Physical Science International Journal

14(4): 1-11, 2017; Article no.PSIJ.32273
ISSN: 2348-0130

Health Detriment Associated with Exposure to Natural Radioactivity from the Soil of Ondo and Ekiti States South Western, Nigeria

A. E. Ayodele[1*], A. M. Arogunjo[1], J. I. Ajisafe[1,2] and O. T. Arije[1]

[1]Department of Physics, Federal University of Technology, Akure, Nigeria.
[2]Department of Industrial Safety and Environmental Engineering Technology, Petroleum Training Institute, Effurun, Warri, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author AEA is the team leader and prepared the original manuscript for this article. Author AMA conceived the idea and proofread the manuscript and supplied necessary literatures. Author JIA handled the sample collection throughout Ondo and Ekiti States and sample processing prior to analysis. Author OTA handled the area of spectrum analysis and statistical analysis of the results. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/PSIJ/2017/32273
Editor(s):
(1) Thomas F. George, Chancellor / Professor of Chemistry and Physics, University of Missouri-St. Louis, Boulevard St. Louis, USA.
(2) Christian Brosseau, Distinguished Professor, Department of Physics, Université de Bretagne Occidentale, France.
Reviewers:
(1) Ayman El-Gamal, Coastal Research Institute, National Water Research Centre, Egypt.
(2) Angelo Paone, Pusan National University, Busan, South Korea.
(3) Isaac Hyuk Daniel, Kaduna State University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/19153

Original Research Article

Received 18th February 2017
Accepted 27th March 2017
Published 22nd May 2017

ABSTRACT

The health detriment associated with human exposure to 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 continuous 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 naturally 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 gamma ray spectrometry. The measured activity concentrations ranged from 31.93±1.77 to 227.50±4.43 Bq Kg^{-1} for ^{232}Th, 45.60±2.99 to 210.36±8.76 Bq Kg^{-1} for ^{226}Ra, 364.89±6.40 to 1274.57±12.48 Bq Kg^{-1} for ^{40}K, and 48.64±2.04 to 207.22±5.50 Bq Kg^{-1} for ^{232}Th, 73.52±3.81 to 209.15±7.45 Bq Kg^{-1} for

**Corresponding author: E-mail: erastcalc@yahoo.com;*

^{226}Ra, 542.26±10.41 to 2348.86±21.83 Bq Kg^{-1} for ^{40}K for Ondo and Ekiti States, respectively. Absorbed dose was calculated using the measured activity concentrations. The mean absorbed dose rate and standard deviation in nGy h^{-1} were 140.89±65.27 and 173.27±85.40 for Ondo and Ekiti States, respectively. These results are beyond the limits (30 nGy h^{-1}-70 nGy h^{-1}) recommended by UNSCEAR, 1988 for area of normal background radiation. 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. INTRODUCTION

The human environment is composed largely of soil, water, gases and probably microorganisms. Man uses soil or land for various purposes ranging from citing of industries, agriculture and erecting permanent structures for dwelling purposes. The environmentalists have studied for decades the impact of man's activities on his environment or vice-versa. Soil is a product of weathering and contains fossils, 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 and Thorium decay series (^{226}Ra and ^{232}Th) and natural potassium ^{40}K. The activity concentrations 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 Scientists and or radiologists are working to characterise each environment based on the activity concentration and distribution of these radionuclides. Human exposure to radiation is dated back to the creation of the earth. 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 excessive exposure to radiation. Hence, it therefore becomes necessary to quantify human exposure to radiation for environmental monitoring [2]. Several studies performed worldwide to assess the activity concentrations of these radionuclides [3,4,5,6]. 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. It is therefore the aim of this work to carry out a comprehensive analysis of the radionuclides present in the studied area and the associated health detriment to its inhabitants. Ondo (5°48'N, 4°45'E) and Ekiti (8°15'N, 6°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].

2. MATERIALS AND METHODS

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 counting, absorbed dose due to exposure and the associated Health implications to different organs of the body. The study area covers parts of Ondo and Ekiti States. Ekiti State is underlain entirely by crystalline basement rocks, while Ondo State is underlain partly by this basement rocks and partly by sedimentary rocks of the Dahomey basin. The Crystalline rocks of the study area are part of the South Western Nigeria basement which itself is part of the Nigeria Basement complex. The Nigerian Basement Complex is part of the pan African Mobile belt that lies between the West African Craton to the east and the Congo Craton to the South West within the Africa continent. The maps of the studied area are presented in Figs. 1. and 2. Ondo and Ekiti States have a population of about 3.44 M and 2.38 M, respectively [8]. The inhabitants are traditionally farmers, and they cultivate both food and cash crops. Five Cities were selected from each State based on population density, accessibility and geographical location.

