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DETERMINATION OF ABSORBED DOSE RATE AND EFFECTIVE DOSE EQUIVALENT DUE TO NATURAL RADIONUCLIDE PRESENT IN SOIL IN OYO AND OSUN STATE, SOUTH-WESTERN NIGERIA

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ABSTRACT

There has been great concern about the health risks associated with exposure to natural radioactivity present in soil, thus in this work, the natural radioactivity contents in surface soil of Oyo and Osun state in South-Western Nigeria; which is commonly used as building material and farming were analyzed. The analysis was carried out by means of gamma ray spectrometry using NaI(TI) scintillation as the detector coupled to PGT, multichannel analyzer 2100R. The radioisotopes identified in the samples of the materials include those of the series headed by ^{238}U and ^{232}Th as well as the singly occurring isotope ^{40}K. The mean activity concentrations of these radionuclides were found to be 23.39±3.20, 19.37±2.60 and 165.14±7.10 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. The mean absorbed dose rate, annual effective dose equivalent and the collective effective dose equivalent were determined from the measured activity concentration of the radionuclide respectively. The results obtained are lesser than the requirement for materials used in bulk amounts

KEYWORDS: Natural Radioactivity, Atomic Radiation

INTRODUCTION

Natural radioactivity is common in the rocks and soil that make up our planet, in water and oceans and in our building materials. We inhale and ingest radionuclides every day in our lives and radioactive material has been existing on earth since its creation.

People in developing countries spend most of their time indoors. For this reason, it is very important to have knowledge of the constitution of the immediate environment within the premises. It is very well known that people are irradiated mainly by natural sources of ionizing irradiation, therefore there is need for the monitoring at all levels, due to their harmful effects.

Soil not only consists of organic and inorganic compounds but also radioactive materials. The naturally occurring radio nuclides present in soil include the progenies of the series headed by ^{238}U, ^{232}Th and the singly occurring radionuclide ^{40}K. Gamma radiation emitted from these naturally occurring radioisotopes called terrestrial background radiation, represent the main source of irradiation of the human body and contribute to the total absorbed dose via ingestion, inhalation and external irradiation. Uranium is the ultimate source of radium and radon. Radon isotopes are the decay products of radium in uranium decay series. As an inert gas, radon can diffuse through the soil and enter the atmosphere. Radon exposure is associated with the risk of leukemia and certain other cancers, such as malenoma and cancers of kidney.

Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil plays an

important role in radiation protection and measurement. Also, the radioactivity of soil is essential for understanding changes in the natural background.

Beck (1972) showed that 50 – 80% of the total gamma flux at the earth's surface arises from ^{40}K, a singly occurring radionuclide and the ^{238}U and ^{232}Th series in top soil. This study is aimed at determining the activity levels and the resulting human impact due to naturally occurring radionuclides in Oyo and Osun State of Nigeria. These results would also serve as yardstick for any further research in the soil of this part of the country.

MATERIALS AND METHODS

Two hundred and thirty-six soil samples were collected from the study area each weighing 1.00kg. The sampling was done according to the size of the town. Hand- huger was employed for the collection of the samples to the depth of about 5.5cm at 22 towns. After removing the stones and some grasses and leaves, the samples were dried in an oven at a temperature of 50^0C for 24 hours to ensure that as much as moisture as possible was removed from the samples; they were then crushed and pass through 2mm sieve to homogenize them. Representative samples were packed into polyethylene cylindrical containers of 95mm diameter and 38mm height.

