Determination and Evaluation of Radionuclide Contents in the Soil of Oloru, Kwara State, Nigeria

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***Abstract**: The radionuclide contents in soil samples obtained from Oloru, Kwara State have been investigated. The qualitative and quantitative of any radionuclides present in an environment depends on the geological formations such an area. The geological formation of the area considered in this study consists of rocks, hill and steeps, and this may contribute to the presence of radionuclides that may be found in environmental matrices. The gamma spectrometry analysis was conducted using a well shielded and well calibrated NaI(Tl) detector. Three natural radionuclides namely ^{238}U, ^{232}Th and ^{40}K were identified and no artificial radionuclide in the samples assayed. The mean activity concentrations for the samples are 15.65 ± 1.94 Bqkg^{-1} (^{238}U), 4.23 ± 0.27 Bqkg^{-1} (^{232}Th) and 1006.29 ± 53.69 Bqkg^{-1} (^{40}K) respectively. The mean values for ^{238}U and ^{232}Th fall below the recommended mean while that of ^{40}K exceeded the recommended value. The various radiological parameters estimated are all lower than the recommended value. Thus, the community can be considered safe for habitation and the soil can be used for building purposes and other practices without causing any radiological hazard to the occupants. The results obtained may be taken as representing the baseline value of the radionuclide contents in the soil of the area.*

Keywords: Gamma spectrometry, Kwara State, Oloru, Radionuclide contents, Soil

1 INTRODUCTION

The significance of soil to support life by serving as a means of habitation for humans and plant cannot be overemphasized (Akinloye *et al.*, 2012). Radiations present in the environment originates from various sources which are grouped into natural and man-made (NCRP, 1976; UNSCEAR, 2000). Exposure to natural sources of radiation is inevitable and unending process on Earth. Natural radiation originates from cosmic rays that are continuously incident on the Earth's atmosphere, terrestrial radionuclides of primordial origin that spread widely in almost all geological materials found on Earth and internal radiation from radioactive elements found within the body (UNSCEAR, 2000; CNSC, 2012). The medical and industrial applications of radiation contribute majorly to the artificial sources of radiation (UNSCEAR, 2000; IAEA, 2010; CNSC 2012).

Studies have shown that exposures to radiation from natural sources contribute about 85% with the

global average dose of 2.4 $mSvy^{-1}$ while that from man-made sources contribute 15% to the population and the global average dose of 0.4 $mSvy^{-1}$ (UNSCEAR, 2000; WNA, 2013). Human exposure to natural radiation is a function of his or her location on the Earth's surface. Several radiological studies have been carried out by researchers and the results obtained have helped in assessing the effects associated with exposure to radionuclides. The studies show that, soil not only consists of inorganic and organic materials but also radioactive materials (Isola *et al.*, 2015). The distributions of these radioactive materials originate mainly from the radionuclide decay series of ^{238}U and ^{234}Th and the singly occurring ^{40}K (NCRP, 1976; UNSCEAR, 2000). Man-made radionuclides such as ^{137}Cs have also been found as result of fallout from weapons testing and some other human activities involving the use of these radionuclides (NCRP, 1976; UNSCEAR, 2000; Akinloye *et al.*, 2012). This knowledge of radionuclides concentrations and the distribution in the environment have provided useful information from environmental radioactivity can be monitor (Prasong and Susaira, 2008).

The implication of these radionuclides is a consequence of gamma ray exposure of the body and irradiation of lung tissue that may occur from the inhalation of radon and its decay progeny (Singh and Mahayan, 2005; Akinloye *et al.*, 2012). In view of this, the study was conducted so as determine the radionuclide contents and evaluate various radiological parameters associated with soil samples in Oloru community. This study was necessitated by the fact no previous research have been conducted on the area. Therefore, this study will provide a baseline radiological data for the study area and will also help in determining the safety of the area for habitation.

