DETERMINATION OF BASELINE RADIONUCLIDES CONCENTRATIONS IN FOOD SAMPLES AROUND PHOSPHATE DEPOSIT IN OSHOSUN, OGUN–STATE, NIGERIA

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ABSTRACT:
Environmental impact assessment records are necessary before the commencement of mining operations. Deposits of phosphate mineral have been found in Oshosun, a town in Ifo Local Government Area of Ogun State, Nigeria. Radiological assessments of the matrices were carried out prior to commencement of mining. Fourteen foodstuffs samples (14) representing the major sources of dietary requirements to the villagers were collected. They were oven dried at 110 ^{0}C to constant weight, pulverized and sieved. Quantities of the sample, 150 g of each foodstuffs was sealed in cylindrical sample holders and kept for about 28 days to attain secular equilibrium between ^{226}Ra and its decay products before analysis using gamma-ray spectrometry. The energy and efficiency calibrations were carried out using International Atomic Energy Agency certified materials (RGU-1, RGTh-1, and RGK-1). The mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th for the foodstuffs were 140.4±11.6, 47.3±7.6, 28.4±1.9 Bq/kg respectively. The calculated mean effective dose for the foodstuff in the study area was 1.13 mSvyr^{-1}.The mean activity concentrations of naturally occurring radionuclides in the samples were below global averages. These baseline values will serve as a new set of data and references for monitoring and assessing radiological exposures after the commencement of mining operations in the area.

KEYWORDS: Environmental, Absorbed dose, spectroscopy, monitoring.

INTRODUCTION

Phosphate rock is a mineral assemblage that occurs naturally and contains an unusually high concentration of phosphate minerals (UNSCEAR,2000). It is found in igneous and metamorphic rocks as the mineral apatite, Ca5F(PO4)3, but it can also be of sedimentary origin (Koko *et al*.,2012). The most frequent source is one with a high phosphate proportion in nodular or compact masses, however, it can arise from a number of sources. It is the main resource that is extracted in order to make phosphate fertilizers, which are vital for maintaining the global agricultural output. Mineral fertilizer must be added to the soil to increase its nutritional content in order to guarantee an appropriate supply of food for human use (Olanipekun, 2017).

Naturally occurring radionuclides, such as ^{40}K and those from the uranium and thorium decay series (^{238}U and ^{232}Th), may be present in relatively high concentrations in phosphate ore (Koko *et al*.,2012). Concentrations of the ^{232}Th series and ^{40}K in phosphate rocks of all types are similar to those found in soil, whereas concentrations of ^{238}U and its decay products are elevated in sedimentary phosphate deposits. In sedimentary phosphate deposits, the typical activity concentration of ^{238}U is 1500 Bq/kg (RMRDC, 2010).

The release of emissions, such as dust from blasting and other mining operations, can have an impact on air quality. Mining waste discharge can have an impact on the environment, causing air and water pollution and environmental degradation. The radioactive pollutants released into rivers, lakes, seas, and oceans are absorbed by aquatic plants and animals, both directly from the water and through the preceding link in the food chain. The resulting pollution contaminates all living organisms in the body of water, including the people who rely on fish as their primary source of protein and economic livelihood. In addition, the tree's photosynthetic ability to bear fruit is impaired, resulting in a decrease in production. Mining activities may cause health problems in communities near mines, including miners. (Abiye, 2005) determined that the doses in the Jos tin mining area were greater than 0.07 mSv/yr, the maximum permissible dose limit for members of the population. Therefore, the human body may experience a variety of health impacts from the consumption and inhalation of contaminants.

Ionizing radiation is harmful at high doses. Because of the potential health effects, it is imperative to understand the radiation levels in and around mining areas through the food matrix (Abiye, 2005). Certain actions, especially when there are mineral deposits, may increase chronic radiation exposure. Sadly, the general populace is not aware of the radioactive risk that could be present in the soil and food that come from these locations. As a result, mining may raise the concentration of natural radionuclides, although this must be prevented. One option is to obtain baseline data for the area prior to the start of mining. The measurement of natural radioactivity in foods and other sources is crucial because it aids in tracking changes over time in the natural background activity as a result of any radiation releases brought on by mining operations. There is possibilities that Oshosun might soon begin mining.

