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Studies of the Terrestrial outdoor Gamma Dose Rate Levels in Ogun-Osun River Basins Development Authority Headquarters, Abeokuta, Nigeria

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Abstract: Problem statement: The natural radioactivity levels in the soils of Ogun-Osun River Basins Development Authority Headquarters, (O-ORBDA HQ) Abeokuta, South-Western part of Nigeria were measured. **Approach:** (O-ORBDA HQ) is a parastatal of Federal Ministry of Water Resources and Rural Development in Nigeria charged with the responsibility for the development and management of the water resources in its area of coverage. The area of the site was divided into fifteen segments and soil samples were collected at a depth of about 10cm at the intersection of these lines. **Results:** Global Positioning System (GPS) was used to obtain the geographical position of each sample point. NaI (T_l) scintillation detector coupled with a Canberra series 100 plus MCA was used as the detecting device for the gamma scintillation spectroscopy. The average activity concentrations obtained for the three radionuclides were 896.12±274.48 Bq kg^{-1} for ^{40}K, 13.93±2.36 Bq kg^{-1} for ^{238}U and 18.67±5.06 Bq kg^{-1} for ^{232}Th. The average values of the absorbed dose rates in air of each radionuclide were found to be 37.64±11.53 nGy h^{-1} for ^{40}K, 5.98±1.10 nGy h^{-1} for ^{238}U and 12.44±3.37 nGy h^{-1} for ^{232}Th. **Conclusion/Recommendations:** The baseline average outdoor annual effective dose equivalent in O-ORBDA HQ due to the radioactivity concentrations was found to be 68.74±19.51 μSv year^{-1}. This value is less than the world average of 70 μSv year^{-1} specified by UNSCEAR for an outdoor effective dose. Hence the probability of occurence of any of the health effects of radiation is low. Since no artificial radionuclides was detected, this represents the baseline value of natural radioactivity.

Key words: Radioactivity, effective dose equivalent, activity concentration, absorbed dose rate, spectroscopy, health effect

INTRODUCTION

Background radiation consists of three primary types: Primordial, cosmogenic and anthropogenic. Primordial radionuclides are present in the earth's crust and found throughout the environment. Cosmogenic radionuclides are produced when cosmic radiation interacts with elements present in the atmosphere and are deposited through both wet and dry deposition. Anthropogenic sources of radiation result from human activities, but are considered background because their presence is ubiquitous.

Primordial radionuclides include isotopes of uranium, isotopes of thorium and ^{40}K. The natural concentrations of these radionuclides in soils vary regionally and depend upon the type of rock from which the soils were formed. The extent to which these radionuclides are taken up by plants and incorporated in animal tissues depends on the levels present in the environment, the characteristics of the native soils and the chemical behavior of the elements or compounds involved (Green AES., 1955; Shankland, 1960).

Potassium-40 is a naturally occurring radioisotope that is present in all potassium at a very low-percent abundance. Natural uranium consists of three radioisotopes, ^{238}U, ^{235}U and ^{234}U at percent abundances of 99.276, 0.7196 and 0.0057, respectively. It is possible to distinguish between natural and processed uranium by measuring the ratios of the radioisotopes present in environmental samples.

Three of the long-lived primordial radionuclides, ^{238}U, ^{235}U and ^{232}Th, give rise to chains of radioactive decay products known as decay series. The decay products of these isotopes also are considered part of the natural background. The isotopes contained in the decay series for ^{238}U, ^{235}U and ^{232}Th.

Before 1942, human exposure to ionizing radiation was limited to natural radioactivity and medical

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diagnosis. In December 1942, the first controlled, self-sustaining nuclear chain reaction was achieved, followed in July 1945 by the first successful test of an atomic bomb. Since then, the uses of nuclear energy have become more diverse and widespread, encompassing medical diagnosis and treatment, nuclear power and consumer and industrial applications. These applications, however, release radioactivity into the global ecosystem and have added to the levels of existing natural radiation, provoking concern over the possible health effects associated with increased radiation exposure.