2.1 Samples Collection and Preparation

At each of the designated locations, the soil samples were collected at a depth of 10 cm. About 150 g of soil samples were collected from each location; packaged in cellophane bag and labelled for proper identification. The collected

soil samples were taken to the laboratory for preparation before activity counting. The soil samples were oven dried at a temperature of 110℃ to a constant weight of about 120 g; the dried samples were then pulverized and sieved using a 2 mm mesh. The dried soil samples were sealed and stored for about 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 (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 351.9 keV, 609.31 and 1764.49 keV of ^{214}Pb and ^{214}Bi respectively were used to determine ^{226}Ra. The gamma line 583.19 of ^{208}Tl and 911.1 keV of ^{228}Ac 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 certified soil reference standards for various radionuclides. Each soil standard was placed in a 1litre Marinelli beaker, which was placed on the detector. Spectral analyses were performed using MAESTRO-32 software (Canberra Industries Inc.), which allows data acquisition, storage and display. The standards (RGU-238, RGTh-232, RGK-40 and Soil-6) were supplied by Deutscher Kalibrierdienst (DKD-3), QSA Global GmBH, Germany and IAEA. The system was calibrated for energy and relative efficiency on a routine basis. Background measurements were made for the same period. This was done by placing an empty Marinelli beaker which was previously washed with dilute HCl and distilled water on the detector. Counting was done under the same condition as the samples, and later subtracted from the gamma spectra measurement of each of the samples. 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 soil samples using the following expression [9,10,11] after decay correction.

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

Where

N_{sam} = net counts of the radionuclide in the sample
P_E = gamma ray emission probability (gamma yield)
E = total counting efficiency of the detector system
T_c = sample counting time
M = 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

2.3.1 Absorbed dose

The absorbed dose rates, in nGy h^{-1} at a height of 1metre above the ground due to the inhalation of ^{232}Th, ^{226}Ra, and ^{40}K was calculated in this work using the following relation [12].

$$D = A_{\varepsilon i} \times C_f \quad (2)$$

where $A_{\varepsilon i}$ is the activity concentration measured in Bq kg^{-1} and C_f is the dose conversion factor (nGy h^{-1} per Bq kg^{-1}). In this work, the dose conversion co-efficients used for ^{232}Th, ^{226}Ra and ^{40}K where determined by [13] 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 and ^{226}Ra and the non series ^{40}K), thus:

$$D = 0.623A_{Th} + 0.461A_{Ra} + 0.0414A_K \quad (3)$$

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

2.3.2 Effective dose equivalent

The annual outdoor effective dose equivalent **H_E** due to exposure or inhalation of these radionuclides from the soil was estimated taking

into consideration the conversion factor 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 Gy^{-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 [14]:

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

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 factor (0.7Sv Gy^{-1}).

2.3.3 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 [15].

$$S_E = \sum N_i H_{Ei} \quad (5)$$

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 [8].

2.3.4 Collective health detriment

The collective health detriment G (person), due to exposure to gamma radiation in an environment, was calculated using the relation described by [14].

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

where

R_T = Total risk factor
S_E = Collective effective dose equivalent (person – Sv)

The risk factor for each of the body organ used in this work is as given in Table 1.

Table 1. Values of weighing & risk factor [15]

Organs	Weighting factor W_T	Risk factor ($X10^{-3}$ Sv^{-1})
Gonads	0.25	4.00
Breast	0.15	2.50
Red Bore Marrow	0.12	`2.00
Lung	0.12	2.00
Thyroid	0.03	0.50
Bone	0.03	0.50
Others	0.30	5.00
Total	1.00	16.50

2.4 Radium Equivalent Activity (Ra_{eq})

This is a radiation hazard indices used to assess the cumulative effect of gamma radiation hazards due to exposure to a mixture of ^{226}Ra, ^{232}Th and ^{40}K. The Ra_{eq} index is calculated using the relation of [16] and [17] 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. RESULTS AND DISCUSSION

The Activity concentrations of the radionuclides in soil samples from Ondo and Ekiti States have been measured. The result is presented in Table 2. 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 presence of ^{137}Cs in the soil samples might be attributed to radioactive fallout resulting from nuclear weapon testing of 1960's and or Chernobyl nuclear accident of 1986.The contribution from this source however is insignificant, since it is an artificial source.

