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Assessment of Background Radioactivity of Surface Soils in Ondo City, Ondo State, Nigeria

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Abstract
The natural radioactivity of surface soils collected from various locations in Ondo City were measured by means of well calibrated High Purity Germanium (HPGe) detector, Canberra model coupled to a versatile Canberra Multichannel Analyzer, at the Centre for Energy Research and Development of Obafemi Awolowo University. Ile Ife. The soil samples were collected from the fourteen zones that constituted the town with four samples taken from each zone. The emission line spectra used in identifying the natural radioisotopes belong to ^{238}U and ^{232}Th decay series and that of naturally occurring ^{40}K. The gamma activity obtained for ^{40}K ranged from 212.1 Bq/kg to 895.7 Bq/kg with a mean value of 470.4 ± 26.8 Bq/kg. For ^{232}Th, the gamma activity ranged from 30.2 Bq/kg to 72.4 Bq/kg with a mean value of 48.8 ± 8.4 Bq/kg, and from 3.6 Bq/kg to 14.2 Bq/kg with a mean value of 6.9 ± 1.2 Bq/kg for ^{238}U. The mean absorbed dose rate in these locations amounts to 45.36 nGy/h which by approximate conversion gives an indoor annual effective dose of 0.223 mSv/year and outdoor annual effective dose of 0.056 mSv/year. These values constitute the baseline dose equivalent, which is below the 1.0 mSv/year recommended by the International Commission for Radiological Protection (ICRP, 1990) as the maximum permissible dose equivalent for members of public. The results obtained showed that the study area is free from radiological contamination.
Keywords: Radioactivity, Absorbed dose, Radioisotopes, Environment.

1. Introduction

Natural radionuclides have been in existence since the formation of the earth. The radionuclides find their way to the soil through weathering. The presence of natural radionuclides in the soil of an environment accounts for the radioactivity in the environment to which man is constantly exposed. (Michael, 2007).

The natural radionuclides in the earth or soil of an environment are present as daughters of Uranium and Thorium isotopes distributed by natural geological and geochemical processes. In addition, non-related naturally occurring sources such as ^{40}K and small quantities of fission product residues ^{137}Cs from atmospheric weapon test have been detected in soils. (Saiyad et al, 2011).

This study was undertaken in order to determine gamma activity due to the natural radionuclides, ^{238}U, ^{232}Th, and ^{40}K, in soil samples in Ondo city, with a view to establish the baseline activity of radionuclide occurring in the environment and for proper assessment of radiation exposure to the population.

2. Study Area

Ondo City lies on latitude 07^{0}06N and longitude 04^{0}52E and is underlain by crystalline rocks of Precambrian Basement Complex of southwestern Nigeria. The major rock units within the belt are amphibolites complex, the schists and the quartzitie sequence. The location of Ondo City in the middle of Nigeria's rain forest but with good access to the coast made the city a major transit point to northeast of Yoruba land. Ondo City is the second largest city in Ondo State, Nigeria. It has a population of 275,917 (NBS, 2006). Ondo City is the trade center for the surrounding region. Yams, cassava, grain, and tobacco are grown, and cotton is also grown and used to weave cloth. It is also the largest producer of cocoa products in the southwest region.

3. Materials and Methods

3.1 Sample Collection.

Ondo city was demarcated into fourteen zones namely: Sabo, Lipakala, Odojomu, Oka, Ayeyemi, Surulere, Akinjagula, Yaba, Valentino, Itanla, Odotu, Odosida, Fagun and Ademulegun zones.

In each zone, soil samples were collected in four different locations. Core samples at a depth of 50 mm were manually taken from the sampling points with an auger. These samples were bulked separated in plastic bags, which could hold about 2.00 kg soil for laboratory analysis.

Individual soil samples were thoroughly dried at room temperature to constant weight and later crushed to pass through a 2-mm mesh sieve. 250 g each of the sieved soil samples were then transferred to plastic containers prior to gamma-spectrometry. The soil samples remained in the plastic containers for about 28 days, which was a sufficient length of time required to attain a state of secular radioactive equilibrium.

3.2 Gamma Counting and Activity Determination

Counting of the soil samples were done using the High Purity Germanium detector (HPGe), Canberra model, located at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife. The detector had earlier been calibrated for both energy and efficiency so as to aid in the identification and quantification of the radionuclides in the soil samples (Nwankpa, 2004). The current decay data for the nuclides were obtained from the literature (Marina, et al, 2009). All soil samples, standards and the sample container were counted for 10 hours each. Analyses of the various spectra obtained were carried out using a PC based S100 software capable of matching the γ – energies at various levels to a library of possible isotopes. The 1460.75 KeV gamma of ^{40}K was used to determine the concentration of ^{40}K in the different samples. The gamma transition of energy 1764.5 KeV of ^{214}Bi was used to determine the concentrations of ^{238}U while the gamma transition of energy 2614.7 KeV of ^{208}Tl was used to determine the concentration of ^{232}Th in the samples.(Daniel, 2012).