Radionuclides present in the biosphere, whether natural or artificial in origin, ultimately result in irradiation of human populations. The biologic consequences of ionizing radiation exposure involve tissue damage and can cause immediate physiologic harm within a few days or weeks following a large, acute individual dose or delayed effects, the most important of which is the development of various cancers after an extended latent period following low, chronic exposures. Doses received from natural radioactivity and routine exposures from regulated practices are well below levels that would result in immediate harm.

By far, the greatest contribution to the average public radiation exposure comes from radioactive elements in the earth's crust and from cosmic radiation originating in deep space. Natural sources contribute on average more than 98% of the human radiation dose, excluding medical exposures (UNSCEAR, 1988). The global average dose from natural sources as estimated by the United Nations Scientific Committee on the Effects of Atomic Radiation (1993) is about 2.4 mSv $year^{-1}$. Exposure is both external, from direct cosmic and terrestrial radiation and internal, from inhalation and ingestion of terrestrial and cosmogenic radionuclides found in air, water, food and soil.

Terrestrial radiation exposure originates from the primordial radionuclides, whose half-lives are comparable to the age of the earth and the secondary radionuclides produced by their radioactive decay. The naturally occurring radionuclides include mainly ^{40}K and the three radioactive decay chains originating with ^{238}U, ^{232}Th and ^{235}U. These radionuclides are ubiquitously present in low concentrations in soil and water as a result of weathering and erosion of rock. The isotopic abundance of ^{40}K in natural potassium is only about 0.012%, but because potassium is widespread and is taken into the body as an essential element, it contributes on average about one-tenth of the internal dose from natural radiation (UNSCEAR, 1993). Another major exposure pathway to natural radiation results from the decay of ^{226}Ra in the ^{238}U series. This decay results in the formation of gaseous ^{222}Rn, which can enter the atmosphere through emanation from soil and building materials. The principal sources of internal exposure and a major component of total background radiation exposure, are the rapidly decaying radionuclides formed as a result of successive decays of ^{222}Rn. Exposure occurs when these radionuclides, namely ^{218}Po, ^{214}Pb, $_{214}Bi$ and ^{214}Po, are inhaled and retained in the lungs.

Additional but minor contributions to exposure come from the remaining nonseries primordial radionuclides, primarily ^{87}Rb (Tait, 1980) and cosmogenic radionuclides produced in the atmosphere by the interaction of cosmic rays with atmospheric argon, oxygen and nitrogen. Cosmogenic radionuclides reach the earth through atmospheric mixing, precipitation scavenging and gravitational settling; exposures result primarily from ingestion and are relatively constant throughout the world. The four radionuclides that contribute a measurable dose to humans are ^{14}C, ^{3}H, ^{22}Na and ^{7}Be, on the order of 12 µSv annually, but the greatest contribution to this dose is from ^{14}C since it is a relatively long-lived radionuclide and a major constituent in body tissue (UNSCEAR, 1993).

The annual average contribution due to all internally deposited radionuclides is approximately 1.6 mSv, of which about 1.1 mSv results from the inhaled radon decay products. Actual individual exposures to background radioactivity in air, food and water are, however, highly variable and depend on numerous factors including the amount, type and availability of the radionuclide in the environment and the amount inhaled or ingested by the individual.

About Ogun-Oshun River Basin Development Authority (O-ORBDA): Ogun-Oshun River Basin Development Authority is a parastatal of Federal Ministry of Water Resources and Rural Development. Nigeria charged with the responsibility for the development and management of the water resources in its area of coverage. It is one of the eleven of such Authorities established by Federal Government by ministry of water resources following the drought of 1973-74. It became operational in 1974 and made positive impact on our immediate community. Its area of coverage has jurisdiction over the area between Nigeria border with the Republic of Benin to the West and Sasa River to the East. The area covers the whole of Osun, Oyo, Ogun and Lagos State and has an estimated land area of 66,2642 km^2. It is drained by two main rivers-Ogun and Osun rivers after which it is named. And a number of tributaries and small rivers, the most important among which are the Sasa, Ona, Ibu, Ofiki, Oni and Yewa Rivers

The headquarters of the authority is located on a 236 ha estate along Alabata off Ibadan-Abeokuta highway, Abeokuta, Ogun State and three area offices located at Osogbo, Ibadan and Ikeja and a liaison office for Abuja at Suleja.