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}, 45.60 ± 2.99 - 210.36 ± 8.76 Bq kg^{-1}, 364.89 ± 6.40 – 1274.57 ± 12.48 Bq kg^{-1}, and 1.85 ± 0.32 - 5.03 ± 0.56 Bqkg-1^{-1} for ^{232}Th, ^{226}Ra, ^{40}K 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}, 73.52 ± 3.81 – 209.15 ± 7.45 Bq kg^{-1}, 542. 26 ± 10.41 – 2348.86 ± 21.83 Bq kg^{-1}, and 3.09 ± 0.46 – 8.88 ± 0.82 Bq $kg^{-1}$for ^{232}Th, ^{226}Ra, ^{40}K 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 3. The results in this work are a bit higher than findings from other parts of the world and the world average values [2] also reported in Table 3. 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 [18] and comparable to the range of 9.3 ± 3.7 Bq kg^{-1} to 198.1 ± 13.8 Bq Kg^{-1} reported by [14] for the South-western part of Nigeria.

^{232}Th had its highest activity concentration of 227.50 ± 4.43 Bq Kg^{-1} in the soil sample from Ondo town and the least activity concentration of 31.93 ± 1.77 Bq Kg^{-1} in the soil sample from Ikare-Akoko. ^{40}K had its highest concentrations of 1274.57 ± 12.48 Bq Kg^{-1} in the soil sample from Akure and the least of 364. 89 ± 6.40 Bq Kg^{-1} in the soil sample from Owo. This is equally comparable to the range of 34.9 ± 4.4 – 1358.6 ± 28.5 Bq Kg^{-1} reported by [14] and higher to the range of 129 ± 5.7 – 230 1.1 Bq Kg^{-1} reported for ^{40}K by [16] in the soil of Saudi Arabia. The high activity concentration of ^{232}Th in Ondo town might be as a result of emerging industries, while that of ^{40}K in 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 the soil sample from Ado-Ekiti. The highest activity concentrations of 2348.86 ± 21.83 Bq Kg^{-1} was found for ^{40}K in the sample from Aramoko Ekiti and the least of 542.26 ± 10.41 Bq Kg^{-1} was found in the sample from Ise-Ekiti. The calculated mean activity concentrations of (91.76 ± 3.12, 101.12 ± 5.50, 849.03 ± 12.89) Bq kg^{-1} and (105.72 ± 3.50, 118.88 ± 5.55, 1270.74 ± 15.34) Bq kg^{-1} for ^{232}Th, ^{226}Ra and ^{40}K for Ondo and Ekiti States, respectively are higher than the World average values (30, 35, 400) Bq kg^{-1} reported by [2]. The result is however in close range with the findings of [14]. It is evident from the result that factors like local geology and industrial development have notable influence on the activity concentration in environmental samples like soil.

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 ^{40}K, ^{226}Ra and ^{232}Th in the soil of the two states was calculated using equation 3.

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.

The results in both cases is beyond the limits (30 nGy h^{-1}-70 nGy h^{-1}) recommended by the United Nations Scientific Committee on the Effect of Atomic Radiation [19] for area of normal background radiation. The results of the absorbed dose, effective dose equivalent and the health detriment are presented in Tables 4 and 5. for both Ondo and Ekiti States, respectively. The result of annual outdoor effective dose equivalent (μSv y^{-1}) ranged between 0.15 - 0.70 mSv y^{-1}, with a mean annual outdoor effective dose equivalent 0.35 ± 0.16 mSv y^{-1} for Ondo state.

For Ekiti, the range of annual outdoor effective dose equivalent is between 0.22 - 0.79 mSv y^{-1}, with a mean of 0.43 ± 0.21 mSv y^{-1}.

The results were found to be above the world average of 70 $\mu Sv\ y^{-1}$ recommended by ICRP and below the maximum permissible outdoor effective dose equivalent of 1 mSv y^{-1} for individual member of the public [15]. Health detriment resulting from the inhalation of these radionuclides and the health implication to different organs of the body were highlighted and presented in Figs. 3 and 4. For both Ondo and Ekiti States, the body organ tagged ''others'' had the highest health detriment followed by Gonads. Hence, the residents of the two States are advised to reduce their exposure to radiation to the barest minimum.

