HEALTH DETRIMENT ASSOCIATED WITH EXPOSURE TO NATURAL RADIOACTIVITY FROM THE SOIL OF ONDO AND EKITI STATES SOUTH WESTERN, NIGERIA.

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Abstract:

The health detriment associated with primordial radionuclides from the earth crust has been a major source of concern to public health observers across the globe. The level of such detriment can be mitigated by constant monitoring in order to ascertain that the safe threshold is maintained from time to time. In the light of the above, the activity concentrations of natural occurring radioactivity (i.e ^{232}Th, ^{226}Ra and ^{40}K) were determined in seventeen soil samples collected from selected cities across Ondo and Ekiti states using an n-type coaxial HPGe gamma ray detector with ORTEC multichannel analyzer (MCA) and MAESTRO-32 for spectrum analysis and processing. The measured activity concentrations ranged from 31.93 ± 1.77 to 227.50 ± 4.43 Bq Kg^{-1} ^{232}Th, 364.89 ± 6.40 to 1274.57 ± 12.48 Bq Kg^{-1} ^{40}K, 45.60 ± 2.99 to 210.36 ± 8.76 Bq Kg^{-1} ^{226}Ra and 48.64 ± 2.04 to 207.22 ± 5.50 Bq Kg^{-1} ^{232}Th, 542.26 ± 10.41 to 2348.86 ± 21.83 Bq Kg^{-1} ^{40}K and 73.52 ± 3.81 to 209.15 ± 7.45 Bq Kg^{-1} ^{226}Ra for Ondo and Ekiti states respectively. Absorbed dose was calculated using the measured activity concentrations. The mean absorbed dose rate and standard deviation in nGyh^{-1} were 140.89 ± 65.27 and 173.27 ± 85.40 respectively for the two States. Health detriment to various organs of the body resulting from the exposure scenario was evaluated.

|*KEYWORDS: HPGe, Absorbed dose, Annual outdoor effective dose, Health detriment.*

1.0 Introduction

The human environment is composed largely of soil, water, gases and probably microorganism. Man uses soil or otherwise called land for various purposes ranging from citing of industries, Agriculture and erecting permanent structures for dwelling purposes. Man is a product of his environment. The environmentalist has studied for decades the impact of man's activities on his environment or vice-versa. Soil is a product of weathering and contains fossils, dead organic and in-organic matter, gases and physical contaminants called radionuclides or radioisotopes. Radionuclides occur naturally in the soil in the form of the Uranium decay series (^{226}Ra and ^{232}Th) and the non-decay series ^{40}K. The presence of these Primordial radionuclides vary from one location to another and the distribution has been found to be largely dependent on geological and geographical conditions, and appear at different levels in the soils of each region of the world [1]. Hence Nuclear Scientist and or radiologist are working to characterise each environment based on the presence and distribution of these radionuclides. Human exposure to radiation is dated back to the creation of the Earth. And natural sources still contribute almost 80% of the collective radiation exposure of the World's population [1]. Despite the usefulness of radiation in the industry and Medicine (radiotherapy), exposure to radiation beyond a certain threshold value either from the primary or secondary sources pose a threat to human health.

This situation is becoming worrisome as several cases of Tumour and other deadly ailment are linked to exposure to undue radiation. Hence, it therefore becomes important to quantify human exposure to

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radiation for environmental monitoring [2]. Several studies performed worldwide to assess the activity concentrations of these radionuclides are reported [3, 4, 5, 6]. But data regarding the levels of natural radionuclides and the associated radiation doses are still sparse in some area of Ondo and Ekiti states South-western Nigeria. Ondo (5^0 48'N, 4^0 45'E) and Ekiti (8^0 15'N, 6^0 05'É) states are underlain by crystalline rocks or basement complex. The basement complex is of Precambrian age and composed primarily of metamorphic and igneous rock such as granites, gneisses and migmatites [7].

In this work, 17 samples of soil were collected from selected cities across Ondo and Ekiti states and analysed for primordial radionuclides using gamma-ray Spectrometry to evaluate the activity concentration, absorbed dose due to exposure and the associated Health detriment to different organs of the body.