The activity concentration, C_s , of the radionuclides in the various samples were calculated using the formula below: (IAEA,1989):

$$C_s = \frac{N(E_\gamma)_s}{\varepsilon(E_\gamma) M_s P_\gamma t_c} \qquad (1)$$

C_s is the concentration in Bqkg^{-1} of the nuclide having a net photopeak area N(Eγ) contained in a sample of mass M_s in Kg. ε(Eγ) is the efficiency of the detector for the γ – energy of interest; Pγ is the emission probability of the nuclide at the particular energy while t_c is the total counting time for the sample.

4 Results and Discussion

4.1 Activity Concentration of Radionuclides

The gamma activities of the natural radionuclides ^{238}U, ^{232}Th and ^{40}K in the soil samples obtained from Ondo City in Ondo State of Nigeria have been measured. The results obtained in the 14 zones are as shown in Table 1. The gamma lines identified with reliable regularity belonged to the decay series of naturally occurring radionuclides headed by ^{238}U and ^{232}Th. Other gamma lines belong to the singly occurring natural radionuclide ^{40}K. The concentration of ^{238}U ranged from 31.2 – 72.4 Bq/kg with an average of 48.8 ± 8.4 Bq/kg. These values fall within the wide range of values reported for the United States. [4.4 – 140 BqKg^{-1} with a geometric mean of 36 Bkg^{-1}] ; the Yangjiang, PR China [21.1 – 119.2 Bq/kg]; the southern Saskatchewan, Canada [31.4 – 34.1 Bqkg^{-1} for two depth increments (Sutherland and de Jong, 1990)]; Savar, Bangladesh [46.8 – 82.5 Bqkg^{-1} with an average of 62.6 ± 7.9 Bqkg^{-1}] and also for worldwide data [arithmetic mean of 24 Bqkg^{-1}](Fokion, 2012).

The specific activities for ^{232}Th range from 3.6 – 14.2 Bqkg^{-1} with an average of 6.9 ± 1.2 Bqkg^{-1}. The concentration for ^{40}K in the 14 study zones ranged from 209.4 – 895.7 Bqkg^{-1} with a mean of 470.4 ± 26.8 Bqkg^{-1} . The values obtained for numerous Russian soils [430 – 730 Bqkg^{-1}]; those in Southern Saskatchwan, Canada [470 – 520 Bqkg^{-1} (Sutherland and de Jong, 1990)]; those in Louisiana soils, USA [100 – 780 Bqkg^{-1} with an average of 472 Bqkg^{-1}] and those in Ado-Ekiti soil, Nigeria [260 – 512 Bqkg^{-1} (Farai et al, 2006)] were in the same range with the present data. The results for ^{40}K lie within the range obtained elsewhere for surface soil primarily characterized as sand, gravy loams and sandy clays (Kirchner et al., 2002). In fact, ^{40}K, a naturally occurring radionuclide is present abundantly in the earth crust and in human body, hence is expected to contribute significantly to man's committed effective dose through ingestion.

^{238}U, ^{232}Th and ^{40}K were detected in all the soil samples analyzed. The mean activity concentration values of ^{238}U, ^{232}Th and ^{40}K in Ondo City were found to be lower than the earth's crustal mean of 49 Bqkg^{-1} for ^{238}U and about 60 Bqkg^{-1} for ^{232}Th. (Vlado, 2000) This can be attributed to the fact that the geology of the town is mainly of sedimentary origin. The high activity concentrations of ^{40}K (511.7 ± 32.8 Bqkg^{-1} and above) at some locations when compared to other locations in the town could be attributed to the use of potassium based fertilizer. This is because some locations may appear undisturbed whereas agricultural activities might have taken place in the past.(Ahmed and El-Arabi, 2005). The slight variation in the radioactivity content in soils may be observed with different locations worldwide mainly due to type of soil, soil formation and soil transport process. (Rani and Singh, 2009). This may be the reason for the variation observed in this result. ^{137}Cs was not detected in all the soil samples.

Table 1: Results of Natural Activities for Sampling Locations.