The calculated Ra_{eq} index for the study area is presented in Table 2. The mean Ra_{eq} index for Ondo and Ekiti States were 295.07 Bq Kg^{-1} and 359.01 Bq Kg^{-1}, respectively. Though an elevated concentration of Ra_{eq} index was recorded in the samples from Ondo and Okitipupa for Ondo State and in the samples from Ado Ekiti and Aramoko in Ekiti State. 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 [17].

Table 2. Activity concentrations of radionuclides in Ondo and Ekiti states soil samples

	S/N	Activity concentration (Bq kg^{-1})					
		Sample location	**Th – 232**	**K-40**	**Ra - 226**	**Cs -137**	**Ra_{eq} (Bq kg^{-1})**
Ondo soil samples	1	IS_3 – Soil	36.42 ± 1.64	364.89 ± 6.40	48.09 ± 2.89	2.00 ± 0.33	125.71
	2	HS_3 – Soil	62.84 ± 2.21	1274.57 ±12.48	45.60 ± 2.99	1.85 ± 0.32	224.68
	3	KS_5 – Soil	31.93 ± 1.77	627.56 ± 10.65	82.21 ± 4.93	2.08 ± 0.36	171.80
	4	IS_2 – Soil	80.21 ± 3.64	934.81 ± 12.64	71.40 ± 4.44	3.02 ± 0.62	251.54
	5	HS_2 – Soil	93.46 ± 4.43	1047.62 ±18.25	108.00 ± 6.79	4.55 ± 0.88	314.18
	6	ES_1 – Soil	227.50 ± 4.43	1165.50 ±13.54	210.36 ± 8.76	5.03 ± 0.56	612.67
	7	ES_2 – Soil	94.83 ± 2.65	628.09 ± 10.04	84.61 ± 5.09	3.10 ± 0.47	264.18
	8	AS_5 – Soil	115.47 ± 3.03	908.35±11.24	146.08 ± 6.38	4.83 ± 0.50	374.79
	9	AS_1 – Soil	83.16 ± 4.27	1115.39± 20.79	113.70 ± 7.22	2.82 ± 0.88	310.70
Ekiti soil samples	1	OS_3 – Soil	79.19 ± 4.01	683.49 ± 11.86	85.28 ± 4.49	BDL	246.37
	2	TS_1 – Soil	48.64 ± 2.04	1487.76 ±18.50	100.90 ± 6.14	5.51 ± 0.79	274.60
	3	TS_3 – Soil	207.22 ± 5.50	2292.23± 21.14	209.15 ± 7.45	8.22 ± 0.93	665.93
	4	SS_3 – Soil	104.49 ± 3.03	1248.96± 15.78	111.68 ± 5.09	3.97 ± 0.54	348.53
	5	SS_1 – Soil	105.00 ± 2.41	807.94 ± 10.50	104.04 ± 4.12	3.09 ± 0.46	310.75
	6	OS_2 – Soil	72.40 ± 3.18	754.44 ± 12.68	84.56 ± 5.05	BDL	240.90
	7	QS_2 – Soil	176.28 ± 4.93	2348.86± 21.83	181.87 ± 8.22	8.88 ± 0.82	598.37
	8	MS_5 –Soil	52.54 ± 2.90	542.26 ± 10.41	73.52 ± 3.81	3.31 ± 0.47	186.61

BDL= Below Detection Level

H=Akure, E=Ondo, A=Okitipupa, I=Owo, K=Ikare Akoko, T=Ado-Ekiti, S=Erinmope-Ekiti, O=Omuo-Ekiti, Q=Aramoko-Ekiti, M=Ise-Ekiti

Table 3. Comparison of activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in soil measured worldwide

