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Terrestrial Radiation Doses from Selected Towns of Southwestern Nigeria

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Abstract The activity concentrations of natural gamma-emitting radionuclides ^{238}U, ^{232}Th and ^{40}K in soils from 7 sampling sites each in Ondo and Lagos States, southwestern Nigeria have been measured by using a well calibrated Hyper Pure Germanium Detector (HPGe). The mean activity concentration values of 39.24±1.12, 52.86±1.40 and 445.02±12.24 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively were obtained for Ondo State. Activity concentration values of 23.21±0.92, 22.84 ± 0.78 and 204.02±7.00 Bq kg^{-1} were recorded for ^{238}U, ^{232}Th and ^{40}K respectively for Lagos State. The results obtained were used to estimate the absorbed dose rates in outdoor air which was found to be in the range of 12.35±179.59 nGy h^{-1} for Ondo State and 5.91±83.29 nGy h^{-1} for Lagos State with an overall mean values of 67.50±1.86 nGy h^{-1} and 33.83±1.17 nGy h^{-1} respectively for the two States. The corresponding outdoor annual effective dose rates were estimated to be between 22.7 and 330.6 µSv y^{-1} for Ondo State and between 7.3 and 102.2 µSv y^{-1} for Lagos State assuming 30% and 20% occupancy factors for the two states respectively. The average outdoor annual effective dose rate for towns in Ondo State is 64.85 µSv y^{-1} representing 92.64% of the world average value (70 µSv y^{-1}) given by UNSCEAR. However, the cities in Lagos State have an average outdoor effective dose of 41.52 µSv y^{-1} which is less than 60% of the world average value. The values of the collective effective dose as calculated from the outdoor annual effective dose rates were found to be 540858 and 273296 person-Sv for Ondo and Lagos States respectively.

Keywords: *radionuclide, activity concentration, outdoor, effective dose, absorbed dose*

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1. Introduction

Radionuclides in man's environment are derived from various sources which include environmental matrix such as air, soil, water, foods, vegetation and sediments [10]. The commonest radionuclides are the primordial radionuclides in the earth's crust, ^{238}U and ^{232}Th and their progenies as well as ^{40}K. Most of the elements in the decay series of Uranium and Thorium emit alpha and beta particles, and it is these radiations that form a significant portion of the external field on the earth's surface [3,10]. Beside the primordial radionuclides however, radionuclides may be derived from other sources such as nuclear power generation, fallout from nuclear explosions and medical sources [4,5]. In most cases, these radionuclides find their way into the environment via accidents, transport, routine releases, loss and incorrect disposal and misuse. Radiation from non-primordial sources can only affect a small fraction of the population at any time if properly controlled and managed. Radiation used in health services for both therapeutic and diagnostic purposes most especially in the management of cancer in humans makes a significant contribution to the exposure of man as well. Radiation injury is used as a general term to describe all effects on human beings. These effects include every grade of severity from undetectable to the fatal. They also include late somatic effects and genetic injury. The nature of the injury, the seriousness and outcome depend on such radiological factors as the type of radiation (gamma, beta or alpha), the dose, the equivalent residual dose (ERD), the density of contamination of the skin, and the body burden of radionuclides deposited internally. The effects also depend on the biological action of such ionizing radiation [6]. NCRP [11] estimated that, terrestrial sources are responsible for most of man's exposure to natural radiation, while cosmic rays only contribute less than half of man's exposure to natural radiation [9].

2. Materials and Method

70 soil samples were collected in all, 35 samples from 7 towns in Ondo State and another 35 samples from 7 towns in Lagos State. 5 samples were collected in each town. Each sample was collected between depth 6 and 10cm in the soil after the surface have been cleared of decaying organic matter [7]. The samples were sun dried until they maintain a constant weight. The samples were then ground using a mole grinding machine, sieved with 2mm wire mesh to obtain a fine texture of the samples. The sieved soil samples were weighed 250g lot into a cellophane bag [12]. The packaging was done with the use of thick

cellophane bag with a press-and-key mouth to make it airtight. The cellophane bags were properly labeled to indicate the towns where the samples were collected.

The sieved soil samples were sealed in 76cm^3 container and subjected to gamma ray spectroscopy to determine the activity. Gamma spectroscopy measurements were carried out with coaxial-type Germanium, detectors (HPGe) by Canberra Industries Inc. The detector has a 50% relative efficiency and resolution of 2.4 keV at 1.33 MeV. The detector was properly shielded in lead castle. Calibrations of the measuring systems had been carried out with certified reference standards for various radionuclides. Spectral analyses were performed with the Genie 2K spectrometry software, version 2.1 (Canberra Industries Inc.)

Each sample was counted for 24 hours to achieve minimum counting error. Specific activity of each radionuclide in soil samples was expressed in Bq kg^{-1} of dry mass of soil and corrected for the time elapsed since the samples were collected in the field [7].