2.0 Material and Methods

2.1 Samples Collection and Preparation

At each of the designated locations, the soil samples were taken using cutlass from a depth of 10 cm. the quantity taken was about 120g; packaged in cellophane bags and labelled based on the Alphabet ascribed to each location, table 1.0 gives the Samples Code and interpretations.

The collected soil samples were transferred to the laboratory and thereby oven dried at a temperature of 110^{o}C to a constant mass, the dried samples were then pulverized and sieved using a 2 mm mesh, whilst retaining the previous labelling to indicate the city where the sample was collected. The sample was left untouched for about three or four weeks to allow the samples achieve secular equilibrium between parent and daughter nuclides prior to analysis.

2.2 Samples Analysis

The activity Concentrations of the soil samples were measured using an N-type coaxial High Purity Germanium Detector (HPGe) gamma-ray detector at the laboratory of Ghana Atomic Energy Commission Accra with ORTEC Multichannel Analyzer (MCA) and MAESTRO-32 evaluation software for spectrum acquisition and processing. The relative efficiency of the detector was 28.5 % with energy resolution of 1.8 keV at gamma ray energy of 1332 keV of ^{60}Co. The gamma lines 609.31 and 1764.49 keV of ^{214}Bi were used to determine ^{226}Ra. The gamma lines 583.19 of ^{208}Tl were used to determine ^{232}Th and that of ^{40}K was determined from the gamma line of 1460.83 keV. The samples were counted for 18,000 seconds (5 hours). The energy and efficiency calibrations were performed using mixed radionuclide calibration standard in the form of solid water, serial number NW 146 A with approximate volume 1000 mL and density 1.0 gcm^{-3} in a 1.0 L Marinelli beaker. The standard was supplied by Deutscher Kalibrierdienst (DKD-3), QSA Global GmBH, Germany. Background measurements were made for the same period. Density corrections were also made where appropriate.

The specific activity concentrations (A_{sp}) of ^{226}Ra, ^{232}Th, and ^{40}K were determined in Bq kg^{-1} for the water samples using the following expression [8, 9, 10] after decay correction.

$$A_{sp} = \frac{N_{sam}}{P_E.\varepsilon.T_c.M} \qquad 1$$

where; N_{sam} is net counts of the radionuclide in the sample, P_E is gamma ray emission probability (gamma yield), ε is total counting efficiency of the detector system, T_c is sample counting time and M is mass or weight of the Sample.

The specific activity obtained using equation (1) coupled with appropriate dose conversion factors form the basis for the evaluation of the radiological health hazards posed by the analysed samples from the study area.

2.3 Calculation of Absorbed Dose, Dose Equivalent and Health Detriment

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Absorbed Dose

The absorbed dose rates, in $nGyh^{-1}$ at a height of 1m above the ground due to the ingestion or inhalation of ^{232}Th, ^{226}Ra, and ^{40}K was calculated in this work using the following relation [11]:

$$D = A_{\varepsilon i} \times C_f \qquad 2$$

where $A_{\varepsilon i}$ is the activity concentration measured in Bq kg^{-1} and C_f is the dose conversion factor (nGy/h per Bqkg-1). In this work, the dose conversion factor used for ^{232}Th, ^{226}Ra and ^{40}K where the ones determined by [12] and described by [2]. Hence equation 2 is then modified to reflect the dose conversion factor and presented as equation 3. Equation 3 is then the total absorbed dose due to gamma radiation from these radionuclides (^{232}Th & ^{226}Ra and the non series ^{40}K), thus:

$$D = 0.623A_{Th} + 0.461A_{Ra} + 0.0414A_K \qquad \ldots \qquad 3$$

Where A_{Th} = activity concentration of ^{232}Th, A_{Ra} = activity concentration of ^{226}Ra and A_K = activity concentration ^{40}K.