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

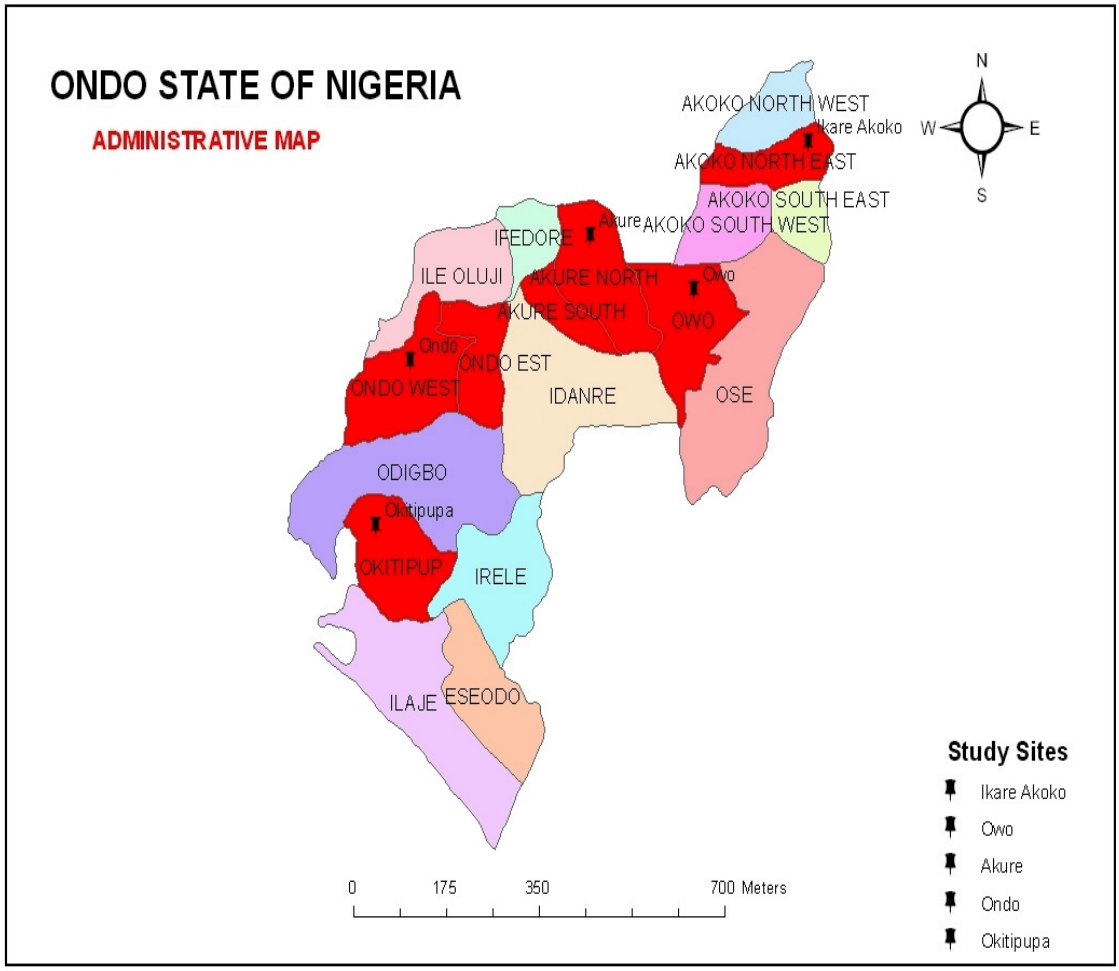

Fig. 1. Ondo state map showing the sample locations

Table 4. Absorbed dose and health detriment from Ondo state soil samples

Sample location	AB DOSE nGy/h	$H_E(\mu^{Svy^{-1}})$	AVE	S_E (person-sv)	Organs	R_T(/Sv)	G(Person)
IS3	59.9656	110.3883			Gonad	0.004	3569765
HS3	112.9382	207.9034			Breast	0.0025	2231103
ES2	124.0872	228.4272			RBM	0.002	1784882
AS5	176.8864	325.6231			Lung	0.002	1784882
IS2	121.5874	223.8254			Thyroid	0.0005	446220.6
KS5	83.77218	154.2129			Bone	0.0005	446220.6
HS2	151.385	278.6786			Others	0.005	4462206
ES1	286.9602	528.2536			TOTAL	0.0165	14725280
AS1	150.4015	276.8681					
		2334.18	**259.3534**	**892441209**			

