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Baseline Measurement of Natural Radioactivity in Soil, Vegetation and Water in the Industrial District of the Federal Capital Territory (FCT) Abuja, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. AMU designed the study, collected and prepared the field samples, participated in the laboratory procedures, performed the statistical analysis and wrote the first draft of the manuscript. MYO contributed to the experimental set up and statistical analysis and SAJ supervised the analyses of the study and handled the literature search and review. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Natural radioactivity in environmental samples (soil, vegetation and water) from the (Idu) industrial district of Federal Capital Territory (FCT) Abuja, Nigeria was measured by means of gamma-ray spectrometer with NaI (Tl) detector to establish a baseline data for activity concentration of ^{40}K, ^{226}Ra and ^{232}Th. The highest activity concentration of ^{40}K, ^{226}Ra and ^{232}Th were found in soil collected from location S_2 (943.1 Bq/kg), in vegetation V_C (82.3 Bq/kg) and in soil collected from location S_3 (107.3 Bq/kg), respectively, where only the activity from S_2 is higher than the world average of 420 Bq/kg and the highest activity concentrations of both ^{226}Ra and ^{232}Th from V_C (82.3 Bq/kg) is above the world average of 50 Bq/kg (UNSCEAR, 2000). Results from the twelve field samples analysed also indicated that the activity concentration due to ^{40}K in the soil samples ranked highest against the lowest value obtained for sediments in the water samples.

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1. INTRODUCTION

The main aim of the study is to identify and quantify prominent naturally occurring gamma emitting radionuclide's to form basis for comparative analysis, in any observed elevated activity concentrations in the future due to human activities in the event of occupational and residential settlement on the land. For this aim, the activity concentrations of ^{232}Th, ^{226}Ra and ^{40}K in environmental samples (soil, vegetation and water) collected from the designated industrial district of the Federal Capital Territory were determined using gamma-ray spectrometric technique.

Baseline measurement of activity concentration levels in a natural, undisturbed environment offers the opportunity to document present conditions in order to scientifically assess future effects due to other external factors such as human activities. Such study enables the understanding of the decay chain where a series of stepwise decay in terms of half lives of nuclei of unstable radionuclide's lead to a stable state in a form of another nuclide. A typical decay chain is one that describes the decay of ^{232}Th to a stable state of ^{208}Pb (Jonah et al., 2002):

Th-232(α) $\rightarrow$ Ra-228(β) $\rightarrow$ Ac-228(β) $\rightarrow$ Th-228(α) $\rightarrow$ Ra-224(α) $\rightarrow$ Rn-220(α) $\rightarrow$ Po-216(α) $\rightarrow$ Pb-212(β) $\rightarrow$ Bi-212(β) $\rightarrow$ Tl-208(β) $\rightarrow$ Pb-208(stable)

So far only one similar or related study has been reported on the subject in the FCT. Analysis of thirty samples collected from across the six area councils of the FCT (covering the entire 52 districts and cadastral zones presently marked in phases I, II and III) was done using NaI (Tl) detector, from which the assessment of radiological indices returned low chances of health hazards due to presence of the primordial radionuclides to the populace Awodugba et al., 2011; However, similar studies within the same scope are reported to have been done in other locations within the country. These include a study that determined the concentration of 44 different types of rocks samples around Ondo and Ekiti States using NaI (Tl) detector, (Ajayi and Kuforiji, 2000); Measurement of activity concentration of ^{40}K, ^{226}R and ^{232}Th for assessment of radiation hazards from soils of southern region of Nigeria where 38 samples were analysed to obtain range of activities for the respective nuclides from which radiological indices were also estimated for likely radiation hazards (Ajayi, 2009); Characterization of activity concentration of primordial radionuclides in the Zaria area using high-resolution gamma ray spectrometry, which was compared with natural radionuclide concentrations determined for ^{232}Th, and ^{238}U with those determined by laboratory based NaI(Tl) detector system, where values were significantly different for these nuclides but in general agreement with that for ^{40}K by both techniques, (Auwal et al., 2010); Findings of a baseline study undertaken to evaluate the natural radioactivity levels in soil, sediment and water samples in four flood plain lakes of the Niger Delta activity profiles of the radionuclides have clearly showed low activity concentrations across the study area and these values compared well with other values obtained within Nigeria, indicating that the terrestrial soil and sediment of the area have no immediate health implication for the inhabitants

(Agbalagba and Onoja, 2011). Other related studies are Jibiri and Okeyode, (2012); and Alatise et al., (2008).

