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Radioactivity Analysis of Plantain Food Crops Contamination in Kolo Town in Ogbia Local Government Area of Bayelsa State, Nigeria Due to Radium-226, Thorium-232 and Potassium-40 Concentrations in the Environment

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ABSTRACT

One of the three goals of the United Nations for sustainable food security is to ensure that all people have access to sufficient food that is nutritionally adequate and safe. Kolo town of Ogbia local Government Area of Bayelsa State is a home to some crude oil and other important minerals deposits. As a result of the mineral occurrence, some parts of the town have become associated with significant levels of natural radioactivity. The exploration and exploitation of these minerals are known to have enormous consequences on the Kolo and its environs. The present study therefore examines the levels of natural radionuclides, 40K, 226Ra and 232Th in some samples of plantain food crops harvested in a farm in Kolo town in Ogbia Local Government Area of Bayelsa State. The activity concentrations of 40K, 226Ra and 232Th were determined in the plantain food samples using γ- ray spectrometry in the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife. Results of measured activity concentration in Bq/kg of the radionuclides indicated a result of a mean decreasing order of 40K > 226Ra > 232Th, with 40K contributing the highest percentage to the total radioactivity content in the plantain food stuffs. The high concentration observed in 40K in the plantain foodstuffs may be due to its essential nature to crops and natural abundance of potassium radionuclide in the earth crust as well as the possible use of enriched potassium fertilizers and agrochemicals by farmers during cultivation for greater crop yields. Also, the mean concentration of 232Th are lower than the 40 Bq/kg limit, 226Ra recorded values lower than the 370 Bq/kg world limit in samples. The low rate of absorption from the soil to crop as well as atmospheric deposition might have affected the low values recorded in the plantain samples recorded.

Keywords: Environment, Contamination, Minerals, Radioactivity, Plantain.

INTRODUCTION

Food is one of the most basic requirements for man to survive after air and water. Therefore, food production must be secured for the world's growing population. Hence, the application of chemical fertilizers and agrochemicals by man in agriculture has been used to reclaim land and soil quality and improve agricultural yields in our farms and gardens in order to meet up with the growing world's population (Uwaoluetan et al., 2022; Ononugbo et al., 2019). However, these chemical fertilizers and agrochemicals applied by man are on the other side transferred back to man through the food chain in the form of internal exposure since natural radionuclides get transferred to plants along with other micronutrients through the mechanism of soil-plant root interaction and ingestion pathway (Ugbede and Akpolile, 2020; Ugbede et al., 2022). Also, all these different levels of these harmful elements are transferred into man when consumed either directly or as supplements (Harikrishnan et al., 2020) and the presence of radioactivity in the edible parts of crops causes human internal exposure (Tawalbeh et al., 2014).

All types of food contain some natural radionuclides that are transferred from the soil to the crops on land and from water to fish in rivers, lakes and the sea. Moreover, the levels of natural radionuclides in food and drinking water are generally very low and safe for human consumption. However, the concentrations of natural radionuclides differ between food categories and in each category, such as vegetables, cereals, fruits, meat and fish because of different environmental conditions, agricultural practices and other factors that affect radionuclide transfer from the environment to crops and animal products (UNSCEAR, 2000). In addition, doses due to food consumption also vary, depending on the food types that are consumed in the various countries (IAEA, 2016). Therefore, it is important to know radioactivity levels in food and inform consumers about potential hazard risks associated with consuming such foodstuffs.

Radiation doses from the consumption of foodstuffs typically range from a few tens to a few hundreds of μSv/y (IAEA, 2016; FAO/WHO, 2001). On average, the global population receives a total radiation dose of about 0.3 mSv each year due to radionuclides of natural origin in the diet. Typically, this represents 10 % of the average annual radiation dose of 3 mSv/y from all sources received by an individual (IAEA, 2016).

Plantain is a fruit tree and an important biennial food crop that is largely grown and consumed in Nigeria. It is a popular delicious staple food that is rich in iron that is eaten boiled, baked, fried, mashed or roasted by humans and animals (Makinde et al., 2019). Also, all the different parts of the plant are used for different purposes. The edible parts of the plants includes the pulp, peels (Agama et al., 2018) while the stem, the leafy part fund usage as platters for serving food, for packing and wrapping food materials, especially when dried and also used as medicines. It is also a cheap source of food for some domestic animals. The plantain leaves and peels can also be used as adsorbents (Akpor et al., 2020) for heavy metal remediation in the environment Czarnowska and Milewska, 2018; Chibuike and Obiora, 2017).