Geographical location of O-ORBDA headquarters: The O-ORBDA permanent Headquarter is located some 11 km to Abeokuta on Alabata road off the Ibadan-Abeokuta highway, South-Western Nigeria. It is situated on a 2.4 km^2 (236.4 ha) area of land allocated to it by the Ogun State Government.

OORBDA permanent Headquarters site is in Odeda local Government (Ogun state) Nigeria, few km North of the state capital-Abeokuta. Abeokuta metropolis lies approximately on latitude $7^0 3^1$N and longitude $3^0 54^1$E. The average annual minimum temperature of Abeokuta lies around 22°C and maximum of about 30°C.

The soil of this site are found to be the complex basement rock of coastal area. Most the soils are sand-loamy compacted with clays. The soils of this area are ferralitic; that is that is these soils formed from complete basement rocks which are as a result of sedimentary activities.

Motivation for the studies: The aim of this project is to know if O-ORBDA HQ and its environment are safe from radiation hazards by setting a base line for future assessment.

Since in O-ORBDA HQ, there are lots of activities carried out there, like the drinking water industry where a water treatment plant is being used which releases lots of exhaustible gases, also, there is electricity generating plant, Gari processing industry, poultry-rearing, abandoned petrol filling station and different farmlands put into practice.

All these activities could have contributed to addition of more chemicals to the soil nutrients and could have caused some release of some kinds of radionuclides into the environment. Therefore, knowledge of the baseline value of radioactivity in an environment provides the criteria for assessing radioactive pollution of the environment in case of an accidental release in future.

MATERIALS AND METHODS

Soil samples collection: The area map of the site was divided into fifteen segments and fifteen soil samples were collected. The geographical location of each sample point was taken by means of Global Positioning System (GPS) and recorded as shown in Table 1. Each soil sample was collected by digging the soil to about 10 cm deep at various points of intersection and then packed in a nylon made of non-radioactive material sealed and labeled to avoid samples been mixed up and contaminated. Each soil sample was dried, grounded and sieved.

As 250 g of each of the dried, grounded, sieved soil sample was put in a plastic container sealed with paper cello tape and kept for twenty-eight days, so that both parent and daughter nuclei would be in a state of equilibrium before measurement were carried out on them.

The counting assembly: The counting system used in the determination of natural radionuclide contents of the soil samples consists of a scintillation detector and a multichannel spectroscopic analyzer (Camberra series 10).

A 7.6×7.6 cm NaI (Tl) crystal (Model no 802 Series) is the detector D placed in a Lead castle, this detector, is interfaced with the electronic system through 50 Ω coaxial cable. The purpose of the Lead castle was to shield the detector from external background radiation, which can influence readings taken on the multi channel analyzer.

The Multi Channel Analyzer (MCA) electronic system consists of an internal spectroscopic amplifier (AMP), a 100 mHz Wilkinson type of Analogue to Digital Converter (ADC), Control logic (Cl) with input and output devices and multichannel scaling input, 4 k Memory (M), Display and analysis Logic (DAL) and Screen Display (SD). The MCA has the facilities to supply a stabilized extra high voltage.

For the purpose of this work, three Regions Of Interest (ROI) were defined on the multichannel analyzer. They were potassium-40, Uranium-238 and Thorium 232.

Table 1: The geographical location of each sample point was taken by means of GPS

Sr. No.	Sample points	North	East	Altitude
1	1	7.19603	3.43950	163
2	2	7.19715	3.43643	146
3	3	7.19841	3.43296	153
4	4	7.19929	3.42913	152
5	5	7.19994	3.42696	151
6	6	7.21177	3.42539	139
7	7	7.19738	3.43988	156
8	8	7.19862	3.43740	156
9	9	7.20702	3.43115	135
10	10	7.20429	3.43012	167
11	11	7.20206	3.42933	168
12	12	7.20904	3.43653	137
13	13	7.19863	3.44020	155
14	14	7.20141	3.43117	135
15	15	7.20925	3.43288	143

Calibration of equipment/energy calibration: A uniform distribution of the radionuclide was assumed for the purpose of this study, also all daughters including gaseous ^{222}Rn and ^{220}Rn from the ^{238}U and ^{232}Th series respectively were considered to be in equilibrium with their parents and as such, the effects of the gaseous components were not taken into account.