2 MATERIALS AND METHODS

2.1 Description of the Study area

Oloru, is located in Moro local government area of Kwara State, Nigeria. It is situated at the west of central region of Nigeria and bounded by latitudes $8^0 27^l$ N and $8^0 30^l$ N and longitudes $4^0 36^l$ E and $4^0 9^l$ E. The geological formation of the study area consists of rocks, hill and steeps, and lie entirely within the basement rocks of Nigeria (Rahama, 1988). These geological formations may contribute to the presence of radionuclides that may be found in study area environmental media.

2.2 Sampling and Sample Collection

The study area was group into five locations so as to have good representative sampling of the

area, keeping in mind the population density, location of residential areas and schools. A total of 25 soil samples were collected across each location. The soil samples were collected by clearing the surface vegetation from each location afterwhich the soil samples were collect at depths ranging from 3 cm to 10 cm. This was done so as to determine the presence of ^{137}Cs that may be present into player of the soil. Each soil sample was packaged in a black polypropylene nylon after which the samples were taken to the laboratory for furtherpreparation.

The soil samples were oven-dried at 100^{o}C for 2 hrs using an electrically heated temperature controlled oven so as to remove the moisture content present in the soil samples. Thereafter, the samples were then pulverized, sieved through a 2 mm mesh, and packed inside a cylindrical polypropylene container that matches the geometry of the detector and tightly sealed with a polypropylene tap for a period of 28 days which was a sufficient period required to attain a state of secular radioactive equilibrium between radium isotopes and it progenies before the gamma spectrometry analysis.

2.3 Sample measurement

The spectrometry analysis of the samples was carried out at the National Institute of Radiation Protection and Research (NIRPR) situated at the University of Ibadan, Nigeria. The gamma spectrometry system used consist of a Sodium Iodide activated with Thallium [NaI(Tl)] detector, Model 802 (3'' x 3'') with serial number 13000850 couple to an Osprey multichannel analyzer (MCA) manufactured by Canberra. The data acquisition was achieved through a Genie 2k software. The energy and efficiency calibration of detector was carried out using both the point sources and IAEA-385 standard sediment source.

Prior to the sample measurement, an empty container of the same geometry of the detector was counted for 36000 s so as to determine the background gamma ray distribution. The sealed samples after attaining a state of secular equilibrium, the samples were then counted for the same period of time. The gamma energies used for the estimation of radionuclide concentrations were ^{214}Pb with 352.0 keV, ^{214}Bi with 609.3 keV for ^{238}U, ^{208}Tl with 583.2 keV and ^{228}Ac with 911.1 keV for ^{232}Th and ^{40}K at 1460.8 keV. The samples activity concentrations A (Bqkg^{-1}) were determined using Equation1:

$$A = \frac{C_{net}}{P_{\gamma} \times \varepsilon \times m \times t} \qquad (1)$$

Where C_{net} is the net peak area, $P\gamma$ is the absolute gamma ray emission probability, ε is the full energy

peak efficiency of the detector, t is the counting time, and m is sample mass.

2.4 Estimation of Radiological Parameters

The contribution of the radionuclides identified in the samples to the absorbed dose rate due to external exposure was evaluated using Equation2:

$$ADRA\ (\text{nGy}h^{-1}) = C_U A_U + C_{Th} A_{Th} + C_K A_K \qquad (2)$$

Where C_U = 0.042, C_{Th} = 0.043, and C_K = 0.666 are the conversion coefficient and A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K respectively (UNSCEAR, 2000).

The annual effective dose equivalent due to the radionuclides detected in the soil samples was estimated using Equation3:

$$AEDE(\mu\text{SvG}y^{-1}) = ADRA \times O_f \times C_c \times T \qquad (3)$$

Where ADRA is the absorbed dose rate due to external exposure, O_f is the outdoor occupancy factor (0.2), C_c is the dose conversion coefficient (0.7 $SvGy^{-1}$) and T is the time of exposure for a year (8760 h) (UNSCEAR, 2000).