Similarly, studies have been carried out on the subject matter in other parts of the world. Some documented results are presented by a study where beach regions were selected to study the ambient radiation environment. The activity concentrations of ^{40}K and the decay products of ^{232}Th, and ^{238}U were obtained using an innovative method in single channel NaI (Tl) gamma-ray spectrometry. The counts for both the sample and the reference material in a specific window for a particular radionuclide were compared to arrive at the activity concentration of the radionuclide in the sample from a gold mine (Odumo et al., 2011).

The Federal Capital Territory (FCT) is a relatively new creation of the Federal Government of Nigeria sequel to a decision in 1975 to relocate the seat of the central government to Abuja, a city within the FCT, from the former capital city of Lagos. The seat of government formally moved to the area in the December of 1991. In-between when the idea was born until the first phased movement, the FCT much like other modern new cities was elaborately planned to house and host all expected paraphernalia of the Federal Government and supporting infrastructure including industrial development.

The Territory is still in its formative stage as infrastructural development is carried out through a planned and step wise implementation of approved master plan. So, area layouts mapped for hosting industrial infrastructure are also being gradually inhabited. With a land area of 8,000 square kilometers and located within latitude 7º25' N and 9º20' North of the Equator and longitude 5º45' and 7º39', there are two main types of soils in FCT; the sedimentary belt in the southern and south-western extremities of the territory and the pre-Cambrian Basement complex rock country which accounts for more than 80 percent of the territory. The particular target area for this study is a virgin, uncultivated parcel of land situated within cadastral zone C16, marked as Industrial Area 1, which is one of 19 such districts and cadastral zones in the phase III of the FCT (www.fct.gov.ng). “Fig. 1” is a map of the Abuja Phase III General Land Use showing the (Idu) Industrial District area of FCT.

It is therefore worthwhile to make contribution to the information data base on scientific and technical findings to guide and support formulation of informed policies on infrastructural development matters. In this regard determination of the distribution of the natural and anthropogenic radionuclide’s is essential for evaluation of public exposure, storage reference data records on radionuclide’s for producing a radiation map of the country and ascertaining possible changes in environmental radioactivity caused by nuclear, industrial and other human activities.

Fig. 1. Abuja phase III general land use showing the industrial area 1 of FCT

2. MATERIALS AND METHODOLOGY

2.1 Sample Collection and Preparation

Twelve field samples (of about 1 kg for soil & vegetation) three each for soil, S_1, S_2, S_3 to a depth of about 10 cm; vegetation, V_1, V_2, V_3; and water from small streams, W_1, W_2, W_3 (about 2 l) within the area of consideration were collected at random, initially filled into polyethylene bags separately for respective points in equal measures and labeled accordingly. And, additional control samples for the soil, $S_{c;}$ vegetation, V_C and water, W_c (from a lake) were also collected at a selected location away from the target site, at a short distance away from a border of the industrial area and analysed for benchmarking purposes. Each of the water samples were treated with drops of nitric acid in order to maintain its original integrity over time. The samples were brought into the laboratory and left open for slightly over twenty four (24) hours under ambient temperature. Following thorough drying the soil and vegetation were pulverized to fine power and packed to fill cylindrical containers of height 7cm by 6cm in diameter which is the same as the geometry of the counting detector. Each container accommodated approximately 300 g of sample. Similarly, the liquid sediment packed and was carefully sealed (using vaseline petroleum jelly) and kept for over 30 days (Jibiri and Okeyode, 2012).

2.2 Experimental Set up

The gamma-ray spectrometry set-up is made up of a 7.62 cm by 7.62 cm NaI (Tl) detector housed in a 6 cm thick lead shield (to assist in the reduction of the background radiation) and lined with cadmium and copper sheets CERT Manual, 1999. The samples were placed on the detector surface and each counted for about 29,000 seconds in reproducible sample-detector geometry. The configuration and geometry was maintained throughout the analysis, as previously characterized based on well established protocol of the laboratory (at the Centre for Energy Research and Training, Zaria). A computer based Multichannel Analyser (MCA) MAESTRO Programme from ORTEC was used for data acquisition and analysis of gamma spectra. The 1764 keV Gamma-line of ^{214}Bi for ^{238}U was used in the assessment of the activity concentration of ^{226}Ra, while 2614.5 keV Gamma-line of ^{208}Tl was used for ^{232}Th. The single 1460 keV Gamma-line of ^{40}K was used in its content evaluation.