One way to monitor food doses is through Total Diet Studies. This method is recommended by the European Food Safety Authority (EFSA), Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), in order to determine the mean concentration levels of substances in the average human diet (INFOSAN, 2011).

Therefore, determination of the levels of radionuclide concentrations of plantain in the area will help in accessing the health risk associated with its usage as food for humans and animals and its other food related applications. It can also be sued in evaluating the soil-to-plant transfer factor for the plantain foodstuff.

2.1 Study Area

The study area is Kolo town in Ogbia Local Government Area of Bayelsa State within latitude 4°46'26.7"N (4.7740900°), longitude 6°19'36.7"E (6.3268600°). Ogbia Local Government Area has an area of 695 Km^2 and a population of over 179,926. It is well known for its historic value to the today Nigerian state economy mainstay. Crude oil was first discovered in commercial quantity at Oloibiri Town on Sunday 15 January 1956 in Ogbia Local Government Area of Bayelsa State (Alagoa, 1966). The vast majority of the people in the area engage in farming plantain only second to palm cutting and fishing. Plantain farming operations in the area involve mainly of several dug pits, both manually and mechanically, in the farming area populated by plantain (*musa paradisiaca*) (Figure 1).

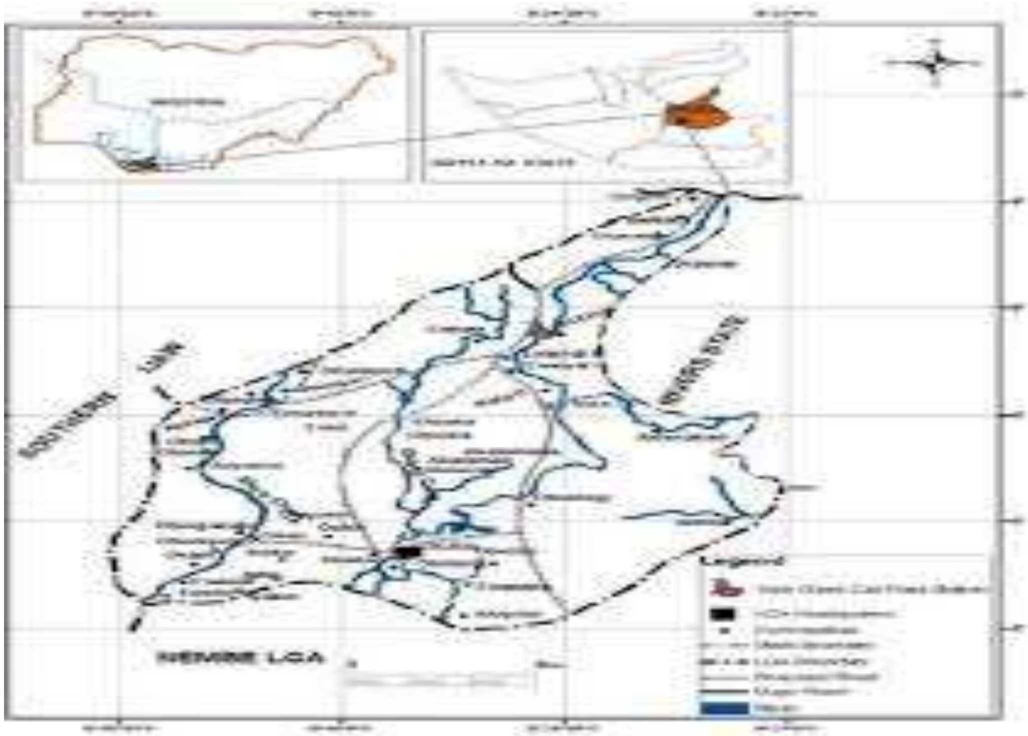

Figure 1: Map of Ogbia Local Government Area.

Figure 2: Plantain farm grown in Kolo town

Figure 3: Plantain food crops harvested from the farm in Kolo town of Ogbia L. G. A

2.2 MATERIALS AND METHODS

In this study, samples of some plantain food stuffs were bought in the Kolo market after harvesting from a plantain farm Kolo town in Ogbia Local Government Area of Bayelsa State, Nigeria. After peeling off the mesocarp, the edible part (pulp) of the plantain was selected for this study. The edible part (pulp) were cut into small pieces and dried for 48hrs. They were later collected and kept in labelled polythene bags in order to avoid soil contamination of the samples. The dried samples were then ground and sieved with a 2 mm mesh. Ground samples from each sampling point were kept for radioactivity study.