It is impossible to completely rule out the possibility of mining-related chemical and heavy equipment pollution of the environment's matrix-like diet, and it is always challenging to monitor the radiological and environmental effects after operations begin. Therefore, it is necessary to conduct a baseline evaluation of the area prior to the start of mining operations.

According to (Obaje *et al.*, 2013), Nigerian phosphates from the Sokoto and Ogun regions have been shown to have a very high reactivity, making them ideal as a fertilizer material, even when applied directly to the soil to increase fertility and agricultural production (Obisesan, 2004). The deposit, according to the Ministry of Solid Minerals Development (2000), is 40 million tonnes (Adebanwo *et al.*,2010). By the time operations start, phosphate mining would accelerate the development of Ogun State's and Nigeria's infrastructure.

Since mining has not yet started on the Oshosun Phosphate Deposit, there have been no industrial operations there. As a result, the levels of NORMS in the region are caused by what occurs naturally in the environment and not by human activity. Through this study, adequate data on natural and artificial radionuclide concentrations will be established. This will help in assessing any possible radiological hazard that the population could be exposed to in the future when the mining activities start. Such detailed baseline data will be made available to guide all stakeholders involved in the monitoring of the environment for environmental pollutants including radiation exposures.

MATERIALS AND METHODS

Samples Collection and Preparation

The food samples were collected randomly from various farms in and around Oshosun. Samples of each food stuffs were washed to remove dirt . Each of the samples collected were then transferred into polythene bag and labeled. The total number of representative food crop samples collected from Oshosun and its environ were fourteen . The samples were taken to laboratory where they were cut into pieces, dried in oven at 110^0 C until a constant weight was obtained, this was followed by pulverization and then sieving of the samples. The process was followed by packaging into radon-impermeable cylindrical plastic containers. To prevent radon-222 escape, the packagings in each case were tightly sealed. The prepared samples were then stored for a period of about four weeks to attain secular equilibrium between radon (^{226}Ra) and its daughters prior to analysis using NaI(TI) gamma ray spectrometer (Khater *et al.*, 2001), (Eric, 2014).