Radium equivalent activity (Ra_{eq}) is used to assess the different mixtures of environmental materials and hazards associated with radionuclide contained in the materials. The radium equivalent measured in $Bqkg^{-1}$ was calculated using Equation 4. (EC, 1999), where A_U, A_{Th} and A_K are as already define.

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \qquad (4)$$

The hazard indices evaluate the potential radiological hazard. It is a safety criterion for materials used for building purposes. External hazard index (H_{ex}) was calculated using Equation 5:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (5)$$

The internal hazard index (H_{in}) further quantify the exposure to radon and its decay products when samples are used as part of building materials, and this was determined using Equation 6:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (6)$$

3 RESULTS AND DISCUSSION

Table 1 present the results obtained for radionuclides detected in the samples analyzed and this shows that the radionuclides detected belong to the natural terrestrial radionuclides headed by ^{238}U, ^{232}Th series and the singly-occurring radionuclide ^{40}K. No artificial radionuclide was detected. The mean values obtained are 15.65 ± 1.94 Bqkg^{-1} for ^{238}U, 4.23 ± 0.27 Bqkg^{-1} for ^{232}Th 1006.29 ± 53.69 Bqkg^{-1} for ^{40}K. The mean values obtained for ^{238}U and ^{232}Th in all the samples are below the recommended means of 35 Bqkg^{-1} and 30 Bqkg^{-1} while that of ^{40}K exceed the recommended mean of 400 Bqkg^{-1} (UNSCEAR, 2000). The result obtained for the activity concentration of ^{40}K can be attributed to the geographical formation of the study area.

The various radiological parameters estimated for the soil samples are presented in Table 2. The estimated ADRA values range from 19.97 ± 3.61 nGyh^{-1} to 71.36 ± 4.26 nGyh^{-1} and fall within the range of 24 to 160 nGyh^{-1} recommended by (UNSCEAR, 2000). The mean value of 52.02 ± 3.27 nGyh^{-1} obtained can be compared with the mean value of 55 nGyh^{-1} within the limit of experimental error. Similarly, the estimated AEDE for the radionuclides range from 24.48 ± 4.24 µSvy^{-1} to 87.52 ± 5.22 µSvy^{-1} with a mean value of 63.79 ± 4.07 µSvy^{-1}. The mean value obtained for all the samples is less than 70 µSvy^{-1} recommended (UNSCEAR, 2000). These results are in agreement with the results obtained by Nwankwo and Olubo (2016) and this is due to the fact the geographical formation of Kwara State are the same.

The values obtained for Ra_{eq} range from 40.66 ± 7.03 to 136.83 ± 8.41 Bqkg^{-1} with a mean value of 96.63 ± 6.45 Bqkg^{-1}. The mean Ra_{eq} obtained fall below 370 Bqkg^{-1} recommended (EC, 1999). The obtained values for H_{ex} and H_{in} range from 0.11 ± 0.02 to 0.37 ± 0.02 Bqkg^{-1} with a mean value of 0.27 ± 0.02 Bqkg^{-1} and 0.15 ± 0.02 to 0.43 ± 0.03 Bqkg^{-1} with a mean of 0.31 ± 0.02 Bqkg^{-1} respectively. This shows that the radiation dose expected to be delivered both externally and internally to the occupants where these soil samples are used as part of building material does not exceed 1 Bqkg^{-1} as the international value (EC, 1999).

4 CONCLUSION

The radiological investigation of soil samples in Oloru community, Kwara State have been carried out using a well calibrated NaI(Tl) detector. The results obtained indicate that primordial radionuclides (^{238}U, ^{232}Th decay series) and singly occurring radionuclide ^{40}K were detected in the soil samples.