Note: N(h/y) = 2629.8 hr, $C_F = 0.7\ Sv\ Gy^{-1}$

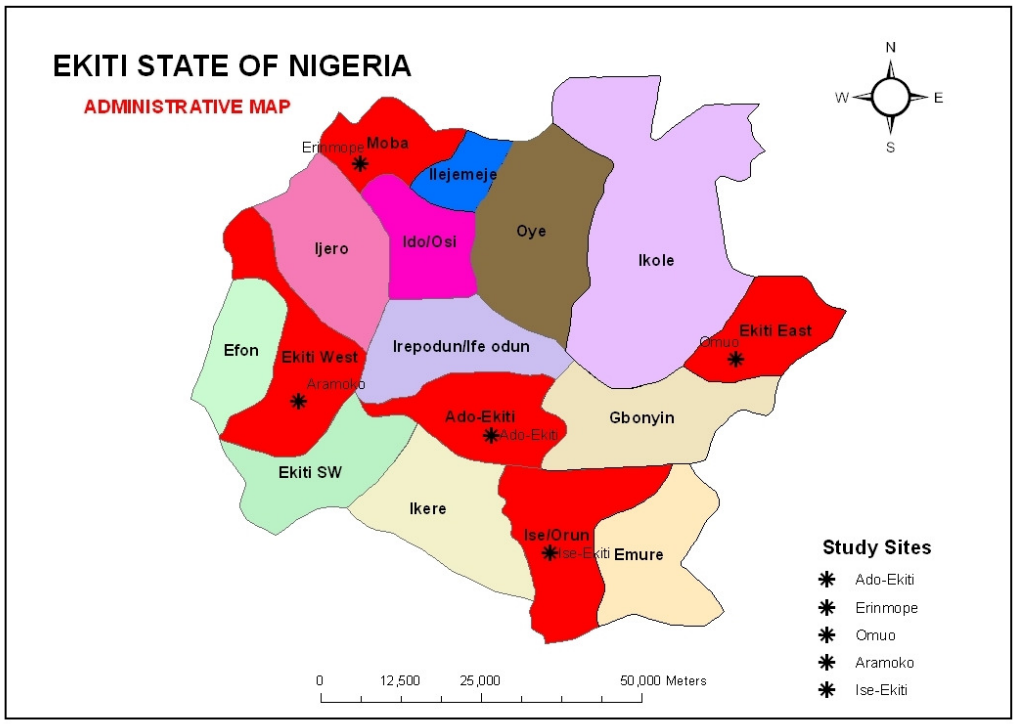

Fig. 2. Ekiti state map showing the sample location

Table 5. Absorbed dose and health detriment from Ekiti state soil samples

Sample location	AB DOSE nGy/h	$H_E(\mu^{Svy^{-1}})$	AVE	S_E (person-sv)	Organs	R_T(/Sv)	G(Person)
OS3	116.9459	215.281			Gonad	0.004	3041993
TS3	320.4145	589.8382			Breast	0.0025	1901246
SS1	146.8262	270.2865			RBM	0.002	1520996
TS1	138.4109	254.7951			Lung	0.002	1520996
SS3	168.2887	309.7959			Thyroid	0.0005	380249.1
OS2	115.3212	212.2902			Bone	0.0005	380249.1
QS2	290.9073	535.5196			Others	0.005	3802491
MS5	89.0747	163.9741			TOTAL	0.0165	12548221
		2551.781	318.9726	760498247			