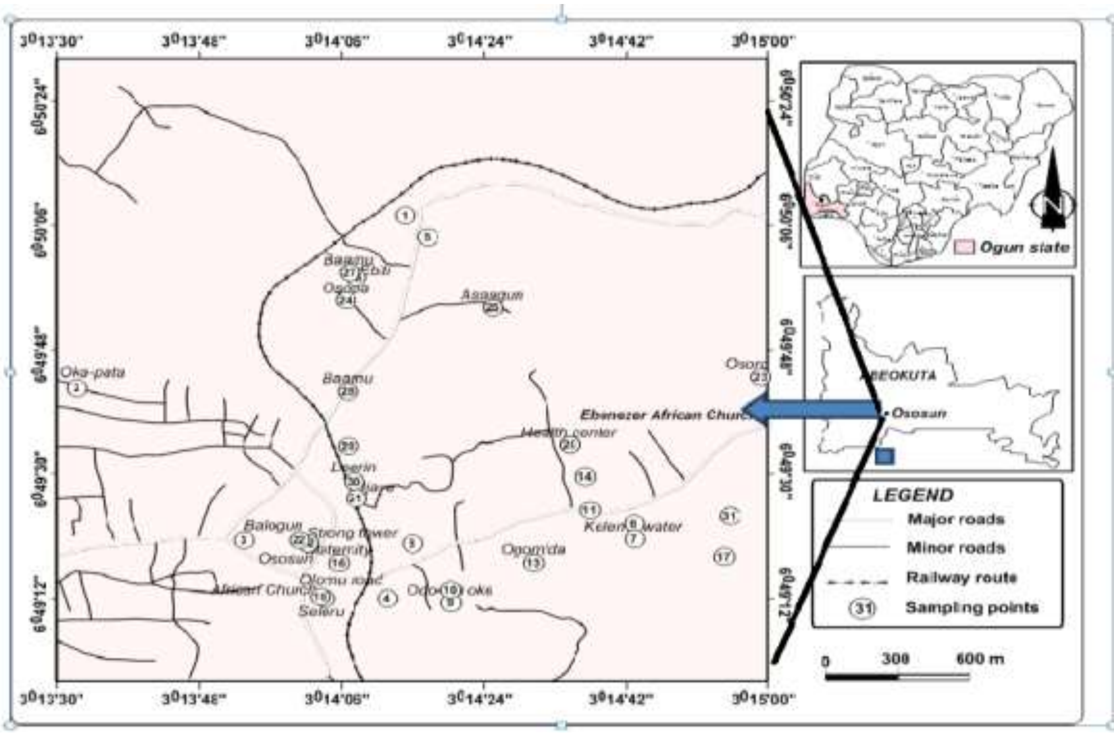

Figure 1: The map showing the locations in Oshosun where samples were collected.

Gamma-Spectrometry using Na(Tl) detector

Measurements of activity concentrations of the naturally–occurring radionuclides (^{40}K, ^{226} Ra and ^{232}Th) in the samples were performed using NaI(TI) gamma ray spectrometer. The gamma-ray spectrometry set-up consists of a 5.08 by 5.08 cm^2 NaI (Tl) detector, housed in a 6.0 cm thick lead shield which is lined with cadmium and copper sheets in order to reduce background radiation. A computer based multichannel analyser (MCA) and an Oak Ridge Technical Enterprises Corp (ORTEC) Digibase connected to a PC was used for the data acquisition and analysis of gamma spectra. The energy and efficiency calibration were performed using reference material. Both the primary reference materials and each of the samples were counted for a period of 10,800 sec, after which the net area under the corresponding gamma -ray peaks within their region of interest (ROI) in the energy spectrum, 1460 keV, 1764.5 keV and 2614 keV for ^{40}K, ^{226} Ra and ^{232}Th respectively, were computed.

Activity Concentration

The activity concentrations, C in Bqkg^{-1} are calculated from the decay and isotropic data, and the elemental concentration values provided in the reference materials preparation certificates using Equation 2.0 (Otwoma *et al.*, 2012).

$$C\left(\frac{Bq}{kg}\right) = \frac{C_{o.}\ N_{A\ .}\ \lambda\ .\ I}{M_W} \qquad 2.0$$

Where C_o is the Elemental concentration of the standard materials (μg g^{-1}), N_A is the Avogadro number (6.023 x 10^{23} $mole^{-1}$), λ is the decay constant ($sec.^{-1}$), I is the relative isotropic abundance, M_w is the molecular weight (g $mole^{-1}$) (IAEA,2003).

The results obtained from the samples and certified reference materials were substituted in the comparison method formula to get activity concentrations of the primordial radionuclides using Equation 2.1 (Mustapha, 1999).

$$\frac{A_{Sample}}{A_{std}} = \frac{CR_{sample} - CR_{Bgd}}{CR_{std} - CR_{Bgd}} \qquad 2.1$$

where
A_{sample} = Activity concentration of the sample, A_{std} = Activity concentration of the standard, CR_{sample} = Count rate of sample (cps), CR_{Bgd} = Count rate of Background (cps). CR_{st} = Count rate of standard (cps)

Effective dose from ingestion of radionuclides in foodstuffs

The intake of radionuclides in food is dependent on the concentration of radionuclides in the various foodstuffs and the amount consumed. The risk associated with the intake of radionuclides in the body is proportional to the total dose delivered by the radionuclides while staying in the various organs. The effective dose, E (mSv/y) to an adult individual due to intake of natural radionuclides in foodstuffs was calculated on the basis of the activity concentrations of the radionuclides. The committed effective dose owing to ingestion of ^{226}Ra, ^{232}Th and ^{40}K in foodstuffs was calculated using Equation 2.4 (Eric,2014).

$$E_{ing}\ (FS) = \mathbf{\Sigma}(Afs \times Ifs \times IDCFfs) \qquad 2.4$$

where; Afs, is the average activity concentration of radionuclides (Bq/kg) in foodstuffs, Ifs, is the annual intake of foodstuffs, IDCFfs, is the dose conversion factors (Sv/Bq) 40 kg/y for Tubers, 45 kg/y for Vegetables, 75 kg/y for Pawpaw and 50 kg/y Plaintain (RIFE, 2004). The dose coefficients for the public were 4.5 x 10^{-5}, 7.2 x 10^{-5} and 6.2 x 10^{-6} $mSvBq^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K respectively (ICRP,1992), (Jibril and Abiodun 2012).