Dose Equivalent

The annual outdoor effective dose equivalent due to exposure or inhalation of these radionuclides from the soil was estimated taking into consideration the conversion coefficient from absorbed dose in air to effective dose and the outdoor occupancy factor. The former gives the equivalent human dose in Sv y^{-1} from the absorbed dose rate in air (nGy h^{-1}), while the latter gives the fraction of the time an individual is exposed. In this work, an occupancy factor of 0.3 was used (i.e. an individual is assumed to spend an average of 8 hours outdoor) and 0.7 Sv y^{-1} was used for the conversion co efficient according to [2]. Hence, the annual outdoor effective dose rate, H_E, in units of μSv y^{-1}, is calculated using the following relation:

$$H_E = D(\gamma) \times N(h) \times O_f \times C_f \qquad \ldots \qquad 4$$

where $D(\gamma)$ is the calculated absorbed dose (nGy h^{-1}), N(h) is the number of hours in a year ($0.3\times 24h \times 365.25d = 2629.80h/y$) O_f is the occupancy factor (i.e. 0.3) and C_f is the conversion co efficient or factor (0.7Sv Gy^{-1}).

Collective Effective Dose Equivalent

The collective effective dose equivalent to a population is a measure of the collective detrimental effects and the percentage of people at risk of incurring radiation-induced diseases; which is calculated using the expression [13].

$$S_E = \sum N_i H_{Ei} \qquad 5$$

Where S_E = collective effective dose equivalent (person – Sv)

N_i = the numbers of individual exposed to radiation and H_{Ei} is the mean outdoor effective dose equivalent (μSvy^{-1}).The N_i used in this work is 3441024 Persons and 2384212 Persons for Ondo and Ekiti states respectively [14].

Collective Health Detriment

The collective health detriment G (person), due to exposure to gamma radiation in an environment, was calculated using the relation [15].

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$$G = R_T S_E \quad \ldots \quad 6$$

where R_T = Total risk factor

S_E = Collective effective dose equivalent (person – Sv)

2.4 Radium Equivalent Activity (Ra_{eq}): This is a radiation hazard indices used to assess the gamma radiation hazards to humans as a result of using soil for building purposes. The Ra_{eq} index is calculated using the relation of [16] as thus;

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.07A_K \quad 7$$

where A_{Ra}, A_{Th} and A_K are the activity concentrations in Bq Kg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K respectively. This index assumed that 370 Bq Kg^{-1} of ^{226}Ra or 259 Bq Kg^{-1} of ^{232}Th or 4810 Bq Kg^{-1} ^{40}K produce the same gamma dose.