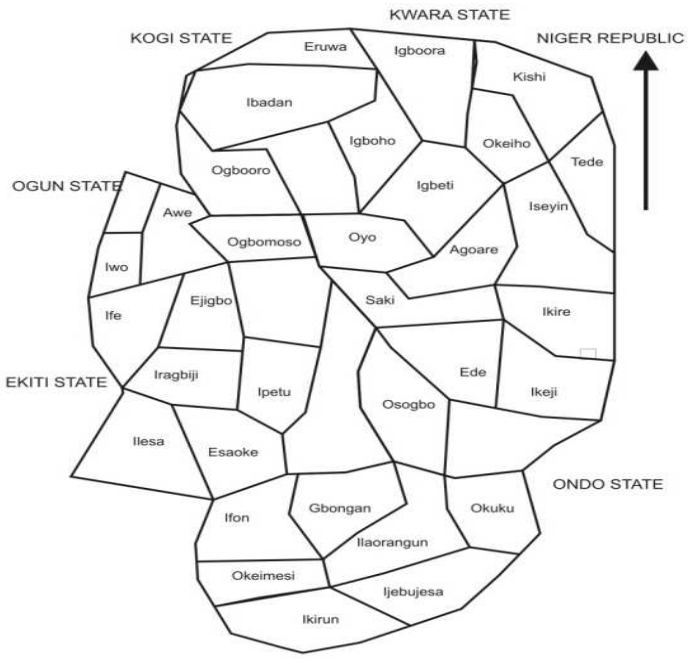

Figure 1: Location of the Towns where Samples were Collected

The packed samples were tightly sealed and kept for 28 days to attain a state of secular equilibrium between radon and its decay products. The samples were thereafter counted for a period of 36000s, using a gamma spectrometry system with NaI (TI) as the detector.

The scintillation detector, a 3x3 inch NaI (TI), a product of Princeton Gamma Tech. USA was placed in a lead shield to reduce the effect of background radiation. Energy and efficiency calibrations of the detector were carried out using a standard source traceable to Analytical Quality Control Services (AQCS), USA; which contains ten radionuclides of y-emitters with energies ranging from 59.54 to 1836keV.

The activity concentration of ^{238}U was determined from the 63.3 KeV peak of ^{234}Th, ^{226}Ra was determined from the average activity concentration of 295.3KeV of ^{214}Pb and 1764.5 KeV of ^{214}Bi. The activity concentration of ^{234}Th was determined from the average concentration of ^{212}Pb (238.6 keV), ^{228}Ac (911.1 keV) and ^{208}Tl (2614.7 keV), and that of ^{40}K 1460.0 keV. The activity concentration of ^{235}U was determined from the 185.7 keV gamma line, which were corrected by removing the contribution from the 186.2 keV of ^{226}Ra using the following equation:

$$A(^{238}U) = \frac{N_{186} - A(^{226}Ra) \cdot f_E(^{226}Ra) \cdot \eta_{186} \cdot M \cdot Tc}{\eta_{186} \cdot f_E(^{235}U) \cdot M \cdot Tc} \quad (1)$$

Where, N_{186} is the total counts for the 186 keV doublets. A (^{235}U) and A(^{226}Ra) are the activity concentrations of ^{235}U and ^{226}Ra respectively, η_{186} is the detection efficiency of the 186keV line, $f_E(^{235}U)$ and $f_E(^{236}Ra)$ are the emission probabilities of the 185.7 and 186.2keV gamma lines of ^{235}U and ^{226}Ra respectively. T_c is the counting time and M is the mass of sample.

The Minimum Detectable Activity (MDA) for each radionuclide ^{226}Ra, ^{232}Th and ^{40}K was calculated using the following equation:

$$MDA = \frac{1.645\sqrt{N_B}}{f_E \cdot \eta(E) \cdot t_C \cdot M} \quad (2)$$

Where, 1.645 is the statistical coverage factor at 95% confidence level, N_B is the background counts at the region of interest, t_C is the counting time, f_E is the gamma emission probability, $\eta(E)$ is the photopeak efficiency and M is the mass of sample. The MDA for each of the radionuclide were calculated as 0.30Bq/kg for ^{238}U, 0.12Bq/kg for ^{226}Ra, 0.11Bq/kg for ^{232}Th and 0.9Bq/kg for ^{40}K respectively.

Calculation of the Absorb Dose Rate and Annual Effective Dose: The absorbed dose rate at 1m above the ground (in nGy/h) due to U-Th series and ^{40}K was calculated using the following equation;

$$D\left(\frac{nGy}{h}\right) = \sum_{i=1}^{n} A_i \cdot DCF \quad (3)$$

Where DCF are the dose coefficient in nGy/h per Bq/kg taken from UNCEAR (2000) report (UNCEAR, 2000) and A_i are the activity concentrations of the radionuclides.

The annual effective dose equivalent, H_E, from external exposure to gamma rays from the soil samples sand was calculated from the absorbed dose rate using the expression (UNSCEAR, 2000):

$$H_E = D(nGy/h) * 8760(h) * 0.2 * 0.7(Sv/Gy) \quad (6)$$

Where, 0.2 is the occupancy factor for outdoor, 8760 is the total time of the year in hours and 0.7SvG/y is the conversion factor for external gamma irradiation.

Radium Equivalent Activity.