RESULTS AND DISCUSSION

The activity concentration oftheradionuclides in food stuff samples taken from different locations in the study are presented in Table 1. The activity concentration of ^{40}K(Bq/kg) ranged from 5.01 ±9.71 in Bitter leaf at Olomu to 138.81± 22.59 in Plantain at the same village with a mean of 68.87 ± 4.47 Bq/kg.^{226}Ra was calculated and the range was from 8.39 ± 78.17 -74.68± 33.47 Bq/kg at Asaagun with a mean of 45.35 ± 15.63Bq/kg.The range of ^{238}Th in the samples were from 13.74±12.21 at Olomu to 47.87 ±9.69 Bq/kg at Osoba with the mean of 28.37±1.90 Bq/kg.The activity concentration of vegetable was low contrary to (Awudu *et al*.2012).

It could be observed that the primordial elements are not uniformly distributed in the samples and also that the measured ^{40}K activity concentration was higher than the values of both ^{226}Ra and ^{232}Th, this attested to the probable high consumable absorption of the element from the land.Also application of fertilizer which is a common practice in the area can enhance the availability of ^{40}K in the soil.The frequency distribution of the activity concentration in the foodstuffare presented in Figures 2,3 and 4 for ^{40}K,^{226}Ra and ^{232}Th respectively. The ^{40}K in the distribution is tri-modal (3 modes). This is not normally distributed because the modes are at both ends of the mean. Figure 2 (^{226}Ra) shows a bimodal distribution. This is somewhat normal because one of the modes is at the same level with the mean. ^{232}Th (Figure 3) in the sample is normally distributed.

The study showed a highly non-uniform distribution of primordial radionuclides in food crop samples, with activity concentrations varying significantly within the study area. ^{40}K has highest concentration when compared with other radionuclides. This may be due to the highly localized mineralization of Potassium in the soil. The calculated mean effective dose for the foodstuff in the study area was 1.13 mSvyr^{-1}.

Table 1: Activity Concentration and Committed Effective dose due to ^{40}K, ^{226}Ra and ^{232}Th in Food stuff Samples

Group	Sample	Botanical name	locations	Activity Concentration (Bq/kg)			Effective dose (Sv/y)
				^{40}K	^{226}Ra	^{232}Th	
	Water yam 1	Dioscorea Alata	Balogun	8.78 ± 22.00	49.89 ± 51.15	22.52 ± 13.6	
	Water yam 2	Dioscorea Alata	Oshosun	94.07 ± 14.70	44.58 ± 67.76	28.37 ± 11.22	
Tuber	Yam 1	Dioscorea Rotundata	Asaagun	72.75 ± 22.87	71.78 ± 44.19	22.51 ± 12.80	
	Cassava 1	Manihot Esculanta	Olomu	58.95 ± 12.46	55.19 ± 31.73	23.49 ± 10.34	
	Cassava 2	Manihot Esculanta	Asaagun	55.19 ± 11.51	58.57 ± 39.65	19.59 ± 10.18	0.22
	Yam 2	Dioscorea Rotundata	Osoro	28.85 ± 11.16	46.99 ± 36.83	35.19 ± 13.07	
	Bitter leaf	Vermonia Amygdalina	Olomu	05.02 ± 9.71	57.32 ± 38.26	13.74 ± 12.21	
	Jute leaf	Corchorus Olitorious	Asaagun	82.79 ± 14.65	27.69 ± 60.68	17.64 ± 10.3	
Vegetable	Lagos Spinach	Celosia Argentea	Asaagun	67.73 ± 15.83	74.68 ± 33.47	26.42 ± 11.34	
	Tree Spinach	Cnidoscolus Aconitifolius	Laaran	15.05 ± 13.01	61.37 ± 61.85	30.32 ± 16.52	
	African spinach	Amaranthus Hybridus	Laaran	122.92 ± 17.87	15.15 ± 60.14	43.97 ± 9.54	
	Atetedaye	Desmodium Intortum	Asaagun	80.28 ± 11.88	8.39 ± 78.17	27.39 ± 10.49	0.19
Plant	Pawpaw	Carica Papaya	Osoba	132.96 ± 12.19	33.96 ± 42.04	47.87 ± 9.69	0.43
	Plantain	Musa Paradisiaca	Olomu	138.81 ± 22.59	29.33 ± 74.88	38.12 ± 11.74	0.29
	Range			5.02- 138.81	8.39 -74.68	13.74-.47.87	
	Mean			68.87	45.35	28.37	