The study area can be considered safe for habitation as the mean AEDE value is 6.34% of the 1.0 $mSvy^{-1}$ recommended as the maximum permissible dose equivalent for the members of the public (ICRP, 1990). This implies that the soil sample obtained from the study area can be used as building material and also for agricultural practices without posing any radiological threat to the public.

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Table 1: Activity concentration of Radionuclides detected in the soil samples analyzed

Sample Code	^{238}U	^{232}Th	^{40}K
S_1	1.10 ± 0.24	3.04 ± 0.20	847.61 ± 43.99
S_2	13.23 ± 1.91	3.88 ± 0.24	1210.73 ± 61.49
S_3	17.67 ± 2.15	4.21 ± 0.26	1351.93 ± 69.22
S_4	20.07 ± 2.29	3.56 ± 0.22	924.84 ± 47.59
S_5	19.76 ± 2.47	5.94 ± 0.36	1232.07 ± 63.13
S_6	13.23 ± 1.61	6.03 ± 0.36	244.21 ± 63.71
S_7	15.58 ± 2.00	4.63 ± 0.28	927.73 ± 47.72
S_8	19.96 ± 2.22	4.52 ± 0.27	1260.54 ± 64.27
S_9	9.47 ± 1.45	1.39 ± 0.09	848.33 ± 43.94
S_{10}	14.17 ± 1.89	4.38 ± 0.27	587.03 ± 30.64
S_{11}	23.89 ± 2.61	6.51 ± 0.39	1248.40 ± 63.85
S_{12}	4.64 ± 0.82	2.94 ± 0.18	878.40 ± 45.40
S_{13}	19.20 ± 2.35	4.16 ± 0.25	1241.42 ± 63.46
S_{14}	17.81 ± 2.10	5.26 ± 0.31	1342.16 ± 68.54
S_{15}	23.56 ± 2.59	4.90 ± 0.29	1380.13 ± 70.23
S_{16}	11.64 ± 1.54	4.47 ± 0.27	1380.70 ± 70.48
S_{17}	12.70 ± 1.61	5.03 ± 0.30	1162.79 ± 59.40
S_{18}	7.81 ± 1.26	2.05 ± 0.13	1131.54 ± 57.89
S_{19}	17.72 ± 2.12	3.72 ± 0.23	1045.52 ± 53.69
S_{20}	14.65 ± 1.92	4.09 ± 0.25	1198.13 ± 61.42
S_{21}	23.85 ± 2.56	4.71 ± 0.28	594.26 ± 30.70
S_{22}	23.08 ± 2.71	4.14 ± 0.25	880.88 ± 45.95
S_{23}	19.14 ± 2.26	5.97 ± 0.35	761.80 ± 39.36
S_{24}	11.69 ± 1.53	5.36 ± 0.32	573.54 ± 30.01
S_{25}	19.74 ± 2.21	5.76 ± 0.34	902.47 ± 46.25
Range	**1.10 ± 0.24**	**1.39 ± 0.09**	**244.21 ± 63.71**
	23.89 ± 2.61	**6.51 ± 0.39**	**1380.70 ± 70.48**
Mean	**15.65 ± 1.94**	**4.23 ± 0.27**	**1006.29 ± 53.69**

