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RADIOLOGICAL HEALTH IMPACT DUE TO ACTIVITY CONCENTRATIONS OF NATURAL RADIONUCLIDES IN THE SOILS FROM TWO MAJOR AREAS IN IJEBU-NORTH LOCAL GOVERNMENT, OGUN STATE, NIGERIA

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The soil samples from two major areas in Ijebu-North Local Government of Ogun State was analyzed for the concentrations of ^{40}K, ^{226}Ra and ^{232}Th using gamma ray spectrometry method. The measured activity concentrations of ^{40}K varied from 245.2 Bqkg^{-1} to 538.1 Bqkg^{-1} with a mean value of 367.9±74.1Bqkg^{-1}, ^{226}Ra in the ranged from 10.4 Bqkg^{-1} to 30.2 Bqkg^{-1} with a mean value of 16.4±4.6Bqkg^{-1} and ^{232}Th ranged from below detection limit (BDL) to 14.1Bqkg^{-1} with a mean value of 3.3±2.0Bqkg^{-1}. The mean external gamma absorbed dose rate in air at 1m above the ground level was 26.4±5.1 nGyh^{-1} which was just about one-half of 56.0 nGyh^{-1}recommended by UNSCEAR (2000). The mean annual outdoor effective dose rate was 32.3±6.3µSvy^{-1}. The collective dose equivalent was 9.18 manSv while the collective health detriment of the population was 0.15y^{-1}.

Keywords: Gamma-ray spectrometry, Natural radioactivity, Absorbed dose, Health detriment.

1. Introduction

Ionizing radiation whether natural or artificial are useful for many purposes but some health risk is associated with them, which increases with exposure. The human environment is often subjected to radiation exposures originating from natural background sources that comprise terrestrial and extra-terrestrial sources and artificial or man-made sources resulting from modern scientific and technological activities [1]. The natural background radioactivity accounts for 96.1% of the total radiation dose to the world population while the man-made sources account for the remaining 3.9% [2]. The terrestrial background radiations are mainly from the primordial radionuclides that include the decay series radionuclides (^{238}U and ^{232}Th) with their progenies and non-decay series radionuclide, ^{40}K. Out of the total natural background radiation dose that the world population receives about 85% is from terrestrial sources [3] and about 23% of the average annual dose to human from all radiation sources [4].

The radioactivity level in any locality is attributed to its geological characteristics and conditions [5]. The activity concentration levels due to terrestrial radiation vary in the soils of all the regions of the world. The terrestrial radiation exposure depends on the lithological compositions of each area, the contents and types of the rock from which the soil originates [2, 6, 7]. Igneous rocks mainly silicates and free silica of granitic compositions were reported to contain uranium and thorium in the form of crystallization of the last magmas and residual solution [8]. Crystalline rocks contained a good distribution of radionuclides [9, 10]. In addition, it has been reported that granite rocks contain high concentration of uranium, thorium and potassium [11, 12]. The study of natural radioactivity in the soil is essentially based on the importance of using the results obtained for assessment of public radiation exposure and performance of epidemiological studies [5].

The land mass area of Nigeria estimated at 923768 square kilometers are one-half underlain by crystalline rock (basement complex) and the remaining one-half by sedimentary rocks. The basement complex of Precambrian age composed primarily of metamorphic and igneous rocks, such as granites, gneisses and migmatites [13, 14]. The non-organic older and younger granites are the two groups of granites that are distinguishable in the geological setting of Nigeria [8]. The geology of Ogun State shows that about three-quarters of its mass area are underlain by sedimentary rock and the remaining one-quarter by basement complex rocks. The basement complex rocks extends from Alla Soka in northwest through Abeokuta to Ijebu-North (Ijebu-Igbo and Ago-Iwoye inclusive) and Omo forest reserves in the southeast of Ogun State [14]. Ijebu-Igbo (Lat. 06^0 58' N, Long.