3.0 Results and Discussion.

The Activity concentration of the radionuclides present in the spectrum result of the gamma ray spectrometry conducted for the soil was calculated using eqn 1. Naturally occurring radionuclides ^{232}Th, ^{40}K and ^{226}Ra were detected in all the Seventeen (17) Soil samples. A trace quantity of ^{137}Cs was also detected in the soil samples of both Ondo and Ekiti states. The activity concentration of these radionuclides were found to be within the range of 31.93 ± 1.77 - 227.50 ± 4.43 Bq kg^{-1}, 364.89 ± 6.40 – 1274.57 ± 12.48 Bq kg^{-1}, 45.60 ± 2.99 - 210.36 ± 8.76 Bq kg^{-1}, and 1.85 ± 0.32 - 5.03 ± 0.56 Bqkg-1^{-1} for ^{232}Th, ^{40}K and ^{226}Ra and ^{137}Cs respectively in Ondo state soil samples. While that of Ekiti States ranged between 48.64 ± 2.04 – 207.22 ± 5.50 Bq kg^{-1}, 542. 26 ± 10.41 – 2348.86 ± 21.83 Bq kg^{-1}, 73.52 ± 3.81 – 209.15 ± 7.45 Bq kg^{-1} and 3.09 ± 0.46 – 8.88 ± 0.82 Bq $kg^{-1}$for ^{232}Th, ^{40}K and ^{226}Ra and ^{137}Cs respectively. ^{137}Cs was not detected in the two soil samples taken from Omuo Ekiti. A comparison of the activity concentration of these radionuclides in soil samples from different countries was done and presented in Table 2.0. The results in this work are a bit higher than findings from other parts of the world and the world average values [2]. In Ondo state soil samples, the range of activity concentrations of ^{226}Ra (45.60 ± 2.99 - 210.36 ± 8.76 Bq kg^{-1}) measured in this work is still less than the international range of 10 Bq Kg^{-1} to 3700 Bq Kg^{-1} reported by [17] and comparable to the range of 9.3 ± 3.7 Bq kg^{-1} to 198.1 ± 13.8 Bq Kg^{-1} reported by [15] for the South-western part of Nigeria. ^{232}Th had its highest activity concentration of 227.50 ± 4.43 Bq Kg^{-1} in one of the samples taken from Ondo town and the least activity concentration of 31.93 ± 1.77 Bq Kg^{-1} in one of the samples taken from Ikare-Akoko and ^{40}K had its highest concentrations of 1274.57 ± 12.48 Bq Kg^{-1} in one of the samples taken from Akure and the least of 364. 89 ± 6.40 Bq Kg^{-1} in one of the samples taken from Owo. This is equally comparable to the range of 34.9 ± 4.4 – 1358.6 ± 28.5 Bq Kg^{-1} reported by [15] and higher to the range of 129 ± 5.7 – 230 1.1 Bq Kg^{-1} reported for ^{40}K by [18] in the soil of Saudi Arabia. The situation in Ondo town might be as a result of emerging Industries, while that of Akure might be as a result of local geology. Similarly, in Ekiti state the highest activity concentrations of (209.15 ± 7.45 Bq Kg^{-1}) and (207.22 ± 5.50 Bq Kg^{-1}) for ^{226}Ra and ^{232}Th were found in one of the samples taken from Ado-Ekiti. The highest activity concentrations of 2348.86 ± 21.83 Bq Kg^{-1} was found for ^{40}K in the sample taken from Aramoko Ekiti and the least of 542.26 ± 10.41 Bq Kg^{-1} was found in the sample taken from Ise-Ekiti. The mean activity concentrations of 118.88 ± 5.55 Bq Kg^{-1}, 105.72 ± 3.50 Bq Kg^{-1} and 1270.74 ± 15.34 Bq Kg^{-1} reported in this work for ^{226}Ra, ^{232}Th and ^{40}K are higher when compared to findings from other part of the world and the World average value of 35, 50 and 400 Bq Kg^{-1} respectively [2]. The result is however in close range with the findings of [15]. It is important to point out that these values are not the representative values for the entire states, but for the regions where the samples were collected.

Table 2.0: Comparison of activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in Soil measured worldwide.

Country	Activity concentration (Bqkg^{-1})	Reference

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	^{40}K	^{226}Ra	^{232}Th	
Pakistan (Punjab)	615 ± 143	35 ± 7	41 ± 8	[20]
Cyprus	105 ± 95	7.1 ± 8.6	5.0 ± 7.1	[21]
Alexandria, Egypt	262 ± 82	16.7 ± 2.7	19.4 ± 5.0	[22]
South India	117.5	35	29.8	[23]
Spain	650	46	49	[24]
Kenya	255 ± 38.5	28.7 ± 3.6	73.3 ± 9.1	[25]
China	578 ± 164	42.7 ± 15	46.3 ± 12	[26]
Republic of Ireland	350	60	26	[3]
Saudi Arabia	225 ± 63	14.5 ± 3.9	11.2 ± 3.9	[5]
Ondo State (Nigeria)	849.03 ± 12.89	101.12 ± 5.50	91.76 ± 3.12	This study
Ekiti State (Nigeria)	1270.74 ± 15.34	118.88 ± 5.55	105.72 ± 3.50	This study
World's average	400	35	30	[2]