The height of each pulse output from the photomultiplier tube and hence the channel number corresponding to it is directly proportional to the initial gamma energy producing the pulse. The equipment was first calibration using a gamma emitter source of known energy for student laboratory experiments (Nucleus Inc., Oak Ridge, TN, USA) to determine the linear equation relating the gamma energy, E to the channel number.

Measurement: The gamma ray detection method using NaI (Tl) detector coupled to camberra series 10 plus (MCA) was used for this work. Shielding was achieved using camberra 10 cm thick lead (Pb) shield. The detector has a resolution of about 8% at 662 KeV of 137 Caecium. This is capable of distinguishing the gamma ray energies considered during these measurements.

Since the number of pulses displayed under a photo peak is proportional to the intensity of the radiation reaching the detector volume, therefore the radiation source should be placed as close to the detector as possible so that the counting system exhibits high efficiency.

Cylindrical plastic containers (geometry) whose diameters are 7 cm were used for the measurement. Three Regions Of Interests (ROI) were created for the purpose of this research using the channel numbers corresponding to their gamma ray energies.

About 15 soil samples were collected from the site. The samples were collected by digging the soil to about 10 cm deep and then packed in nylon (made of non radioactive materials) with identification labels. The soil samples were dried, grounded and sieved. The soil samples were dried in sunrays for some days and then grounded, sieved before they were put into the containers to be used for the measurements.

A mass of 250 g (0.25 kg) of each of the dried and grounded soil sample was put in a plastic container, sealed with paper cellotape and kept for more than twenty-one days so as to reach secular equilibrium after which each sample container was placed directly on top of the detector for counting. The counting time was set at 36000 sec (10 h), this time was long enough for the detector to collect a spectrum with the peaks of interest clearly shown and clearly distinguished. The areas under each photo peak were computed using the algorithm of the MCA and they represented the numbers of count for each radioactive nuclei in a given sample. The net area after background counting was related to the radioactivity concentration of each radionuclide.

The background radiation due to the naturally occurring radionuclides in the environment around the detector was measured by using an empty plastic container, the empty plastic container was counted in the same manner as the soil samples and for the same counting time (36000 sec).

Necessary settings and adjustments were carried out on the MCA e.g., the high voltage settings, the Gain memory settings, the preset time (36000 sec), the Region Of Interests (ROI), Compute area. Each ^{40}K content of the samples was obtained from the intensity of 1.461 MeV gamma ray peak following the decay of ^{40}K, the ^{238}U content from 1.761 MeV peak of $^{214}B_i$ and the thorium content from the 2.614 MeV gamma ray peak from $^{208}T_{i.}$ Thereafter the fifteen soil samples were measured one after the other in order to get their ^{40}K, ^{238}U and ^{232}Th contents.

RESULTS

Result presentations:

Concentration: The concentration of a given radionuclide in a sample is proportional to the counts per seconds obtained under a gamma photopeak due to that radionuclide, i.e., the radioactive concentration is proportional to the net area under the photopeak:

$$C\alpha A = KA \quad (1)$$

Where:

C = The concentration
A = The net area
K = The proportionality constant is the multiplicative factor which is constant for each radionuclide at constant geometry. K is determined by the detector efficiency of the assembly

The calibration factor k, for the three radionuclides was calculated using a standard soil sample prepared from Rocketdyne laboratories, CA, USA, which is traceable to a mixed standard gamma source (no. 48722356) from Analytics Inc., Atlanta, GA.

The concentrations of the radionuclide for each soil sample in Bq kg^{-1} were given in Table 2.