Location	Average Gamma Activity at Soil Depth of 0 –5 cm				Total Average Absorbed Dose Rates in Air (nGy/h)
Yaba	^{40}k (Bq/kg)	^{238}u (Bq/kg)	^{232}th (Bq/kg)	^{137}cs(Bq/kg)	
1	246.4±18.5	37.2±4.3	5.2±1.2	-	29.96
2	212.1±14.2	34.1±2.4	7.2±3.0	-	
3	275.7±14.8	39.4±3.1	4.6±0.9	-	

4	255.3±16.3	36.4±2.9	5.5±2.7	-	
Surulere					
1	324.7±26.7	41.1±2.4	7.4±2.4	-	36.98
2	335.6±27.6	42.5±2.5	5.9±1.8	-	
3	387.9±35.1	45.6±2.7	5.6±2.8	-	
4	329.6±26.0	40.1±1.8	6.9±2.5	-	
Akinjagula					
1	328.8±26.8	32.2±4.2	6.8±1.5	-	34.35
2	406.2±34.3	33.4±6.2	7.9±3.7	-	
3	412.2±23.2	31.2±5.3	5.7±2.8	-	
4	348.2±26.4	30.2±4.2	8.6±1.2	-	
Ayeyemi					
1	243.1±12.6	42.4±4.1	5.3±3.6	-	33.35
2	278.4±16.1	45.6±5.8	4.0±3.1	-	
3	244.4±19.2	44.5±7.6	4.9±3.9	-	
4	251.0±12.4	48.5±7.2	5.1±3.2	-	
Oka					
1	709.6±35.3	56.9±5.7	5.8±3.7	-	61.04
2	895.7±30.6	58.9±8.5	5.5±5.2	-	
3	822.6±28.5	61.2±7.4	5.1±5.7	-	
4	609.8±29.7	59.1±9.6	6.3±4.8	-	
Valentino					
1	365.7±24.8	55.3±5.5	4.7±2.9	-	40.82
2	209.4±23.8	63.5±9.7	5.6±3.2	-	
3	312.3±26.5	49.7±8.8	5.2±3.0	-	
4	385.1±21.2	52.2±3.9	6.9±4.3	-	
Sabo					
1	467.4±24.6	56.6±5.6	10.2±3.8	-	51.87
2	435.1±21.2	65.1±7.2	9.0±3.6	-	
3	511.7±32.8	55.4±3.9	11.8±4.8	-	
4	442.3±24.8	64.3±5.1	7.5±4.5	-	
Lipakala					
1	569.7±36.5	56.1±8.4	8.8±2.9	-	51.43
2	578.2±47.6	53.4±7.5	5.9±1.5	-	
3	534.9±25.1	47.5±3.1	7.8±2.7	-	
4	555.2±36.7	54.0±8.8	8.3±2.8	-	
Odojomu					
1	393.8±26.7	41.2±3.2	5.5±2.8	-	40.36
2	411.7±24.3	46.4±6.2	8.4±3.7	-	
3	406.5±23.7	47.2±4.3	9.6±1.3	-	
4	366.5±26.9	44.5±7.2	3.6±3.2	-	
Odosida					
1	674.1±43.2	47.4±6.4	14.2±2.5	-	57.43
2	688.7±44.8	46.6±5.2	13.9±2.0	-	
3	673.3±36.8	44.4±9.6	13.8±2.8	-	
4	633.1±33.2	48.4±6.9	14.0±2.1	-	
Fagun					
1	557.2±27.1	55.8±4.5	4.8±3.6	-	54.32
2	622.9±25.3	59.8±7.5	5.1±5.2	-	
3	591.2±26.0	60.2±6.4	6.1±5.3	-	
4	672.1±23.2	58.1±8.5	5.3±2.8	-	
Ademulegun					
1	716.7±24.3	64.2±4.5	3.6±1.8	-	60.62
2	702.5±33.2	72.4±9.8	4.5±2.1	-	

3	788.5±26.4	58.6±7.6	4.2±3.0	-	
4	668.4±28.5	61.2±2.8	4.9±5.3	-	
Odotu					
1	441.7±14.8	35.1±3.4	8.2±5.0	-	46.19
2	572.3±26.8	45.4±5.1	7.8±2.6	-	
3	582.1±13.2	58.4±3.6	9.5±4.7	-	
4	468.7±16.7	41.6±7.6	5.1±5.2	-	
Itanla					
1	312.9±11.3	41.5±3.5	6.9±1.8	-	36.26
2	401.2± 16.	38.6±2.1	5.8±2.2	-	
3	312.1±13.2	47.9±1.8	6.3±2.1	-	
4	398.8±16.8	32.6±7.6	5.1±5.2	-	
Average	**470.4±26.8**	**48.8 ± 8.4**	**6.9 ± 1.2**	**-**	**45.36**
World Average	**420**	**33**	**45**		**59**

Table 2: Absorbed Dose Rate, Indoor and Outdoor Annual Effective Dose Rate.