2.3 Gamma Spectrometric Analysis

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th were measured using gamma ray spectroscopy method. The measuring system consists of a scintillation detector sealed with a photo multiplier tube and connected through a preamplifier base to a Canberra series 10 – plus multi-channel analyzer (MCA). The detector is a 3 cm × 3 cm NaI(Tl) (Model No. 3M3/3). The detector has a resolution of about 8% at 0.662 MeV of ^{137}Cs. The detection Energy calibration of the system was carried out using reference standard source (IAEA- 444) prepared from the Radiochemical Centre, Amersham, England. The 1.460 MeV photopeak was used for the measurement of ^{40}K while the 1.120 MeV photopeak from ^{214}Bi and the 0.911 MeV photopeak from ^{288}Ac were used for the measurement of ^{238}U (^{226}Ra) and ^{232}Th, respectively. Efficiency calibration was done using standard reference source (IAEA- 375) whose energies and activities are known (Nwankpa and Essiett, 2019). Each sample was counted for 7 hours and the data acquired. The MAESTRO software program automatically searches for the peak, evaluates the peak position in energy, identifies the radionuclides by use of nuclide library. It calculates the net peak areas, subtracts the background count and then displays the activity concentration in selected units. Also, an empty Marinelli beaker was counted under identical geometry as the samples in other to determine the background spectrum distribution which was subtracted from the values. Based on this and other defined parameters of net counts under, efficiency, gamma intensity, sample mass and counting time, the activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in each sample was estimated using the following relation (Jibiri et al., 2007).

$$AC\ (Bq/kg) = \frac{C_n}{\varepsilon P_y M_s} \qquad 1$$

Where; AC is the activity concentrations of radionuclides in the sample, C_n is the total net count rate under each photopeak, Pγ is the absolute transition probability of the specific gamma energy; ε is the efficiency of the detector for the specific gamma energy and M_s is the mass of the sample in kilogram (kg).

2.4: Estimation of Radium equivalent activity (Raeq)

Radionuclides or natural occurring radioactive materials are not uniformly distributed in any sample. Therefore, radium equivalent activity (Raeq) is used to quantify the uniformity of activity of the radionuclides as a single quantity as defined (UNSCEAR, 2000). The radiation risk of contamination is measured by evaluating the total effect of ^{226}Ra, ^{232}Th and ^{40}K as the radium equivalent activity in the sample. The radium equivalent (Raeq) represents the weighted sum of the activities of ^{226}Ra, ^{232}Th and ^{40}K in the soil or food samples. This is assumed by the observation that 370 Bq/kg of ^{226}Ra or ^{238}U, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same gamma dose rate (UNSCEAR, 2000).

Based on this, the radium equivalent index (Raeq) in Bq/kg in the food samples were evaluated using the following relation (Beretka and Mathew, 2019; UNSCEAR, 2020).

$$Raeq = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad 2$$

Where; A_{Th}, A_{Ra} and A_K represent, respectively, the activity concentration of ^{232}Th, ^{226}Ra and ^{40}K in the samples respectively.

2.5: RESULTS AND DISCUSSION

Table 1: Measured activity concentration of radionuclides and radium equivalent activity (Bqkg^{-1}) in plantain food samples of Kolo 1

S/N	Sample ID	^{40}K	^{226}Ra	^{232}Th
1.	K_1P_1	298.14±14.71	4.79±6.24	3.63±0.25
2.	K_2P_2	425.07±9.30	28.41±2.79	3.76±0.22
3.	K_3P_3	210.26±15.32	9.89±1.77	3.32±0.44
4.	K_4P_4	238.71±18.18	26.55±3.75	2.80±0.07
5.	K_5P_5	293.73±22.01	15.96±3.25	1.33±0.16
	Mean	293.182±1.04	17.120±1.18	2.968±3.10

Table 2: Measured radium equivalent activity (Raeq) (Bqkg^{-1}) in plantain food samples of Kolo 1

S/N	Sample ID	1	2	3	4	5	Mean
1.	K_1P_1	32.938	66.517	30.828	48.627	40.479	23.878
2.	K_2P_2	17.994	16.383	17.697	43.284	56.173	30.306
3.	K_3P_3	62.612	41.851	30.778	30.585	48.778	42.921
4.	K_4P_4	77.681	44.448	51.160	69.128	40.941	56. 672
5.	K_5P_5	53.005	99.112	24.818	73.512	43.516	58.721