Table 2: Estimated Radiological Parameters of the soil samples analyzed

Sample Code	ADRA ($nGyh^{-1}$)	AEDE ($\mu SvGy^{-1}$)	Ra_{eq} ($Bqkg^{-1}$)	H_{ex} ($mSvy^{-1}$)	H_{in} ($mSvy^{-1}$)
S_1	38.10 ± 2.08	46.72 ± 2.56	70.71 ± 3.91	0.19 ± 0.01	0.19 ± 0.01
S_2	59.12 ± 3.56	72.51 ± 4.37	112.01 ± 6.99	0.30 ± 0.02	0.34 ± 0.02
S_3	67.18 ± 4.01	82.39 ± 4.91	127.78 ± 7.85	0.35 ± 0.02	0.39 ± 0.03
S_4	49.84 ± 3.13	61.13 ± 3.84	96.37 ± 6.27	0.26 ± 0.02	0.32 ± 0.02
S_5	64.20 ± 3.95	78.73 ± 4.85	123.12 ± 7.85	0.33 ± 0.02	0.39 ± 0.03
S_6	19.96 ± 3.61	24.48 ± 4.42	40.66 ± 7.03	0.11 ± 0.02	0.15 ± 0.02
S_7	48.75 ± 3.05	59.78 ± 3.74	93.64 ± 6.07	0.25 ± 0.02	0.30 ± 0.02
S_8	64.54 ± 3.83	79.15 ± 4.70	123.49 ± 7.55	0.33 ± 0.02	0.39 ± 0.02
S_9	40.63 ± 2.53	49.83 ± 3.10	76.78 ± 4.96	0.21 ± 0.01	0.23 ± 0.02
S_{10}	33.76 ± 2.28	41.29 ± 2.80	65.63 ± 4.64	0.18 ± 0.01	0.22 ± 0.02
S_{11}	67.04 ± 4.06	82.22 ± 4.98	129.32 ± 8.06	0.35 ± 0.02	0.41 ± 0.03
S_{12}	40.85 ± 2.38	50.09 ± 2.92	76.48 ± 4.57	0.21 ± 0.01	0.22 ± 0.02
S_{13}	63.17 ± 3.84	77.47 ± 4.71	120.74 ± 7.59	0.33 ± 0.02	0.38 ± 0.03
S_{14}	67.53 ± 3.99	82.82 ± 4.89	128.68 ± 7.82	0.35 ± 0.02	0.40 ± 0.03
S_{15}	71.36 ± 4.26	87.52 ± 5.22	136.84 ± 8.41	0.37 ± 0.02	0.43 ± 0.03
S_{16}	65.97 ± 3.80	80.91 ± 4.66	124.35 ± 7.35	0.34 ± 0.02	0.37 ± 0.02
S_{17}	57.65 ± 3.39	70.70 ± 4.15	109.43 ± 6.61	0.21 ± 0.01	0.33 ± 0.02
S_{18}	52.25 ± 3.06	64.08 ± 3.75	97.87 ± 5.90	0.26 ± 0.02	0.29 ± 0.02
S_{19}	54.01 ± 3.32	66.24 ± 4.07	103.54 ± 6.58	0.35 ± 0.02	0.33 ± 0.02
S_{20}	59.34 ± 3.57	72.78 ± 5.85	112.75 ± 7.01	0.31 ± 0.02	0.34 ± 0.02
S_{21}	38.35 ± 2.58	47.03 ± 3.16	76.34 ± 5.32	0.21 ± 0.01	0.27 ± 0.02
S_{22}	49.70 ± 3.26	60.95 ± 4.13	96.87 ± 6.60	0.26 ± 0.02	0.32 ± 0.03
S_{23}	44.20 ± 2.86	54.21 ± 3.51	86.34 ± 5.79	0.23 ± 0.02	0.29 ± 0.02
S_{24}	32.69 ± 2.13	40.09 ± 2.61	63.52 ± 4.29	0.17 ± 0.01	0.20 ± 0.02
S_{25}	50.23 ± 3.12	61.60 ± 3.82	97.47 ± 6.26	0.26 ± 0.02	0.32 ± 0.02
Range	**19.96 ± 3.61**	**24.48 ± 4.42**	**40.66 ± 7.03**	**0.11 ± 0.02**	**0.15±0.02**
	71.36 ± 4.26	**87.52 ± 5.22**	**136.83 ± 8.41**	**0.37 ± 0.02**	**0.41**±0.03
Mean	**52.02 ± 3.27**	**63.79 ± 4.07**	**99.63 ± 6.45**	**0.27 ± 0.02**	**0.31 ± 0.02**