The exposure due to the γ radiation, defined in terms of the radium equivalent activity Ra_{eq} is given by equation (2) (Faheem *et al*, 2008):

$$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \leq 370 \quad (2)$$

According to this formula, 1Bq/kg of ^{226}Ra, 0.7Bq/kg of ^{232}Th and 13 Bq/kg of ^{40}K yield the same γ ray dose. The radium equivalent activity for the material analyzed in this work was calculated and a value of 53.80 Bq/kg was obtained. This value is much less that the upper limit of 370Bq/kg. by (UNSCEAR).

RESULTS AND DISCUSSIONS

The results of measurements for 34 soil samples collected at different locations in Osun and Oyo state are presented in Table 1. The activity concentrations of the radionuclides in Bqkg^{-1} ranged between 14.38 ± 2.50 and 32.72 ±5.00 for ^{226}Ra, 12.50 ± 1.50 and 28.42 ± 4.30 for ^{232}Th and from 130.42 ± 6.00 and 230.12 ± 12.00 for ^{40}K respectively. Substitution of these values into equation 3 gives the mean absorbed dose rate due to the three natural radionuclides as 29.39 $\pm$ 0.012 for the two states. A conversion factor of 0.7Sv.Gy^{-1} was employed to convert the absorbed dose rate to human effective dose equivalent with an outdoor occupancy of 20% on the absorbed dose rate that arrive at the mean annual effective dose equivalent of 0.036 mSvyr^{-1} in the two states.

The radium equivalent activity values ranged from 48.70 to 91.08 Bqkg^{-1}. These values are less than 370 Bqkg^{-1}, thus the material may be considered acceptable for safe use. The mean absorbed dose in air obtained was 29.39 nGyhr^{-1} (min. 22.85 nGyhr^{-1}and maximum 41.88nGyhr^{-1}), this is comparable to the world average of 57 nGyhr^{-1}.

The calculated values of external hazard index and internal hazard index have mean values of 0.17 ± 0.02 and 0.24 ±0.03 respectively. Since these values are lower than unity, it can be said that the radiation hazard is negligible. The calculated values of annual effective dose range from 0.028 to 0.051 mSvyr^{-1}with a mean value 0f 0.036 mSvyr^{-1}, this is much lower than the world average of 0.48 mSvyr^{-1}.

Table 1: Activity Concentration, Radium Equivalent Activity and Calculated Absorbed Dose Rate, Effective Dose Rate for Soil Samples

Serial No	Towns	No of Sample	Ra – 226 (Bqkg^{-1})	Th – 232 (Bqkg^{-1})	K – 40 (Bqkg^{-1})	Ra_{eq} (Bqkg^{-1})	Absorbed Dose Rate (nGyh^{-1})	Effective Dose Rate (mSvyr^{-1})
1	Iwo	8	21.02 ± 2.40	17.25 ± 1.50	152.52 ± 6.00	57.43	26.49	0.032
2	Oyo	8	23.92 ± 2.50	18.27 ± 1.70	164.62 ± 6.20	62.72	28.95	0.036
3	Iseyin	6	22.32 ± 2.30	21.38 ± 2.00	173.50 ± 7.40	66.25	30.46	0.037
4	Ede	8	23.72 ± 2.50	20.55 ± 1.40	150.32 ± 5.50	64.68	29.64	0.036
5	Ejigbo	5	18.75 ± 2.50	15.35 ± 1.00	152.71 ± 6.00	52.46	24.30	0.030
6	Iragbiji	4	24.90 ± 2.90	12.50 ± 1.50	183.33 ± 8.00	56.89	26.70	0.033
7	Ikeji	4	20.32 ± 2.50	17.21 ± 1.50	151.62 ± 5.80	56.61	26.11	0.032
8	Ogbomoso	15	28.30 ± 3.80	18.54 ± 1.40	191.62 ± 8.90	69.56	32.26	0.040
9	Igboora	4	29.05 ± 4.00	22.43 ± 1.90	157.05 ± 6.30	73.22	33.52	0.041
10	Ifon	4	23.40 ± 3.00	19.78 ± 2.00	153.71 ± 6.10	63.52	29.17	0.036
11	Ipetu	4	21.45 ± 2.80	21.54 ± 3.10	156.25 ± 7.00	68.52	31.39	0.038
12	Ibadan	50	23.42 ± 3.00	23.42 ± 3.60	223.54 ± 10.50	75.42	34.89	0.043
13	Erinijesa	4	23.42 ± 3.40	22.48 ± 3.10	165.98 ± 7.50	68.27	31.28	0.038
14	Okeimesi	4	22.30 ± 3.50	17.58 ± 3.60	155.87 ± 7.20	59.44	27.42	0.034
15	Agoare	4	21.45 ± 2.80	21.38 ± 2.90	171.20 ± 7.80	65.21	29.96	0.034
16	Eruwa	4	23.80 ± 3.00	23.42 ± 3.10	152.41 ± 7.00	69.03	31.50	0.037
17	Ogbooro	4	24.85 ± 2.90	15.50 ± 2.00	133.70 ± 5.40	57.31	26.42	0.039
18	Saki	8	20.20 ± 2.70	18.71 ± 2.90	183.70 ± 7.80	61.11	28.30	0.032
19	Tede	4	17.35 ± 2.40	12.58 ± 2.00	173.48 ± 7.00	48.70	22.85	0.035
20	Ijebujesa	4	25.50 ± 3.60	18.05 ± 2.40	165.71 ± 6.90	64.07	29.59	0.028
21	Kishi	4	20.30 ± 2.60	19.72 ± 1.60	144.85 ± 5.70	59.65	27.33	0.036
22	Iloko	4	29.90 ± 4.00	18.42 ± 3.00	181.68 ± 8.00	70.23	32.52	0.034
23	Igboho	4	23.42 ± 3.50	17.53 ± 1.50	133.44 ± 5.00	58.76	26.97	0.040
24	Okeiho	6	20.62 ± 3.40	15.32 ± 1.50	145.50 ± 5.50	53.73	24.85	0.033
25	Ilaorangun	6	26.30 ± 4.20	17.28 ± 2.50	182.30 ± 8.10	65.05	30.19	0.030
26	Esaoke	4	24.48 ± 3.50	18.53 ± 3.00	180.51 ± 8.00	64.88	30.03	0.037
27	Okuku	4	31.42 ± 4.20	26.30 ± 4.30	167.20 ± 6.50	81.90	37.37	0.037