Table 1 shows the measured activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the various plantain food samples that were examined. The presented values are given on dry bases of the samples and in the units of Bq/kg with the analytical uncertainty. It was observed that the activity concentration of ^{40}K in the plantain food samples ranges from 210.26±15.32 – 425.07±9.30 Bq/kg with a mean value of 293.182±1.04 Bq/kg, 4.79±6.24 – 28.41±2.79 Bq/kg with a mean value of 17.120±1.18 of ^{226}Ra and 1.33±0.16 – 3.76±0.22 Bq/kg with a mean of 2.968±3.10 Bq/kg of ^{232}Th for Kolo 1 community. Table 1 clearly shows the observation that the activity concentration in plantain food sample is in the decreasing order of: $^{40}K > ^{226}Ra > ^{232}Th$ with ^{40}K contributing highest percentage to the total radioactivity content of the plantain food stuffs. The high concentration observed in ^{40}K in the plantain foodstuffs may be due to the natural abundance of potassium radionuclide in the earth crust (Nahar et al., 2018) as well as the possible use of enriched potassium fertilizers and agrochemicals by farmers during cultivation for greater crop yields. This is in agreement with the works of (Uwaoluetan et al., 2022; Nahar et al., 2018; Ugbede and Akpolile, 2020). Another possible reason is potassium is a micro primordial mineral that is a much-needed for plant growth and development. It is also easily transferred from soil through plant roots which in turn can get accumulated in various plant parts (Ugbede, 2022). Additionally, the result demonstrates that the radioisotope ^{40}K is the most prevalent in the agricultural soil where the samples were produced. Potassium is also an essential intracellular cation that is distributed easily in various part of the plant and maintains homoeostatic regulation (Hassan et al., 2021). The high concentration of ^{40}K recorded in all samples and in all locations is not unconnected with the essential nature of potassium; also, plants do not have the capacity to differentiate between the isotopes of the metal (Omoboye and Adeniyi, 2017). This result is in agreement with other previous studies carried out in other locations that had also reported higher concentration for ^{40}K than the other radionuclides (Venturini and Sordi, 1999; Arogunjo et al., 2005; Shanthi et al., 2010; Avwiri and Agbalagba, 2013; Alsafar et al., 2015; Jayasinghe et al., 2020) as cited in Uwaoluetan et al., (2022). However, this result is at variance with the work of Makinde et al., (2020) that reported a mean activity concentration value of ^{40}K lower than the world range of 240 Bq/kg. Radium-226 (^{226}Ra) is a radioactive decay product in the uranium-238 (^{238}U) decay series and is the precursor to radon-222 (^{222}Rn). People may ingest radium that is naturally contained in food and/or water, and may also inhale it from dust particles suspended in the air. Most of the radium taken in by ingestion (about 80%) will promptly leave the body in faeces. The remaining parts (20%) enter the bloodstream and are carried to all parts of the body. The metabolic behaviour of radium in the body is similar to that of calcium. For this reason, an appreciable fraction is preferentially deposited in bones and teeth. Radium can also be produced in the body from its parent radionuclide (uranium) that has been inhaled or swallowed, but this is normally not a significant source (Tawalbeh et al., 2014) while the mean concentration of ^{232}Th in plantain samples are lower than the 40 Bq/kg limit, ^{226}Ra was recorded in lower values than the 370 Bq/kg world limit in plantain samples. Low rate of absorption from the soil to crop as well as atmospheric deposition might have affected in the low values recorded in the plantain samples recorded. The mean radium equivalent (Raeq) (Bq/kg) investigated for all the plantain samples as shown in Table 2 were less than the global permissible safe limit of 370Bq/kg.This implies that consumption of plantain may not pose any harm to residents in the study area but may overtime constitute a threat due to over accumulation of the radionuclides in the plantain crops planted in the study area.

CONCLUSION

Radionuclides (^{40}K, ^{226}Ra and ^{232}Th) concentrations in some plantain food stuffs harvested in Kolo town of Bayelsa State, Nigeria have been determined. Measured concentrations of the radionuclides show significant values, with 40K having higher value which can be attributed to the natural abundance of potassium radionuclides and its essential to crops in the earth crust as well as use of fertilizers and other agrochemicals such as pesticides to improve crop yields. The results obtained correlates with other similar studies reported in literature. Therefore, the present data will be valuable to policy framework of food agencies and FAO/WHO in Nigeria for the radiological and toxicological food safety monitoring.

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