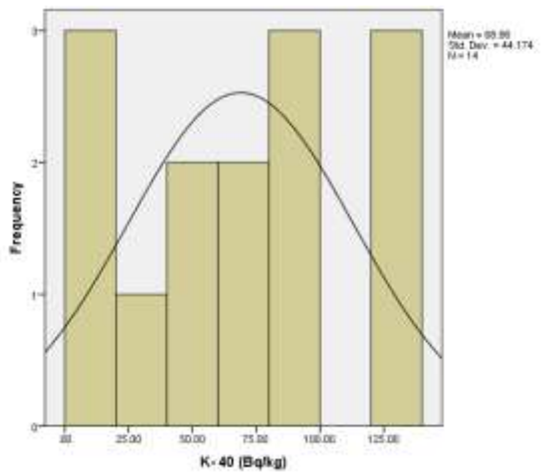

Figure 2: Frequency distribution of Activity Concentration of ^{40}K in Food samples from Oshosun.

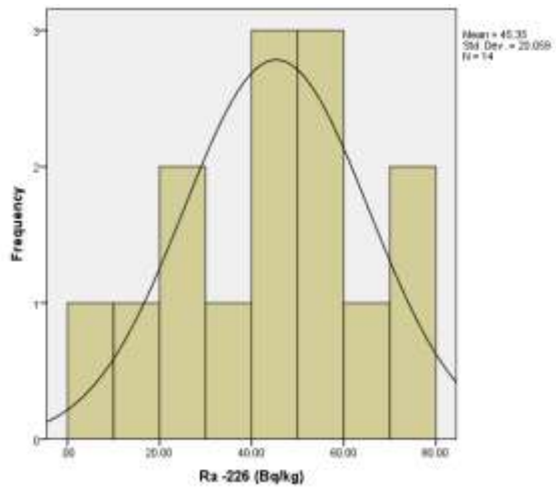

Figure 3: Frequency distribution of Activity Concentration of ^{226}Ra in Food samples from Oshosun.

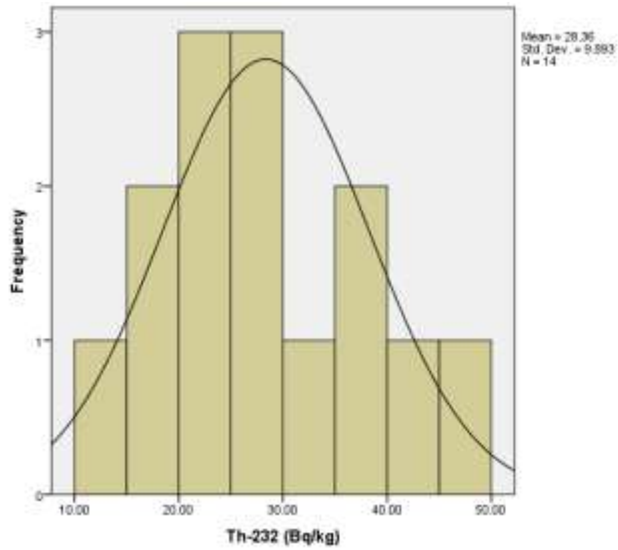

Figure4: Frequency distribution of Activity Concentration of ^{232}Th in Food samples from Oshosun.

CONCLUSION

During mining, the quality of the air can be affected due to the release of dust from blasting, drilling, loading and haulage of the earth materials as well as heavy trucks exhaust gases. This will also increase the radiation dose individual is exposed to since the release are from radionuclides of terrestrial origin.

The result revealed a highly mineralization of potassium which is an important requirement for plant growth and development in the soil. The results obtained in this work are within the tolerable values, but every effort must be made to monitor the environment in order to control the radiation dose released to man from the environment.

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