All the obtained raw data were converted to conventional units using calibration factors to determine the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th respectively. In order to determine the specific activity concentrations in the samples, the IAEA mixed standard consisting of ^{40}K, ^{226}Ra and ^{232}Th of the same dimension as the samples were subjected to the same experimental procedures. After the subtraction of background counts, conversion of the count per second to activity concentration in Bq/kg was performed using the conversion factors which are different for each nuclide such that for ^{40}K, ^{226}Ra and ^{232}Th are 6.431, 8.632 and 8.768, respectively.

3. RESULTS AND DISCUSSION

3.1 Results

Results show that while activity concentration in the soil samples is highest due to ^{40}K at 943.1 Bq/kg, the lowest is obtained for ^{226}Ra with concentration of 9.2 Bq/kg. For the vegetation samples, a control sample obtained from outside the primary field of interest, V_c contains higher activity concentration value when compared with the total of all the three vegetation samples, V_1, V_2, V_3, which are well below the world average of 420 Bq/kg.

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the respective samples are presented in "Tables 1a and 1b". "Fig. 2a and 2b" show bar charts showing the deduced activity concentrations for the samples.

Table 1a. Measurement of count rate and deduced activity concentrations of (soil and vegetation) samples

Sample ID	^{40}k (CPS)	Activity (Bq/Kg)	^{226}Ra (CPS)	Activity (Bq/Kg)	^{232}Th (CPS)	Activity (Bq/Kg)
S1	0.14	223.5 ± 8.4	0.04	41.1 ± 4.4	0.07	78.6 ± 2.9
S2	0.61	943.1 ± 5.3	0.01	9.2 ± 0.7	0.06	71.1 ± 2.2
S3	0.29	452.1 ± 7.2	0.01	14.4 ± 0.6	0.09	107.3 ± 2.2
Sc	0.17	264.1 ± 8.6	0.03	34.9 ± 0.8	0.08	96.1± 1.2
V1	0.02	35.2 ± 2.0	0.03	33.2 ± 2.0	0.05	59.2 ± 0.8
V2	0.05	81.8 ± 2.6	0.01	13.5 ± 0.4	0.02	18.4 ± 0.4
V3	0.03	44.8 ± 3.0	0.03	28.6 ± 1.8	0.05	51.6 ± 1.0
VC	0.11	166.6 ± 3.4	0.07	82.3 ± 2.4	0.03	33.7 ± 0.2
Lab Bgrnd	0.19	287.5 ± 21.2	0.02	22.5 ± 1.1	0.10	109.0 ± 9.3

Table 1b. Measurement of count rate and deduced activity concentrations of (water) samples

Sample ID	^{40}k (CPS)	Activity (Bq/l)	^{226}Ra (CPS)	Activity (Bq/l)	^{232}Th (CPS)	Activity (Bq/l)
W1	0.01	20.1 ± 4.3	0.02	27.9 ± 1.4	0.03	33.1 ± 2.4
W2	0.03	49.9 ± 6.5	0.01	15.1 ± 1.3	0.02	24.6 ± 1.3
W3	0.02	32.6 ± 5.6	0.02	17.3 ± 0.4	0.04	40.8 ± 1.3
WC	0.07	111.8 ± 7.5	0.02	18.4 ± 2.7	0.03	36.4 ± 2.2

3.2 Discussion

The overall picture indicates that commonly occurring nuclides of ^{226}Ra, ^{232}Th and ^{40}K within the research site are not uniformly distributed in the soil, vegetation and water sediments.

Similar pattern is also noticed for the water samples, where the control sample, W_c indicates highest radioactivity due to ^{40}K at 111.8 Bq/l over and above the three water samples collected within the target study area showing lowest value of 20.1 Bq/l for W_1. The explanation for this pattern of results as regards the control area may not be farfetched, as the considered location is an artificial lake, the Jabi (park) lakeside, within residential vicinity of the city, where domestic liquid affluent flow into. Overall, results show that radioactivity effect due to the water, is lowest compared to soil and vegetation. As expected the radioactivity concentrations due to ^{40}K is highest compared with ^{226}Ra and ^{232}Th.