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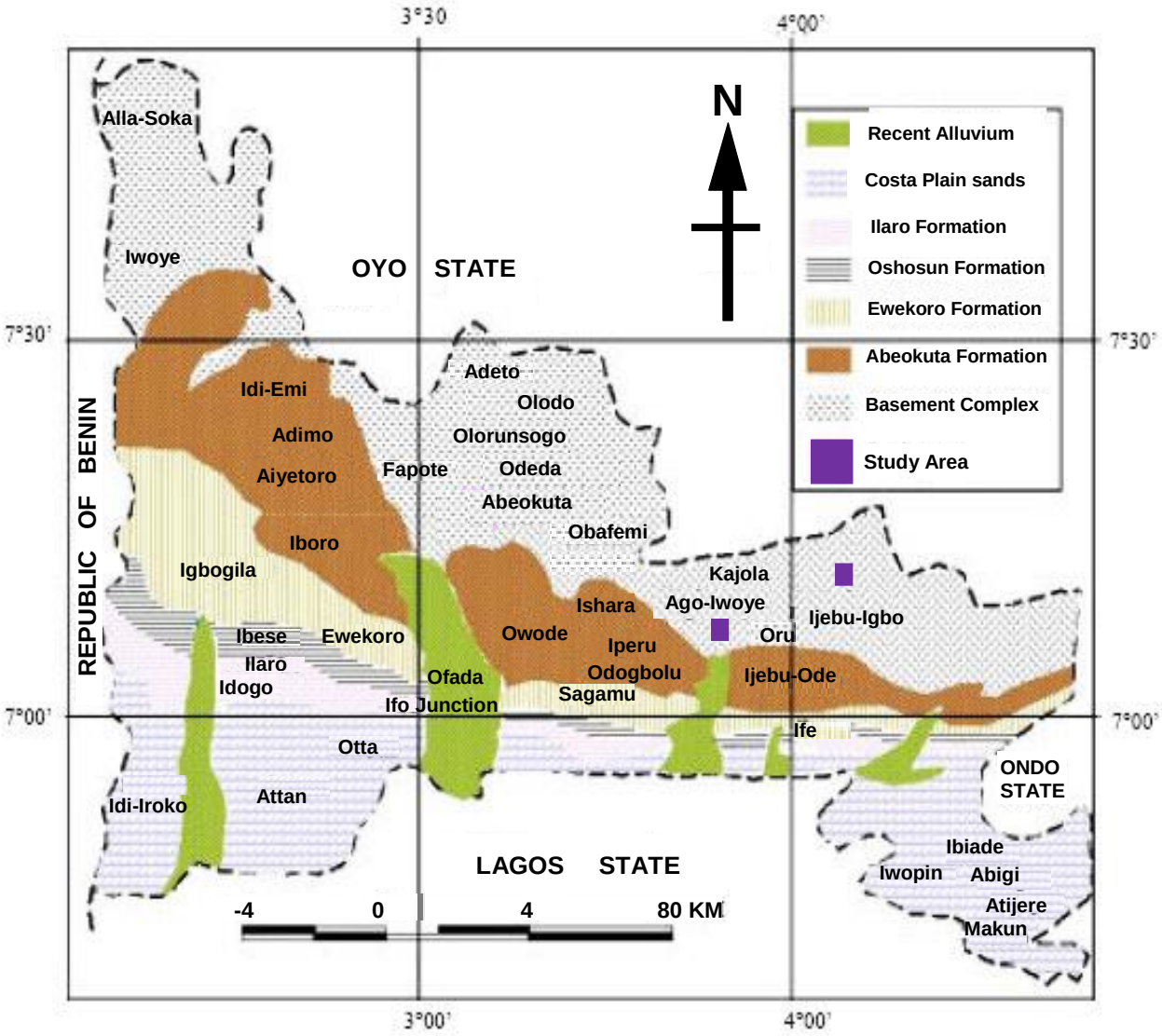

Figure 1. Geological map of Ogun State showing the study area [14].