3.1 Absorbed Dose Rate, Health Detriment and Radium Equivalent index

The absorbed dose rate in air at a gonadal height of 1m resulting from the presence of ^{232}Th, ^{40}K and ^{226}Ra in the soil of the two states was calculated using equation 3 above. The mean absorbed dose rate in nGy h^{-1} and the standard deviation were respectively 140.89, 65.27 and 173.27, 85.40 for Ondo & Ekiti states soils. The results in both cases is beyond the limits (30 nGy h^{-1}-70 nGy h^{-1}) recommended by [19] for area of normal background radiation. Annual outdoor effective dose equivalent (µSv y^{-1}) was calculated using an occupancy factor of 0.3 and a conversion factor of 0.7 Sv Gy^{-1} using the relation discussed as eqn 4. The results ranged between 0.15 - 0.70 mSv y^{-1}, mean outdoor annual effective dose equivalent and standard deviation 0.35 mSv y^{-1} and 0.16 mSv y^{-1} for Ondo state. For Ekiti, the range is between 0.22 - 0.79 mSv y^{-1}, mean of 0.43mSv y^{-1} & standard deviation 0.21 mSv y^{-1}. The result exceeds the values recommended by ICRP (70µSv y^{-1}), but below the world's average of 1.0mSv y^{-1}. Health detriment resulting from the inhalation of these radionuclides was calculated using equation 5 and 6 and the health implication to different Organs of the body highlighted and presented in Figures 1.0 and 2.0. The calculated Ra_{eq} index for this work is presented in Table 3.0. The mean Ra_{eq} index for Ondo and Ekiti States are 295.07 Bq Kg^{-1} and 359.01 Bq Kg^{-1} respectively. Though an elevated concentration of Ra_{eq} index was recorded in one of the samples taken from Ondo and Okitipupa for Ondo State and in the sample taken from Ado Ekiti and Aramoko, the area under investigation is still safe for habitation since the mean value for the two states are still less than the 370 Bq Kg^{-1} of ^{226}Ra international standard.

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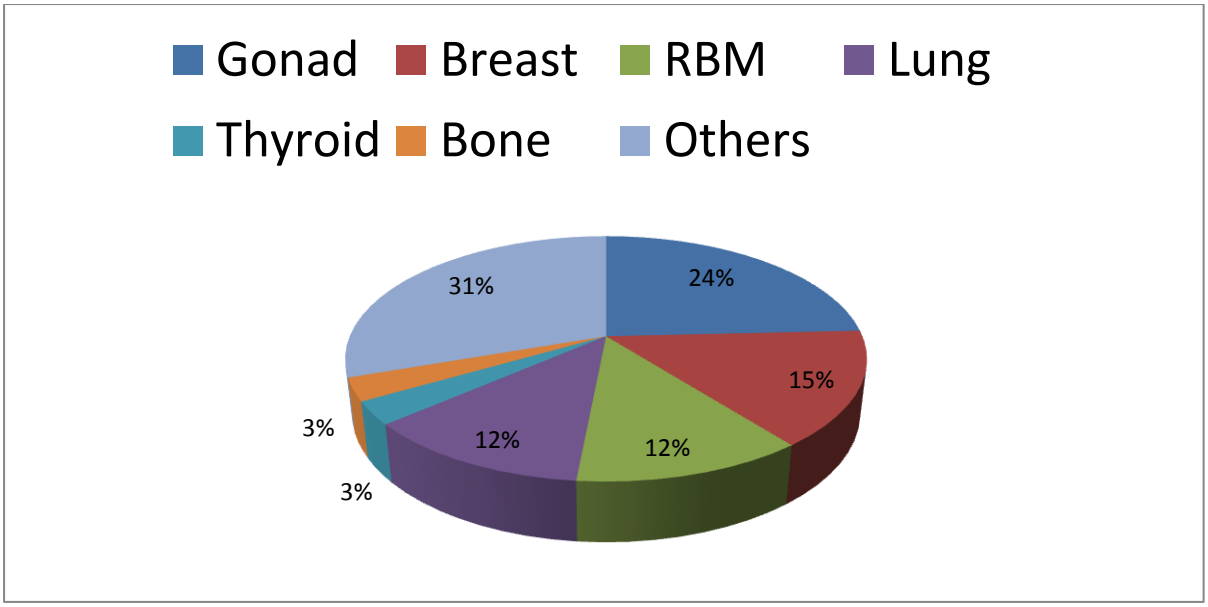

Figure 1.0: Percentage Distribution of Health Detriment From the Soil of Ondo state to different Organs of the Body