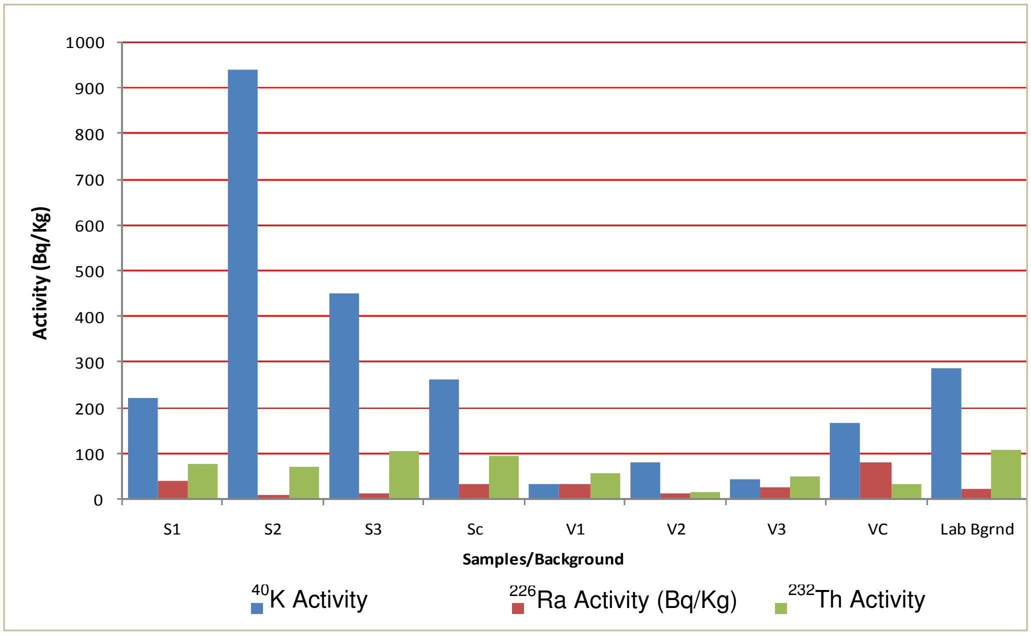

Fig. 2a. A graph of activity concentration for soil & vegetation samples/background

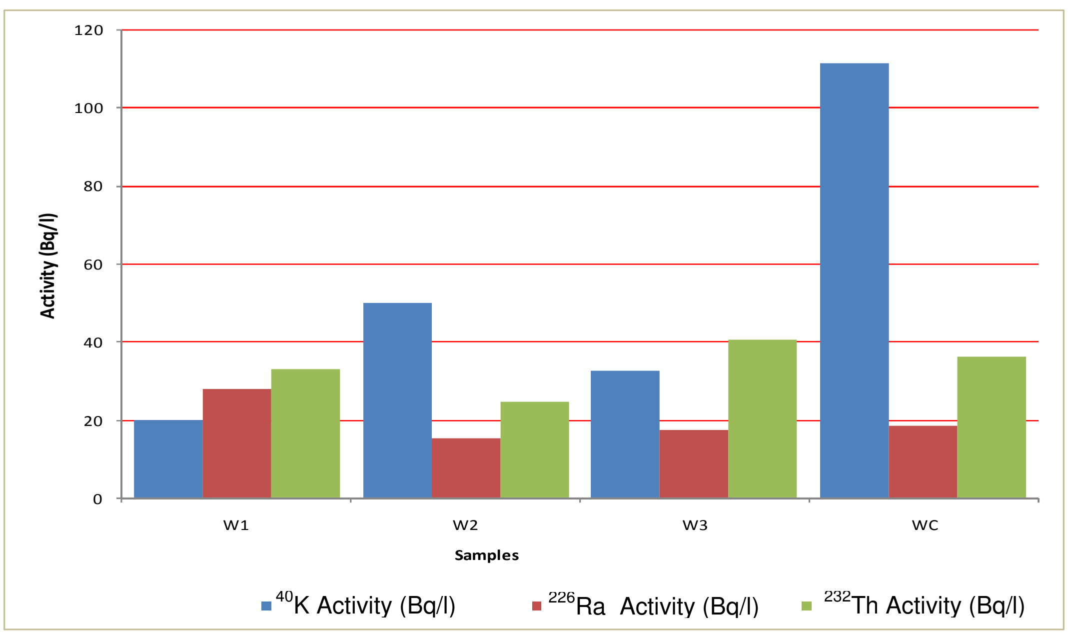

Fig. 2b. A graph of activity concentration for water samples

It is worthy to note that, except for the soil sample, S_2 collected at location number 2, all activity levels are lower than the world background average for soils given as 420 Bq/kg due to ^{40}K (UNSCEAR, 2000). For ^{226}Ra concentration, only one location presents levels higher than world background average put at 50 Bq/kg, which is vegetation collected at a point within the control site, a location not far from a border of the target study area, carved out from fully built neighbourhood for recreation purposes but with similar physical land marks. The industrial district is largely virgin land not inhabited but for isolated small (hamlet like) settlements of squatters with very little evidence of subsistence farming around some border areas. There is currently strict enforcement of environmental laws in the FCT to maintain compliance to the master plans. However, for the activity due to ^{232}Th, exactly half of the total samples collected (for all types) and analysed indicate values higher than the world average put at 50 Bq/kg (UNSCEAR, 2000).