Determination of gamma absorbed dose rate: The gamma absorbed dose rate in air can be calculated using (Beck *et al*., 1972) the equation:

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

where, D is the total absorbed dose rate in air measured in nGy h^{-1}. S_K, S_U and S_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232} Th in Bq kg^{-1} respectively. The absorbed dose rate in air due to each radionuclide were presented in Table 3. The total gamma dose rate in air in nGy h^{-1} and the corresponding concentrations were presented in Table 4.

Outdoor annual effective dose equipment in O-ORBDA Headquarters (Hq): The absorbed gamma dose rates in air are usually related to human absorbed γ dose in order to assess the effectiveness of the gamma dose in causing damage to human tissues. One can make an assessment of the outdoor effective dose equivalent to the population by considering two factors. The first is a conversion factor which converts the absorbed dose rate in air to human effective dose equivalent while the second factor gives a measure of the proportion of the total time for which an individual is exposed to a radiation field either indoors or outdoors.

The United Nation Scientific Committee on Effect of atomic Radiation (UNSCEAR), has recommended 0.7 Sv $year^{-1}$ as the value of the first factor and 0.2 as the outdoor occupancy factor.

The outdoor annual effective dose equivalent were obtained by using Eq. 3.

Outdoor annual effective dose equivalent = Total absorbed dose rate:

$$(Gy\ h^{-1})\times 0.2\times 0.7\times 24\times 365\times 10^{-9} \quad (3)$$

The outdoor annual effective dose equivalent in μSv $year^{-1}$ for the samples were presented in Table 5.

Table 2: Concentrations of radionuclide for each soil sample

Location	^{40}K (Bq Kg^{-1})	^{238}U (Bq Kg^{-1})	^{232}Th (Bq Kg^{-1})
Sample 1	815.70±250.03	11.75±1.76	21.600±6.10
Sample 2	954.85±292.24	16.12±2.61	18.070±4.31
Sample 3	931.09±285.05	13.41±1.54	34.750±12.51
Sample 4	879.42±269.49	17.68±3.93	24.040±4.60
Sample 5	986.92±302.06	16.31±2.54	16.230±5.62
Sample 6	905.25±277.38	13.20±2.24	15.270±3.27
Sample 7	739.60±226.94	11.53±1.69	13.490±2.17
Sample 8	712.02±218.57	9.06±1.94	1.089±2.25
Sample 9	1098.57±336.02	11.58±2.19	19.57 0±6.28
Sample 10	835.31±256.02	12.47±2.16	17.980±4.02
Sample 11	1079.38±330.19	12.44±1.59	18.730±2.80
Sample 12	831.15±254.69	17.17±3.62	14.860±3.12
Sample 13	1057.69±323.56	11.72±2.01	15.020±5.24
Sample 14	966.98±295.97	11.15±2.18	16.310±6.92
Sample 15	647.81±199.02	14.39±3.34	23.240±6.70

Table 3: Gamma absorbed dose rate due to each radionuclide

^{40}K (nGy h^{-1})	^{238}U (nGy h^{-1})	^{232}Th (nGy h^{-1})	TD (nGy h^{-1})
34.26±10.50	5.04±0.76	14.43±4.06	53.73±15.32
40.10±12.27	6.92±1.12	12.04±2.87	59.05±16.26
39.11±11.97	5.75±0.66	23.14±8.33	68.00±20.96
36.94±11.32	7.59±1.69	16.01±3.06	60.53±16.07
41.45±12.69	7.00±1.09	10.81±3.74	59.26±17.52
38.02±11.65	5.66±0.96	10.17±2.18	53.85±14.79
31.06±9.53	4.95±0.73	8.95±1.45	44.96±11.70
29.91±9.18	3.89±0.83	7.25±1.50	41.04±11.51
46.14±14.11	4.97±0.94	13.03±4.18	64.14±19.24
35.08±10.75	5.35±0.93	11.98±2.68	52.41±14.36
45.33±13.87	9.20±0.68	12.47±1.87	67.01±16.42
34.91±10.70	7.37±1.55	9.90±2.08	52.17±14.33
44.42±13.59	5.03±0.86	10.00±3.49	59.45±17.94
40.61±12.43	4.78±0.94	10.86±4.61	56.26±17.98
27.21±8.36	6.17±1.43	15.48±4.46	48.86±14.25