04^0 0' E) and Ago-Iwoye (Lat. 6^0 56' N, Long 3^0 55' E) are the major two towns in Ijebu-North Local Government. The Local Government has an estimated population of about 284,336 [15]. The study area is situated in the basement complex of granitic rock (Figure 1). The basement rocks comprise of folder gneiss, schist, quartzite, older granite and amphibolites [16]. This basement complex is rich in ^{226}Ra, ^{232}Th and ^{40}K radionuclides [2]. Abeokuta and Ijebu-North are in the similar geological setting, they are both situated on a basement complex characteristically granite base as shown in Figure 1 but Abeokuta had been reported to be about four of magnitude higher in radioactivity than the world average [17]. Therefore, the aims of the study are to measure the radioactivity levels in soil samples from Ijebu-North; compare the obtainable results with the values reported in Abeokuta and recommended world average; and also determine the radiological health impact on the population of the area.

2. Material and Methods

2.1 Soil Sample Collection

Soil samples were collected from two major areas; Ijebu-Igbo and Ago-Iwoye studied, in Ijebu-North Local Government in Ogun State, Nigeria. A total of fifty-six soil samples were collected from the areas. Thirty (30) soil samples were collected from Ijebu-Igbo and twenty-six (26) from Ago-

Iwoye. In order to ensure adequate and good coverage, the whole study area was divided into ten sites. Each site was sub-divided into five grids and at least one representative sample was collected from each grid. At each sampling point, soil was collected to a depth of 150mm below the ground surface and in a grid, soil samples were collected at five different points, mixed together thoroughly to form a representative sample of about 300gm.The soil samples were then packed in polythene bags, labeled and taken to a laboratory for preparation.

2.2 Soil Sample Preparation

In the laboratory, the soil samples were oven dried at a steady temperature of 110^0C until the masses of the samples reduced to a constant value. The oven dried soil samples were thoroughly crushed, and pulverized. The powdered soil samples were sieved with a 2mm sieve to attain the same matrix as the reference standard soil sample from Rocketdyne Laboratories, California, USA activity concentration in which are traceable to a mixed standard gamma source (Ref. No. 48722-356) by Analytic Inc., Atlanta Georgia. 200gm each of the powdered soil samples was packed into a clean and radon- impermeable plastic container of uniform size and sealed for a period of about 30 days to allow for secular equilibrium to establish between ^{226}Ra and ^{228}Ra and their respective gaseous progenies prior to gamma spectroscopy.

2.3 Activity Measurements

The soil samples were analysed using a single crystal 0.51cm × 0.51cm NaI(Tl) detector, manufactured by Scintitech Instrument, USA, is coupled with a Hamamatsa (R1306NSV3068) photomultiplier tube and a Multichannel Analyser, MCA (2100R:01) manufactured by Price gamma Technology, USA. It does not require any internal PC interface slot or special memory reservations. The MCA 2100R includes Quantum MCA software for qualitative analysis. The MCA 2100R performs an automatic adjustment of the detector bias and amplifier gain. All calibration functions were made through the software. The detector has an energy resolution (FWHM) of about 6.2% in 0.662MeV (^{137}Cs) which is considered enough to distinguish the gamma ray energies of interest in the present study. The activity concentration of ^{214}Bi determined from its 1.760MeV γ-ray peak was chosen to provide an estimate of ^{226}Ra (^{238}U) in the sample, while that of the daughter radionuclide ^{208}Tl, determined from its 2.615MeV γ-ray was chosen to estimate ^{232}Th. The ^{40}K radionuclide was determined by measuring the 1.460MeV γ-ray emitted during its decay. Each soil sample was counted for a period of 36000 seconds. Equation (1) shows expression of activity concentration [18, 19].

$$C = \frac{C_n}{\varepsilon_p I_\gamma m_s} \quad (1)$$

where C is the activity concentration of the radionuclide in the sample (Bqkg^{-1}); C_n is the count rate under the photo peak, ε_P is the detector efficiency at the specific γ-ray energy, I_γ is the absolute transition probability of specific γ-ray and M_s is the mass of the sample (kg).