Note: N(h/y) = 2629.8 hr, $C_F = 0.7\ Sv\ Gy^{-1}$

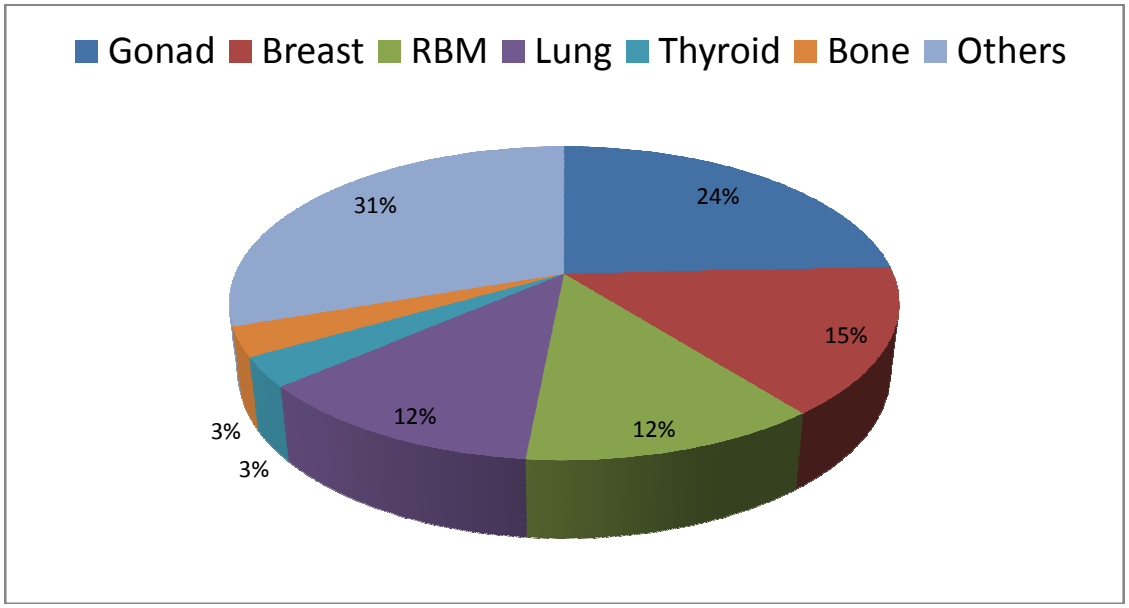

Fig. 3. Percentage distribution of health detriment from the soil of Ondo state to different organs of the body

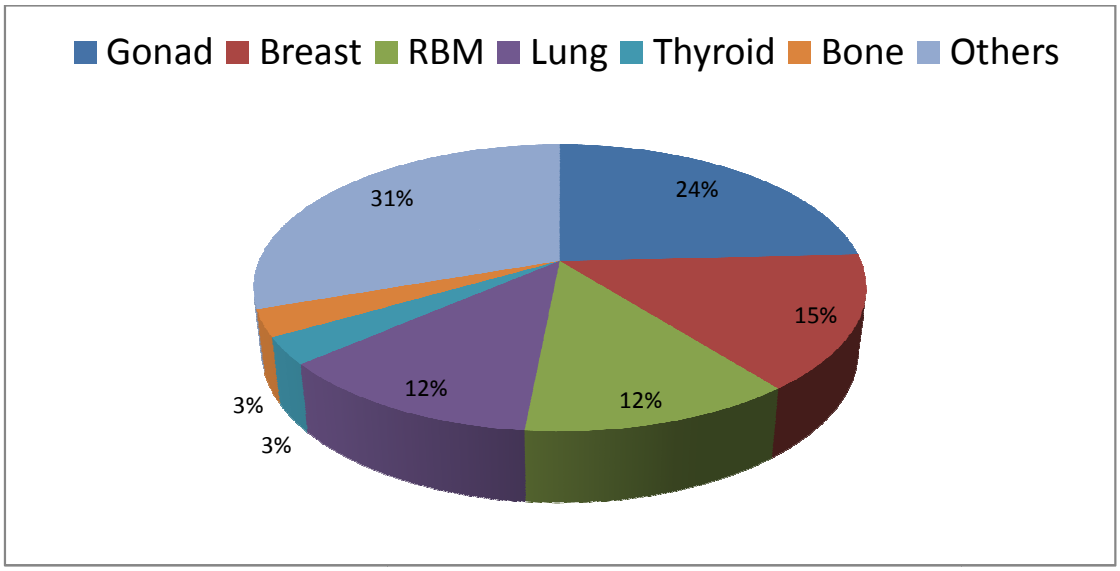

Fig. 4. Percentage distribution of health detriment from the soil of Ekiti state to different organs of the body

RBM= Red Bone Marrow

4. 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 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]. This was attributed to excessive use of potassium-rich phosphate fertilizers in agricultural practices, industrial development and local geology across the studied area. 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 world average of 70 $\mu Sv\ y^{-1}$ recommended by ICRP and below the maximum permissible outdoor effective dose equivalent of 1 mSv y^{-1} for individual member of the public [15]. 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.