3. Results and Discussion

3.1. Calculation of Absorbed Gamma Dose

In estimating the heath risk associated with exposure to radiation from radioactivity in the soil, it is necessary to convert the activity concentration to absorbed gamma dose rates in air at 1m above the ground surface. This is calculated using the equation given by Beck et al. 1972 as shown in the following expression;

$$D = 0.042S_K + 0.429S_U + 0.666S_{Th} \text{ [2]} \quad (1)$$

where D is the absorbed dose rate in air (nGy h^{-1}), and S_K, S_U, S_{Th} are the soil specific activity concentration of ^{40}K, ^{238} U and ^{232} Th respectively taking ^{214}Bi and ^{208}Tl as indicators for ^{238}U and ^{232}Th respectively. The results for the absorbed dose rate in Ondo State and Lagos State are shown in Tables 1 and 2 respectively.

In Ondo state the extracted values ranged from 2.30 to 64.68nGyh^{-1} (^{232}Th) with a mean of (22.68±0.6) nGyh^{-1}, from 5.75 to 64.08nGyh^{-1} (^{238} U) with a mean of (26.14±0.75)nGyh^{-1}, and from 4.30 to 57.06 (^{40}K) with a mean of (18.69±0.52)nGyh^{-1} respectively. The relative contribution to dose due to ^{238}U is 38.7%, followed by lower contributions due to ^{232}Th and ^{40}K (33.6% and 27.7% respectively). However, these values are comparable.

For Lagos state, the contribution to dose due to ^{238}U is the most important, followed by ^{232}Th and ^{40}K. The corresponding dose rate calculated for ^{232}Th, ^{238}U and ^{40}K in the soils of the state ranged from 0.94 to 25.88nGyh^{-1} with a mean of (9.80±0.26)nGyh^{-1}, from 0.80 to 36.83 nGyh^{-1} with a mean of (15.46±0.61)nGyh^{-1}, and from 1.88 to 20.58 with a mean of (8.57± 0.29)nGyh^{-1} respectively. The relative contribution to the dose due to ^{238}U is higher (45.7%) than for ^{232}Th and ^{40}K (29.0% and 25.3% respectively).

Table 1. Contribution of ^{40}K, ^{208}Tl and ^{214}Bi concentration to Absorbed dose (Ondo State)

Location	^{40}K		^{208}Tl		^{214}Bi	
	Concentration Bq kg^{-1}	Absorbed Dose nGy h^{-1}	Concentration Bq kg^{-1}	Absorbed Dose nGy h^{-1}	Concentration Bq kg^{-1}	Absorbed Dose nGy h^{-1}
Oba	1358.60± 28.54	57.06 ±1.20	150.76± 3.19	64.68 ±1.37	86.86 ±2.29	57.85 ±1.53
Ugbe	292.49 ±11.13	12.29 ±0.47	50.46 ±1.56	21.65 ±0.67	N D	-
Ogbagi	449.46 ±13.22	18.88 ±0.56	27.20 ±0.87	11.67 ±0.37	22.92± 0.85	15.27± 0.57
Owo	102.33 4.18	4.30 ±0.18	5.35 ±0.34	2.30 ±0.15	8.63 ±0.48	5.75 ±0.32
Ikare	323.76± 9.57	13.60± 0.40	91.05±2.14	39.06 ±0.92	96.21± 2.05	64.08 ±1.37
Ogbese	282.22± 9.91	11.85± 0.41	17.87±0.83	7.67 ±0.38	33.39 ±1.22	22.24 ±0.81
Irun	306.30± 9.16	12.87± 0.39	27.34±0.84	11.7±3 0.36	26.66± 0.94	17.76± 0.63

ND – Below detectable limit.

Table 2. Contribution of ^{40}K, ^{208}Tl and ^{214}Bi concentration to Absorbed dose (Lagos State)

Location	^{40}K		^{208}Tl		^{214}Bi	
	Concentration Bq kg^{-1}	Absorbed Dose nGy h^{-1}	Concentration Bq kg^{-1}	Absorbed Dose nGy h^{-1}	Concentration Bq kg^{-1}	Absorbed Dose nGy h^{-1}
Ojota	54.45 ± 6.02	2.29± 0.25	32.24± 1.29	13.83± 0.55	26.51±1.33	17.66± 0.89
Ikoyi	318.91± 9.37	13.39± 0.39	16.75± 0.69	7.19± 0.30	37.08± 1.23	24.70± 0.82
Berger	44.74 ± 3.41	1.88 ± 0.14	21.69± 0.72	9.31± 0.31	18.20± 0.74	12.12± 0.48
V. I	60.10 ± 3.51	2.52 ± 0.15	2.18± 0.25	0.94± 0.11	4.10± 0.35	2.73± 0.23
Agege	364.40± 10.60	15.30± 0.45	24.18±0.86	10.37± 0.37	20.10± 0.91	13.39± 0.61
Obalende	95.60 ± 4.69	4.02± 0.20	2.54± 0.28	1.09± 0.12	1.20± 0.45	0.80± 0.30
Owode	489.96± 11.35	20.58± 0.48	60.33±1.39	25.88± 0.05	55.30± 1.43	36.83± 0.95

3.2. Calculation of Annual Outdoor Effective Dose Rate

In order to estimate the annual effective dose outdoor, there is need to take into account the conversion coefficient from absorbed dose in air to effective dose and the outdoor occupancy factor. In the UNCEAR recent reports [14,15], the committee used 0.7SvGy^{-1} for the conversion coefficient from absorbed dose received by adults, 0.2 for the outdoor occupancy factor for urban area (this suggests that an average person stays for about 5 hours outside daily) and 0.3 for the outdoor occupancy factor for rural area (meaning that an average person stays about 7 hours outside daily).

