كل منطقة من مناطق الدراسة ، وتم جمع عينات من الأرز بشكل عشوائي ، وتم خلطها بشكل دقيق لتقديم عينة من كل أرض زراعية. تم جمع عينات التربة في كل مزرعة على عمق 15-5 سم من ثماني نقاط مختلفة على الأقل وتم خلطها معًا لتشكيل العينة. تم التحليل الطيفي لهذه العينات. تم استخدام كاشف أشعة كاما NaI (Tl)ذو معايرة جيدة في التحليل الطيفي للعينات واستخدمت الإحصاءات الوصفية لتحليل النتائج.لقد كان متوسط التركيز الاشعاعي للعناصر $^{40}K, ^{232}Th, ^{238}U$,هو 261.8±52.5Bq/kg و 9.6±1.2Bq/kg و 8.7±1.0Bq/kg (أوفادا)،257.3±39.0Bq/kg،9.3±1.1Bq/kg و 7.8±1.8Bq/kg (أباكاليكي) و 248.2±54.8Bq/kg،9.3±0.9Bq/kg،7.6±1.5Bq/kg (أراموكو) على التوالي اما تراكيز النشاط الاشعاعي في التربة للعناصر $^{40}K, ^{232}Th, ^{238}U$,كانت 333.9±62.8Bq/kg،11.1±1.1Bq/kg و 11.0±1.4Bq/kg (اوفادا) 306.8±36.0Bq/kg،10.7±0.8Bq/kg و 9.4±1.8 Bq/kg (أباكاليكي) و 321.8±42.4Bq/kg،10.9±0.5Bq/kg و9.5±0.6Bq/kg (أراموكو). تم تسجيل أعلى متوسط جرعة 106.0±8.0μSv/yوالجرعة الفعالة في الهواء الطلق البالغة 32.4±3.40μSv/yفي .Ofada وان أعلى معدل لخطر الاصابة بسرطان قدره $x10^{-3}$ (0.33±0.004) تم تسجيله في (أراموكو). أشارت النتائج إلى أن جرعة النويدات المشعة أقل بكثير من الحد العالمي البالغ 290μSv/y ومخاطر انخفاض السرطان عن الحد الذي أوصى به UNSCEAR وهو $0.29x10^{-3}$ ، وبالتالي فإن استهلاك الأرز ofada من المناطق قد لا يشكل أي تأثير صحي خطير.

الكلمات المفتاحية: تربة المزرعة، نيجيريا، أرز أوفادا، المناطق المنتجة، التأثير الإشعاعي.