Table 1: Contd.,

28	Ilesa	8	25.57 ± 3.50	24.03 ± 3.30	156.08 ± 7.50	71.95	32.84	0.046
29	Ikire	4	19.82 ± 3.50	18.44 ± 3.00	143.90 ± 7.00	57.27	26.30	0.040
30	Gbongan	6	14.38 ± 2.50	21.88 ± 3.40	155.28 ± 7.00	57.62	26.33	0.032
31	Ikirun	4	15.08 ± 2.00	18.24 ± 3.40	156.65 ± 7.50	53.23	24.52	0.030
32	Igbeti	6	19.29 ± 3.50	20.33 ± 3.50	130.42 ± 6.00	58.40	26.63	0.033
33	Ife	8	32.72 ± 5.00	28.42 ± 4.30	230.12 ± 12.00	91.08	41.88	0.051
34	Osogbo	8	27.77 ± 4.30	15.70 ± 3.00	184.50 ± 8.00	64.43	30.01	0.037
35	Awe	4	22.55 ± 3.50	19.78 ± 3.30	175.58 ± 7.90	64.36	29.69	0.036
Mean			**23.39 ± 3.20**	**19.37 ± 2.60**	**165.14 ± 2.60**	**53.80**	**29.39**	**0.036**

CONCLUSIONS

This study has presented the results of the measurements of the activity concentrations of terrestrial gamma emitters for soil samples from Oyo and Osun states South-West, Nigeria. The analysis was undertaken by means of gamma-ray spectrometry using the results obtained indicated that, samples from the area have activity concentrations ranging from 14.38 ± 2.50 to 32.74 ± 5.00 Bqkg^{-1} for ^{226}Ra, 12.50 ± 1.50 to 28.42 ± 4.30 Bqkg^{-1} for ^{232}Th and 130.42 ± 6.00 to 230.12 ± 12.00 Bqkg^{-1} for ^{40}K. The values of the absorbed dose rate in the samples range from 22.85 to 41.88 nGyh^{-1} with a mean value of 29.39nGy^{-1}. The annual effective dose rates in the air varied from 0.028 to 0.051 mSvyr^{-1} with an average value of 0.03 mSvy^{-1}. This value is about 22% compared with the world average of 70.0 μSvy^{-1} and about 80% value of the result obtained in Ondo and Ekiti State.

The values obtained for the natural radioactivity and absorbed dose rates due to the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K of the study area with population of about 5.5millons could not be considered to constitute radiological hazard and can be safely used in construction and for other uses without posing any significant radiological threat to the population.

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