TD: Total Dose in nGy h^{-1}

Table 4: The total absorbed dose rates and corresponding concentration

Location	^{40}K Conc.	^{238}U Conc.	^{232}Th Conc.	TD (nGy h^{-1})
1	815.70±250.03	11.75±1.76	21.600±6.10	53.73±15.32
2	954.85±292.24	16.12±2.61	18.070±4.31	59.05±16.26
3	931.09±285.05	13.41±1.54	34.750±12.51	68.00±20.96
4	879.42±269.49	17.68±3.93	24.040±4.60	60.53±16.07
5	986.92±302.06	16.31±2.54	16.230±5.62	59.26±17.52
6	905.25±277.38	13.20±2.24	15.270±3.27	53.85±14.79
7	739.60±226.94	11.53±1.69	13.490±2.17	44.96±11.70
8	712.02±218.57	9.06±1.94	1.089±2.25	41.04±11.51
9	1098.57±336.02	11.58±2.19	19.570±6.28	64.14±19.24
10	835.31±256.02	12.47±2.16	17.980±4.02	52.41±14.36
11	1079.38±330.19	12.44±1.59	18.730±2.80	67.01±16.42
12	831.15±254.69	17.17±3.62	14.860±3.12	52.17±14.33
13	1057.69±323.56	11.72±2.01	15.020±5.24	59.45±17.94
14	966.98±295.97	11.15±2.18	16.310±6.92	56.26±17.98
15	647.81±199.02	14.39±3.34	23.240±6.70	48.86±14.25

Table 5: Outdoor annual effective dose equivalent

Locations	μSv year^{-1}
1	65.894472±18.788448
2	72.418920±19.941264
3	83.395200±25.705344
4	74.233992±19.708248
5	72.676464±21.486528
6	66.041640±18.138456
7	55.138944±14.34888
8	50.331456±14.115864
9	78.661296±23.595936
10	64.275624±17.611104
11	82.181064±20.137488
12	63.981288±17.574312
13	72.909480±22.001616
14	68.997264±22.050672
15	59.921904±17.4762
Average	68.7372672±19.512024

DISCUSSION

Environmental radioactivity measurement is usually based on the evaluation of radionuclide distribution in the soil. The three primordial radionuclide in this project work, ^{40}K, ^{238}U and ^{232}Th, had been detected and measured in the fifteen soil samples and the activity concentration of the natural radionuclides in the region is in agreement with the global trend on the distribution of natural radionuclides in the soil (Arogunjo, 2007). The results of the measured soil samples were strongly influenced by the geology of the site and other modifying factors in the environment such as soil utilization pattern, climate conditions, application of fertilizers, evaporation and so on. From the result of the concentration of each radionuclide in each of the fifteen soil samples measured as presented in Table 2, it could be seen that ^{40}K had the highest value of concentration in Bq kg^{-1}. This may be due to the presence of potassium bearing minerals in the soil such as biotite, microcline, muscovite, fieldspars and so on. It could also be due to its abundant nature in the soil because potassium is usually the most abundant element in the soil. The highest specific activity concentration of ^{40}K (1098.57±336.02 Bq kg^{-1}) was found at location 9, (Fig. 1 and 2).

The highest value of ^{238}U concentration was found at location 4 with activity value of 17.68±3.93Bq kg^{-1}. This could be due to high presence of uranium minerals such as uraninite, Zircon, Sphene, monazite and so on. The highest value of ^{232}Th concentration was found at location 3 with activity value of 34.75±12.51 Bq kg^{-1}. This could be due to the presence of abundant radioactive thorium minerals such as monazite, Thorianite and Zircon.