4. CONCLUSION

The activity concentrations due to the presence of three commonly occurring nuclides; ^{40}K, ^{226}Ra and ^{232}Th were determined within the industrial district of the Federal Capital Territory (FCT), Abuja, Nigeria to serve as a baseline data. Results show that only one location out of the twelve sampled, including the control site, gives activity concentration higher than the world average for ^{40}K in soil. Similarly all other activity concentrations due the ^{226}Ra and ^{232}Th are well within the world average except for one location at the control site in vegetation sample, V_c.

From these analyses, it can be inferred that the general distribution of activity concentration in the study areas are within tolerable levels. However, for more conclusive assessment of the potential biological effects of the nuclides this result is expected serve as input to further analysis in the estimation of relevant radiological hazards indices that may guide to setting up of control and radiation protection regimes within the area by relevant competent authorities of government.

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COMPETING INTERESTS

There is no competing interest whatsoever that could have influenced the outcome of this study in any manner.

REFERENCES

Agbalagba, E.O., Onoja, R.A. (2011). Evaluation of natural radioactivity in soil, sediment and water samples of Niger Delta (Biseni) flood plain lakes, Nigeria. Journal of Environmental Radioactivity, 102, 667-671.

Ajayi, I.R., Kuforiji, O.O. (2000). Natural radioactivity measurements in rocks samples of Ondo and Ekiti states in Nigeria. Science Direct, Short Communication.

Ajayi, O.S. (2009). Measurement of activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th for assessment of radiation hazards from soils of the southwestern region of Nigeria. Radiat Environ Biophys, 48, 323–332.

Alatise, O.O., Babalola, I.A., Olowofela, J.A. (2008). Distribution of some natural gamma-emitting radionuclides in the soils of the coastal areas of Nigeria. Journal of Environmental Radioactivity, 99(11), 1746-1749.

Argonne National Laboratory. (2005). EVS, Human Health Fact Sheet.

Auwal, M.M., Funtua, I.I., Malam, S.P., Abdullahi, A.S. (2010). Distribution of gamma-emitting radionuclides in soils around the centre for energy research and training (CERT) Ahmadu Bello University, Zaria, Zaria-Nigeria. Journal of American Science, 6(12), 995-1001.

Awodugba, A., Bioye, A., Adekunle, D., Ologun, O., Oyekunle, I., Oni, O., Techokossa, P. (2011). Basement data of the terrestrial radionuclide level of Abuja Federal Capital Territory, (FCT), Nigeria. Journal of Environmental Protection, 2, 359-364.

CERT Manual. (1999). Operation of Sodium iodide-Thallium Gamma Spectrometry System Manual, Centre for Energy Research and Training, Ahmadu Bello University, Zaria.

Federal Capital Territory Administration FCTA. (2009). Official website, www.fct.gov.ng.

Jonah, S.A., Okunade, I.O., Ibeanu, I.G.E., Jimba, B.W. (2002). Natural radionuclides and elemental composition of chemical fertilizers used in Nigeria. Nucl. Sci., 4(1), 49-52.

Jibiri, N.N., Okeyode I.C. (2012). Radiation physics and chemistry 81 (2012) evaluation of radiological hazards in these sediments of Ogun River, South Western Nigeria. Radiation Physics and Chemistry, 81,103- 112.

Odumo, O.B., Mustapha, A.O., Patel, J.P., Angeyo, H.K. (2011). Radiological survey and assessment of associated activity concentration of the naturally occurring radioactive materials (NORM) in the Migoriartisanal gold mining belt of southern Nyanza, Kenya. Applied Radiation and Isotopes, 69, 912–916.

Rahman, S.U., Matiulah, F.M., Rafique, M., Anwar, J., Ziafat, M., Jabbar, A. (2010). Measurement of naturally occurring/fallout radioactive elements and assessment of annual effective dose in soil samples collected from four districts of the Punjab Province. Pakistan J Radioanal Nucl Chem., 287, 647-655.

UNSCEAR. (2000). Sources and effects of ionizing radiation report to the general assembly with scientific annexes. United Nations Scientific Committee on the Effect of Atomic Radiation, New York.