ACKNOWLEDGEMENTS

The Authors wish to acknowledge the support of Mr Nicholas Opata of the Ghana Atomic Energy Commission in analysing the samples using gamma ray spectrometry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. United Nations Scientific Committee on Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR Report, New York; 1993.
2. United Nations Scientific Committee on Effects of Atomic Radiation, (UNSCEAR). Report to general assembly, report Vol 1. Sources and Effects of Ionizing Radiation, with Scientific Annexes, United Nations, New York; 2000.
3. McAulay IR, Morgan D. Natural radioactivity in soils in the republic of Ireland, Radiat. Prot. Dosimetry. 1988; 24(1-4):47-49.
4. Jibiri NN, Alausa SK, Farai IP. Radiological hazard indices due to activity concentrations of natural radionuclides in farm soils from two high background radiation areas in Nigeria. Int. J. Low Radiation. 2009;6(2):79-95.
5. Alaamer AS. Assessment of human exposure to natural sources of radiation in soil of Riyadh, Saudi Arabia. Turkish J. Eng. Env. 2008;32:229–234.
6. Boukhenfouf W, Boucenna A. The radioactivity measurements in soils and fertilizers using gamma spectrometry technique. Journal of Environmental Radioactivity; 2011.
DOI: 10.1016/j.jenvrad
7. Rahaman MA. Recent advances in the study of basement complex of Nigeria. In: Proceedings of First Symposium on the Precambrian Geology of Nigeria. 1988;11-43.
8. National Population Census of Nigeria; 2006.
9. Uosif MAM, El–Taher A, Abbady, Adel GE. Radiological significance of beach sand used for climatotherapy from Safaga, Egypt, Rad. Prot Dosimetry. 2008;1-9.
10. Darko EO, Faanu A. Baseline radioactivity measurements in the vicinity of a gold processing plant. J. Applied Science & Technology. 2007;12(1-2):18-24.
11. Darko EO, Faanu A, Awudu AR, Emi-Reynolds G, Oppon OC, Mensah-Brobbey I, Quansah T, Dapaah K, Addo W. Public Exposure to hazards associated with NORMS in mining and mineral processing activities in Ghana. Final Technical Report of data, IAEA TC Project GHA 9005, Accra; 2008.
12. Kohshi C, Takao I, Hideo S. Terrestrial gamma radiation in Koshi prefecture, Japan. Journal of Health Science. 2001; 47(4):362-372.
13. Saito K, Jacob P. Gamma ray fields in the air due to sources in the ground. Radiat. Protect. Dosim. 1990;58:29-45.
14. Ajayi OS, Ibikunle SB, Ojo TJ. An assessment of natural radioactivity of soils and its external radiological impact in Southwestern Nigeria. Nigerian Journal of Health Physics. 2008;94(6):558-566.
15. International Commission on Radiological Protection ICRP 1991. Recommendations of the International Commission on Radiological Protection New York: Elsevier, ICRP Publication 60, Ann ICRP. 1990;21:1-3.
16. El-Aydarous A. Gamma radioactivity levels and their corresponding external exposure of some soil samples from Taif

governorate, Saudi Arabia. Global Journal of Environmental Research. 2007;1(2):49-53.
17. Beretka J, Matthew PJ. Natural radioactivity of Australian building materials, industrial wastes and by-products. Health Physics. 1985;48:87-95.
18. Trabidou G. Radiological study in radioactive spring areas. Athens, Greece; University of Athens; 2004.
19. United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), Sources and effects of ionizing radiation. New York: United Nations; 1988.
20. Tahir SNA, Jamil K, Zaidi JH, Arif M, Ahmed N, Ahmad SA. Measurement of activity concentrations of naturally occurring radionuclides in soil samples from Punjab province of Pakistan and assessment of radiological hazards. Radiat. Prot. Dosimetry. 2005;113(4):421-427.
21. Tzortzis M, Svoukis E, Tsertos H. Comprehensive study of natural gamma radioactivity levels and associated dose rates from surface soils in Cyprus, Radiat. Prot. Dosimetry. 2004;109:217–224.
22. Saleh IH, Hafez AF, Elanany NH, Motaweh HA, Naim MA. Radiological study on soils, foodstuff and fertilizer in the Alexandra Region. Egypt. Turkish J. Eng. Env. 2007; 31:9–17.
23. Narayana Y, Somashekarappa HM, Karunakara N, Avadhani DN, Mahesh HM, Siddappa K. Natural radioactivity in the soil samples of coastal Karnataka of South India. Health Physics. 2001;80:24-33.
24. Baeza A, Del Rio M, Mir C, Paniagua JM. Natural radioactivity in soils of the province of Caceres Spain. Radiat. Prot. Dosimetry. 1992;45:261-263.
25. Mustapha AO, Patel JP, Rathore IVS. Assessment of human exposure to natural sources of radiation in Kenya, Radiat. Prot. Dosimetry. 1999;82:285–292.
26. Ziqiang P, Yin Y, Mingqiang G. Natural radiation and radioactivity in China, Radiat. Prot. Dosimetry. 1988;24(1-4):29–38.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/19153