Zone	Absorbed Dose Rate (nGy/h)	Annual Effective Dose Rate (mSv/y)	
		Indoor	Outdoor
Yaba	29.96	0.147	0.037
Surulere	36.98	0.181	0.045
Akinmjagula	34.35	0.169	0.042
Ayeyemi	33.35	0.164	0.041
Oka	61.04	0.299	0.075
Valentino	40.82	0.200	0.050
Sabo	51.87	0.255	0.064
Lipakala	51.43	0.252	0.061
Odojomu	40.36	0.198	0.049
Odosida	57.43	0.282	0.070
Fagun	54.32	0.266	0.067
Ademulegun	60.62	0.297	0.074
Odotu	46.19	0.227	0.057
Itanla	36.26	0.178	0.045
Average	**45.36**	**0.223**	**0.056**
World Average	**59**	**0.50**	**0.07**

4.2 The Absorbed Dose Rate

The absorbed dose rate in air at 1m above the ground of each sample was determined using the relation ;(Blanco et al, 2005)

$$D = 0.042\ S_K + 0.429\ S_U + 0.666\ S_{Th} \quad (2)$$

Where D is the absorbed dose rate in air ($nGyh^{-1}$), and S_K, S_U and S_{Th} are the soil specific activities of ^{40}K, ^{238}U and ^{232}Th in $BqKg^{-1}$ respectively.

Table 2 shows that the absorbed dose rates due to the terrestrial gamma rays at 1m above the ground in the study area are in the range of 29.96 $nGyh^{-1}$ to 61.04 $nGyh^{-1}$ with an average of 45.36 $nGyh^{-1}$ which is lower than the world average value of 59 $nGyh^{-1}$ (UNSCEAR, 2000).

4.3 Annual Effective Dose Rate.

To estimate the annual effective dose rate ($mSvy^{-1}$) due to the natural radionuclides in the soil samples, the following factors were considered (i) the conversion factor of 0.7 $SvGy^{-1}$ which converts the absorbed dose in air to effective dose. (ii) The indoor and outdoor occupancy factors of 0.8 and 0.2 were used respectively (Masok, et al; 2015), these occupancy factors are the proportion of the total time during which an individual is exposed to a radiation field. (iii) Eight thousand seven hundred and sixty hours per year (iv) the factor converting nano to milli (10^{-6}). The effective dose rate was calculated using the equation:

$$IAEDR = D \times 0.7 \times 8760 \times 0.8 \times 10^{-6} \quad (3)$$

$$OAEDR = D \times 0.7 \times 8760 \times 0.2 \times 10^{-6} \quad (4)$$

Where (IAEDR) is the indoor annual effective dose rate and (OAEDR) is the outdoor annual effective dose rate.

The indoor annual effective doses are in the range of 0.147 $mSvy^{-1}$ to 0.299 $mSvy^{-1}$ with an average of 0.223 $mSvy^{-1}$ while the outdoor annual effective doses are in the range of 0.037 $mSvy^{-1}$ to 0.075 $mSvy^{-1}$ with an average value of 0.056 $mSvy^{-1}$ both of which are lower compared with the world average values of 0.5 $mSvy^{-1}$ and 0.07 $mSvy^{-1}$ respectively (UNSCEAR, 2000).

These values constitute the baseline dose equivalent which is below the 1.0 mSv/year recommended by the International Commission for Radiological Protection (ICRP, 1990) as the maximum permissible dose equivalent for members of public which by present knowledge carries a negligible probability of severe somatic or genetic health problems.

5. Conclusion

The gamma lines identified with reliable regularity belonged to the decay series of naturally occurring radionuclides headed by ^{238}U and ^{232}Th. Other gamma lines belong to the singly occurring natural radionuclide ^{40}K. The mean absorbed dose rate in these locations amounts to 45.36 nGy/h which by approximate conversion gives an indoor annual effective dose of 0.223 mSv/year and outdoor annual effective dose of 0.056 mSv/year. These values constitute the baseline dose equivalent, which is below the 1.0 mSv/year recommended by the International Commission for Radiological Protection (ICRP, 1990).

Therefore, the results obtained showed that the study area is free from radiological contamination.

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