Thus the effective dose rate outdoor in units of Sv per year is calculated by the formula:

$$E(\chi) = D(\gamma) \times N(h) \times O_f \times C_f \ [15] \qquad (2)$$

Where $E(\chi)$ is annual outdoor effective dose rate (μSv y^{-1}), $D(\gamma)$ is the absorbed dose rate in air (nGy h^{-1}), $N(h)$ is number of hours in a year (24x365.25), O_f is the outdoor occupancy factor, and C_f is the conversion factor (Sv Gy^{-1}).

Table 3 and Table 4 give the effective dose rate assessment for Ondo state (rural area) and Lagos state (urban area) respectively.

The average annual outdoor effective dose for towns in Ondo state with the exception of Oba and Ikare is 64882.95μSv y^{-1} representing 92.7% of the world value (70000 μSv y^{-1}) given by UNCEAR [14] and 66.1% of Nigeria value (98000 μSv y^{-1}) given by Olomo et al. [13]. The cities in Lagos state have an average outdoor effective dose of 41519.28μSv y^{-1} which is less than 60% of the world value and about 42% of the value estimated for Nigeria by Olomo et al. [13]. The overall average effective dose of towns in Ondo state (Oba and Ikare inclusive) is 124273.83μSv y^{-1}.

This high value is as a result of the high dose rate obtained for rocky towns of Oba and Ikare. The value is almost three times the value estimated for the cities in Lagos state. Hence, the result shows the effect of rock and duration of exposure to dose in air by an individual.

Table 3. Outdoor Annual Effective Dose Rate for Ondo State

Location	Absorbed dose nGy h^{-1}	Effective dose μSv y^{-1}
Oba	179.53	330600.04
Ugbe	33.94	62478.79
Ogbagi	45.82	84348.21
Owo	12.35	22734.62
Ikare	116.74	214902.00
Ogbese	41.76	76874.31
Irun	42.36	77978.83

Table 4. Outdoor Annual Effective Dose Rate for Lagos State

Location	Absorbed dose nGy h^{-1}	Effective dose μSv y^{-1}
Ojota	33.78	41456.17
Ikoyi	45.28	55569.43
Berger	23.31	28606.96
V.I	6.19	7596.62
Agege	39.06	47935.99
Obalende	5.91	7252.99
Owode	83.29	102216.82

3.3. Calculation of Collective Effective Dose Equivalent

The collective effective dose equivalent to a population, which is a measure of the collective detrimental effects and the percentage of people at risk of incurring radiation-induced diseases, was estimated in this work using the expression given by ICRP [8].

$$S_E = \sum_i N_i H_{Ei}, \ [8] \qquad (3)$$

where S_E is the collective effective dose equivalent (person-Sv), N_i is the number of individuals exposed to radiation, and H_{Ei} is the mean outdoor effective dose equivalent (μSv y^{-1}). This quantity was estimated for each of the two states using population figure in Table 5. The results are represented in Table 5. The values obtained are 540858 person-Sv for Ondo and 273296 person-Sv for Lagos. The results show that about 13.6% and 4.2% of the population of Ondo and Lagos, respectively are at risk of incurring radiation-induced diseases per year.

Table 5. Collective Effective Dose Equivalent for the Two States

State	Average Effective dose μSv y^{-1}	Population Person [1]	Collective Effective dose person-Sv
Ondo	124273.83	3,969,726	540858
Lagos	41519.28	6582388	273296

4. Conclusion

The results of radiation parameters (Effective dose rate and Collective effective dose) obtained for Ondo State is relatively higher when compared with that of Lagos State. This is because Ondo State is characterized by heavy agricultural activities involving the use of inorganic fertilizer and chemicals coupled with the availability of rocks and a few number of flowing rivers. It should also be noted that the drying of cocoa seed on bare sand should be discouraged in Ondo State. Other activities that should be reduced in Ondo State are, the use of earthen (clay) pot in the processing of cassava flour, cooking of food, and keeping of drinking water at homes. The use of sand to roast ground – nut should also be given an alternative. Processed food items not ready for consumption should be properly covered to avoid soil particulates settling on them.

However, since some food items like fruits, vegetables, cassava and yam flours are being supplied to Lagos State partly from Ondo State, it should be noted that individuals in Lagos State could cultivate the habit of raising vegetables like Pumpkin, bitter leaf and other vegetables in gardens within their residence. Food items could also be brought into the state from other states with less estimated values of radionuclide concentration and absorbed dose.

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