Equation (2) shows the expression for detection limit (DL) which describes the operational capability of the measuring system without the influence of any sample

$$LLD(Bqkg^{-1}) = \frac{4.66SD_b}{\varepsilon \times I_\gamma} \quad (2)$$

where SD_b is the estimated standard error of the net background count in the peak; ε is the counting efficiency (cps/Bq) of the detector at energy E(keV) and I_γ is the abundance of gamma emissions per radioactive decay.

The lower limit of detection (LLD) obtained were 21.3Bqkg^{-1}, 9.1Bqkg^{-1} and4.9Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively. The values that were lower than these values of detection limits in the present study were considered as below detection limit (BDL) of the detector. One-half of the detection limits, DL value was considered for calculating the mean activity concentration and other radiological assessments whenever the concentration of any radionuclide was below the detection level [21].

3. Results and Discussion

3.1 Activity Concentration

The activity concentrations of the decay series radionuclides (^{226}Ra and ^{232}Th) and the non- decay series radionuclide (^{40}K) were measured in the soil of the two districts of Ogun State, Nigeria and presented in Table 1. The activity concentrations were recorded with the statistical standard error from the spectroscopic system and the error terms in the mean values were the standard deviation of the range of values across the measured activity concentrations. The results in Table 1 showed that the mean activity concentrations of ^{40}K, ^{226}Ra and

Table 1. Activity concentrations due to ^{40}K, 226Ra and 232Th and gamma dose rates in the soil from Ijebu-Igbo and Ago-Iwoye districts of Ogun State, Nigeria.

Location	^{40}K (Bqkg^{-1})	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	Absorbed dose rate D (nGyh^{-1})	Effective dose rate S_E (μSvy^{-1})
Ijebu-Igbo					
Minimum	271.7±12.5	10.5±6.1	BDL	17.0	20.7
Maximum	538.1±20.4	30.1±7.0	6.9±0.6	37.1	45.5
Mean	358.3±83.7	16.9±5.4	3.0±1.1	24.8±5.6	30.2±6.8
Ago-Iwoye					
Minimum	245.2±14.6	0.4±5.3	BDL	21.4	26.2
Maximum	524.2±16.7	27.4.4±7.6	14.1±0.9	39.4	48.3
Mean	378.9±61.1	15.8±3.5	3.7±2.6	28.3±3.8	34.7±4.6
Ijebu-North					
Minimum	245.2±14.6	10.4±5.3	BDL	17.0	20.7
Maximum	538.1±20.4	30.1±7.0	14.1±0.9	39.4	48.3
Mean	367.9±74.1	16.4±4.6	3.3±2.0	26.4±5.1	32.3±6.3

^{232}Th were 358.3 ± 83.7 Bq kg^{-1}, 16.9 ± 5.4 Bq kg^{-1}, 3.0 ± 1.1 Bq kg^{-1}respectively for Ijebu-Igbo; and 378.9 ± 61.1 Bq kg^{-1}, 15.8 ± 3.5 Bq kg^{-1} and 3.7 ± 2.6 Bq kg^{-1} respectively for Ago-Iwoye. The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the entire study area were averaged as 367.9 ± 74.1 Bq kg^{-1}, 16.4 ± 4.6 Bq kg^{-1} and 3.3 ± 2.0 Bq kg^{-1} respectively. While the activity concentration of ^{40}K was slightly higher in Ago-Iwoye than Ijebu-Igbo, the activity concentrations in^{226}Ra and ^{232}Th were very close. The activity concentrations of each of the three primordial radionuclides from the study area were significantly lower than the values reported for similar radionuclides in some literatures (Table 2). The activity concentrations obtained in the study were lower than the world average values by a factor of about 1.1, 2.0 and 12.1 for ^{40}K, ^{226}Ra and ^{232}Th respectively.