The lowest specific activity of ^{40}K (647.81±199.02 Bq kg^{-1}) was found at location 15 along water reservoir area. The lowest specific activity

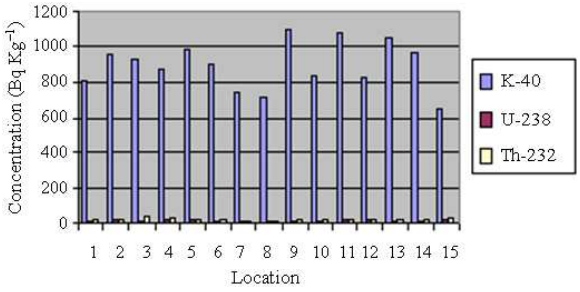

Fig. 1: Chart showing concentration (Bq Kg^{-1}) of all the three radionuclides against location

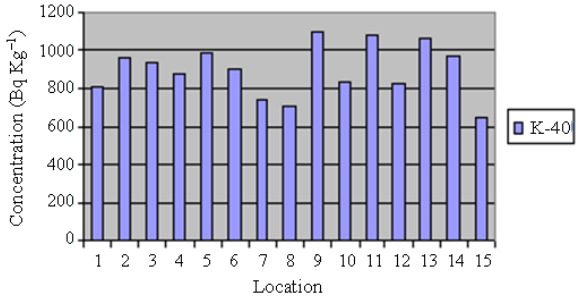

Fig. 2: Chart showing concentration (Bq Kg^{-1}) against location

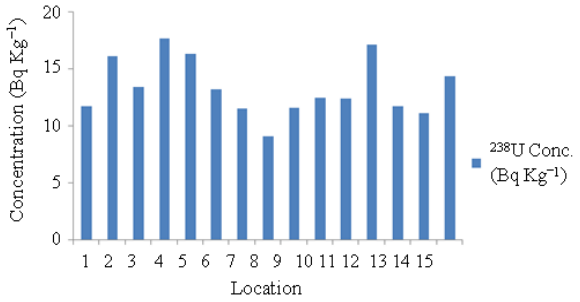

Fig. 3: Showing concentration (Bq Kg^{-1}) of ^{238}U against location

of ^{238}U (9.06±1.94 Bq kg^{-1}) was found at location 8 (Fig. 1 and 3) while the lowest specific activity ^{232}Th (10.89±2.25 Bq kg^{-1}) was found at location 8 (Fig. 1 and 4).

The mean of the radioactive concentrations of the three radionuclides were found to be 896.12±274.48 Bq kg^{-1} for ^{40}K, 13.93±2.36 Bq kg^{-1} for ^{238}U and 18.67±5.06 Bq kg^{-1} for ^{232}Th.

The standard deviations of the radioactive concentration of the three radionuclides were found to be 134.54±40.88 Bq kg^{-1} for ^{40}K, 3.24±0.74 Bq kg^{-1} for Uranium and 5.72±2.80 Bq kg^{-1} for ^{232}Th.

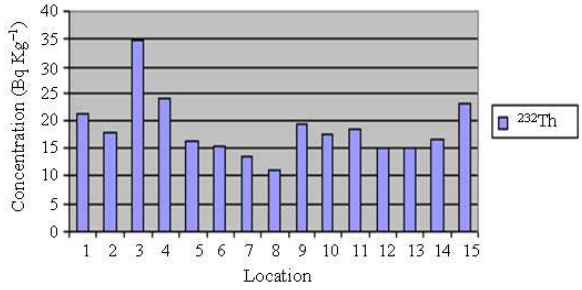

Fig. 4: Chart showing concentration (Bq Kg^{-1}) of ^{232}Th against location

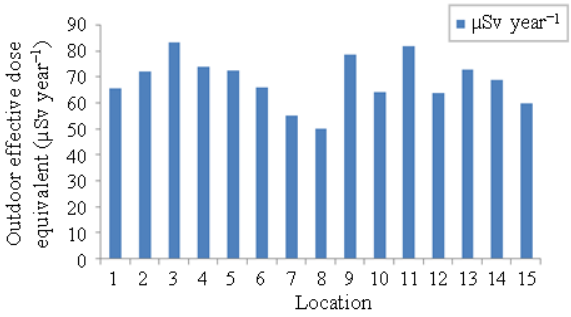

Fig. 5: Showing effective dose equivalent (μSv $year^{-1}$) against location

The range of ^{40}K concentration was found to be 450.76±137.00 Bq kg^{-1}, 8.62±1.99 Bq kg^{-1} for ^{238}U and 32.50±1026 Bq kg^{-1} for ^{232}Th.