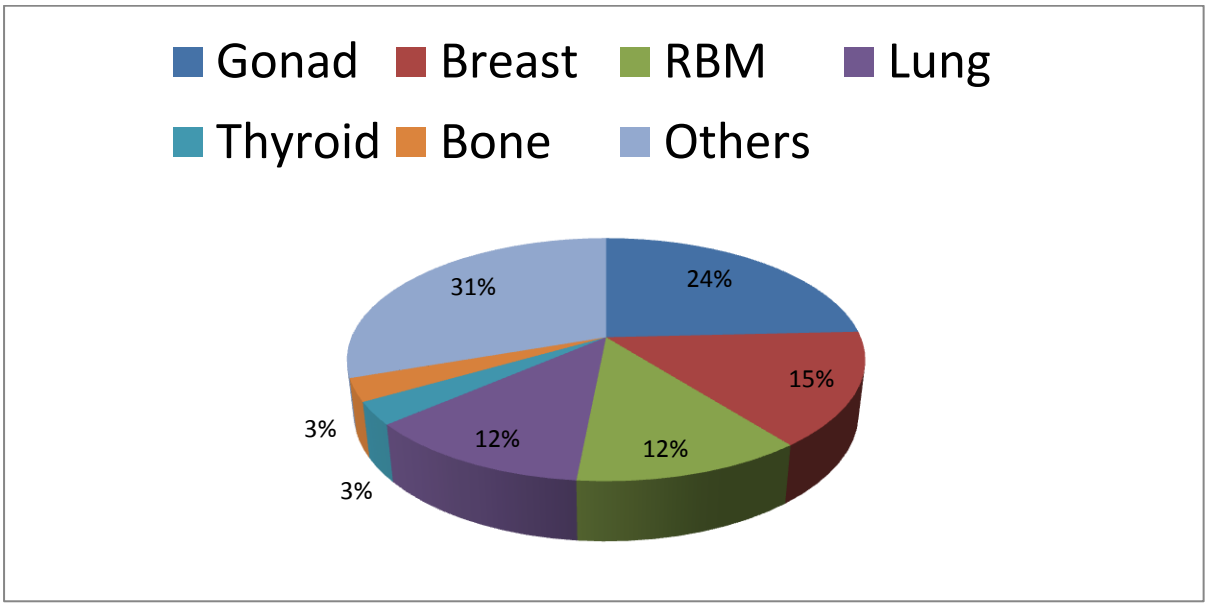

Figure 2.0: Percentage Distribution of Health Detriment From the Soil of Ekiti state to different Organs of the Body

RBM = Red Bone Marrow

4.0 Conclusion

This study investigated the activity concentrations of 17 soil samples taken from selected locations across Ondo and Ekiti States, the radiological health detriment resulting from exposure to different organs of the body and the Radium equivalent index was also evaluated.

Measured activity concentrations recorded in this work ranged from 31.93 ± 1.77 - 227.50 ± 4.43 Bq Kg^{-1} ^{232}Th, 364.89 ± 6.40 - 1274.57 ± 12.48 Bq Kg^{-1} ^{40}K, 45.60 ± 2.99-210.36 ± 8.76 Bq Kg^{-1} ^{226}Ra

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and 48.64± 2.04 - 207.22± 5.50 Bq Kg^{-1} ^{232}Th, 542.26± 10.41 - 2348.86 ± 21.83 Bq Kg^{-1} ^{40}K 73.52± 3.81 - 209.15± 7.45 Bq Kg^{-1} ^{226}Ra for Ondo and Ekiti states respectively. These values are found to be above those reported from other parts of the World and the World average value reported by [2]. Annual outdoor effective dose equivalent was also calculated using a dose conversion factor of 0.7 Sv Gy^{-1} for the two states. The results were found to be above the 70 $\mu Sv\ y^{-1}$ recommended by ICRP and below the world average of 1 mSv y^{-1}. The calculated mean Radium equivalent index for Ondo and Ekiti States are 295.07 Bq Kg^{-1} and 359.01 Bq Kg^{-1} respectively. These values are still below the international standard of 370 Bq Kg^{-1} ^{226}Ra; hence the area under investigation is still safe for Human habitation. Health detriment to various organs of the body resulting from exposure to these radionuclides was also evaluated.

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