3.2 Radiological Assessments

3.2.1 Absorbed Dose Rate

The external absorbed gamma dose rate D (nGyh^{-1}) in air at 1.0m height above the ground level for soil containing natural radionuclides which is the measure of the risk associated with exposure to gamma radiation in an environment was calculated using the equation [2, 5].

$$D_{ext} = \sum_{R} A_R DC_{ext.R} \quad (3)$$

where D_{ext} is the absorbed dose rate, $DC_{ext.R}$ is the coefficient of dose rate per unit activity concentration of radionuclides (nGyh^{-1}/Bq^{-1}) and A_R is the activity concentration of the radionuclide R in the sample (Bqkg^{-1}). UNSCEAR (2000) has recommended $DC_{ext.R}$ coefficient of ^{226}Ra as 0.427nGyh^{-1}/Bq^{-1}, ^{232}Th as 0.662nGyh^{-1}/Bq^{-1}, ^{40}K as 0.043nGyh^{-1}/Bq^{-1} and ^{137}Cs as0.03 nGyh^{-1}/Bq^{-1}. The coefficient of the ^{137}Cs was considered as zero because it was not detected in any of the soil samples.

The absorbed dose rates determined in the present study were 24.8±5.6 nGyh^{-1}and 28.3±3.8 nGyh^{-1} for Ijebu-Igbo and Ago-Iwoye districts respectively. The mean absorbed dose rate 26.4±5.1nGyh^{-1}corresponds to about one-half of 56nGyh^{-1} [5] reported as the world average, and about one-eighth of 214.0nGyh reported in Abeokuta [22]. Karunakara et al. [23] reported a gamma dose rate of 66.1nGyh^{-1} for the region of Kaiga. Avadhani et al. [24] reported a value of 64.0nGyh^{-1} for the region of Gao. The absorbed dose rate obtained in the study was lower than each of reported values above mentioned literatures.

Table 2. Comparison of the range and mean activity concentrations ($Bqkg^{-1}$) of soil samples with other regions.

	^{40}K ($Bqkg^{-1}$)	^{226}Ra ($Bqkg^{-1}$)	^{232}Th ($Bqkg^{-1}$)	Region	Reference
Range	40-800	10-200	3-60	Ireland	[26]
Mean	350	60	26		
Range	48-1570	13-165	7-204	Spain	[27]
Mean	650	46	49		
Range	440-913	40-442	32-88	China	[12]
Mean	672	112	71.5		
Range	151.8-1424.2	7.7-111.6	16.7-98.7	Bangalore, India	[1]
Mean	635.2	26.2	53.1		
Range	217-2296	20-295	53-493	Abeokuta, Nigeria	[22]
Mean	799	83	218		
Range	-	-	-	Kanyakumari, India	[28] HBRA
Mean	1585.4	44.1	215		
Range	-	-	-	Kanyakumari, India	[29] LBRA
Mean	288.6	10.0	21.6		
Range	100-700	8-160	4-130	world average	[5]
Mean	420	32	40		
Range	245.2-538.1	10.4-30.1	BDL-14.1		Present Study
Mean	367.9	16.4	3.3		

HBRA: High background radiation area; LBRA: Low background radiation area.

Table 3. Comparison of external absorbed dose rate ($nGyh^{-1}$) in air with other regions.

Gamma dose rate($nGyh^{-1}$)	Region	Reference
42-87 (66.1)*	Kaiga	[23]
36-101(64.0)	Gao	[24]
35-328(214.0)	Abeokuta Nigeria	[22]
28-120(56.0)	World average	[5]
17.0-39.4(26.4)	Ijebu North Nigeria	Present study

*The parenthesis contains the mean values

3.2.2 Annual Outdoor Effective Dose Rate

The absorbed gamma dose rates in the air usually relate to human absorbed gamma dose in order to assess the radiological impact to the populace in an environment. In assessing the outdoor effective dose equivalent to the populace from the calculated absorbed dose rate, two additional factors were considered. The first is the conversion factor that converts the absorbed dose rates (Gyh^{-1}) in air to human outdoor effective dose rates (Svy^{-1}) and the second factor (occupancy factor) gives the proportions of the total time for which a typical individual is exposed to outdoor gamma radiation. The annual outdoor effective dose equivalent was estimated using the relation [2].