It was observed that the amount of ^{40}K concentration in each soil sample was more than both ^{238}U and ^{232}Th concentration in each soil sample because potassium was the most abundant element of all the three primordial radionuclide in the soil.

From Table 3, it was noticed that the absorbed dose rate deduced from the distribution of three natural radioactive elements varied from one location to the other. ^{40}K at location 9 had the highest value of the absorbed dose rate of 46.14±14.11 nGy h^{-1} while ^{238}U location 8 had the lowest value of the absorbed dose rate of 3.98±0.83.

The standard deviation of the absorbed dose rate of each radionuclide were found to be 5.65±1.72 nGy h^{-1} for ^{40}K, 1.39±0.32 nGy h^{-1} for ^{238}U and 3.81±1.73 nGy h^{-1} for ^{232} Th.

The range of the absorbed dose rate for ^{40}K, ^{238}U and ^{232}Th were 18.93±5.75, 3.69±0.86 and 15.89±6.83 respectively.

The outdoor effective dose equivalent in O-ORBDA HQ had its highest value to be 83.40±25.71 μSv $year^{-1}$ found at location 3; while the lowest value was 50.34±14.12 μSv $year^{-1}$ found at location 8.

The baseline average outdoor annual effective dose equivalent in O-ORBDA HQ was found to be 68.74±18.51 μSv $year^{-1}$. From Table 5, it was seen that 8 locations had their values higher than this baseline average while 7 locations had their values below the baseline average (Fig. 5).

The baseline of O-ORBDA HQ was found to be slightly lower than the world's average of 70 μSv $year^{-1}$ (UNSCEAR, 1988) which is the value for the terrestrial habitat. The reason for this high value baseline average of the outdoor annual effective dose equivalent in O-ORBDA HQ (though slightly lower than the world's average of 70 μSv $year^{-1}$) was due to the fact that O-ORBDA HQ was situated on elevated natural background area of Abeokuta, South-West, Nigeria.

Since the city of Abeokuta, in which O-ORBDA HQ was located, is characterized by extrusive granite rock. The Abeokuta area of southwest part of Nigeria comprises mainly granite gneisses of varied composition. Biotite granite gneiss occurs as one of the prominent member of the series. This biotite granite gneiss is composed of quartz, microcline plagioclase feldspar and other minerals (Anthony and Bolarinwa, 2004).

CONCLUSION

The environmental monitoring of natural background radiation in O-ORBDA HQ using sodium Iodide detector revealed the distribution of the natural radiation level in all the soil samples measured. From the obtained result, one could see that the distribution was not uniform. Also, no artificial radionuclide was detected in any of the measured soil samples.

The baseline average dose equivalent of O-ORBDA HQ was found to be 68.74±18.51 μSv $year^{-1}$ subject to the 15 measured samples. This was slightly lower than the world's outdoor value of 70 μSv $year^{-1}$. This baseline average value of O-ORBDA HQ was a bit high though, it must be noted that Abeokuta is just a city out of the whole world, while O-ORBDA HQ was just a small area out of the whole Abeokuta.

The high baseline average dose equivalent of O-ORBDA was due to the fact that rocky areas are always expected to have higher concentration of primordial radionuclide and presence of abundant radioactive minerals in which Abeokuta is one of those rocky areas and O-ORBDA is a part.

Thus, this high value can be said to be in agreement with the baseline studies of terrestrial

outdoor gamma dose rate level in Nigeria in which only Abeokuta (where O-ORBA is located) and Jos city had dose rate values which were four orders of magnitude higher than the world's average value.

Abeokuta city south-west Nigeria and Jos city also in Nigeria had been reported to have high baseline average dose equivalent (NCRP, 1987).

For practical purposes, the value obtained in this study for O-ORBDA HQ Abeokuta, south-west Nigeria can be taken to represent the baseline value of the terrestrial outdoor gamma dose rate levels.

The baseline level can be kept constant by keeping the environment free of radioactive pollution or wastes and making a proper disposal of radioactive sources.

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