$$E_{ext} = T\ f\ Q\ D_{ext}\ \varepsilon \quad (4)$$

where E_{ext} is the effective dose rate (μSvy^{-1}), T is the number of hours in a year ($8766h.y^{-1}$), f is the outdoor occupancy factor (0.2), Q is the conversion factor ($0.7SvGy^{-1}$), D_{ext} is the absorbed dose rate and ε (10^{3}), a factor that converts nano (10^{-9}) to micro (10^{-6}).

The mean annual outdoor effective dose rates were presented in Table1 with a least value of 20.7 μSvy^{-1}recorded in Ijebu-Igbo and maximum of 48.3

μSvy^{-1} in Ago-Iwoye. The mean annual effective dose rate in the entire area of study was 32.3± 6.3μSvy^{-1}. This mean annual effective dose rate value was significantly small when compared to the worldwide average of 469μSvy^{-1} [1, 5].

3.2.3 Collective Dose Equivalent

In any epidemiological study, the population size involved is very important as this eventually determines the actual number of people that suffer the health effect. The collective effective dose equivalent is a measure of the collective health effect on a population. The number of people at risk of incurring radiation-induce diseases, was calculated using [25]

$$S_e = \sum_{i}^{n} N_i E_{exti} \quad (5)$$

where S_E is the collective effective dose equivalent (man.Sv), N_i is the number of individual exposed to gamma radiation and E_{exti} is the mean outdoor effective dose rate (μSvy^{-1}). The population census figure of 284336 [15] was used to estimate the collective effective dose equivalent of the population in the entire study areas. The collective dose equivalent in the entire study area was determined using Equation (5). With the mean outdoor effective dose of 32.3μSvy^{-1} and the population figure of 284336, the collective dose equivalent was obtained as 9.18man.Sv.

3.2.4 Collective Health Detriment

The linear non-threshold (LNT) model which relates that the number, G of people suffering a form of cancer (collective health detriment) is directly proportional to the collective effective dose equivalent was employed in the present study. The collective health detriment was determined using:

$$G = R_T S_E \quad (6)$$

where G is the collective health detriment due to gamma radiation exposure to the environment, R_T is the proportionality constant called a risk factor and S_E is the collective effective dose equivalent. The whole body risk factor, R_T and the collective health detriment, G have been reported as 16.5x10^{-3} Sv^{-1} and 0.152 Gy^{-1} respectively [3].

The collective health detriment to the entire area of study was determined using Equation (6). With the calculated collective dose equivalent of 9.18 man.Sv and the whole body risk factor of 16.5 x10^{-3}Sv^{-1}, the collective health detriment was obtained as 0.15y^{-1}.

4. Conclusion

The activity concentrations of the radionuclides in the soil of the study area, Ijebu-North, have been measured. In the study, the mean concentrations of ^{40}K, ^{226}Ra and ^{232}Th for the entire study area were 367.9±74.1Bqkg^{-1}, 16.4±4.6 Bqkg^{-1} and 3.3±2.0 Bqkg^{-1}respectively. These values were comparable to that reported for other environments of the world. The average absorbed dose rate, 26.4±5.1nGy^{-1} for the two districts corresponds to one-half of the 56nGy^{-1} reported as the world average. Abeokuta that has the same geological basement complex with the study area has absorbed dose rate of about 214nGy^{-1} [22]. This value translates to eight times the value obtained in the study area. The relatively high radioactivity levels reported from Abeokuta may be attributed to the broken masses of gray granite rocks that sprawl out over an extensive area in every part of the city. The radioactivity level in the study area is low and no serious radiological implication is expected. However, human activity such as exploration or mining that increases the radioactivity level in the environment must be discouraged so as to maintain the radioactivity level of the study area in the near future.

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