Radioactivity of surface soils from Oyo state, South Western Nigeria

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ABSTRACT

Background: The activity concentrations of some radionuclides in soil samples collected from 20 locations in 8 major towns in Oyo State, Southwestern Nigeria have been determined by gamma-ray spectrometry technique. ***Materials and Methods***: The activity concentrations were determined using high-purity germanium (HPGe) detector (Canberra Industries Inc.). The outdoor absorbed dose rates in air at about 1.0 m height were estimated from the activity concentrations and dose rate conversion factors for the radionuclides. The annual outdoor effective dose equivalent rates were also estimated for urban and rural areas of the state using the calculated absorbed dose rates in air. ***Results***: Determined specific activity concentrations of the radionuclides ranged from 1±0.4 Bq kg^{-1} for ^{137}Cs to 1190±30 Bq kg^{-1} for ^{40}K. The estimated outdoor absorbed dose rates in air varied from 52 nGy h^{-1} in Egbeda (a rural area) to 414 nGy h^{-1} in Eruwa (also a rural area). The mean annual outdoor effective dose equivalent for the urban areas in the state was 0.1 mSv y^{-1} while that of rural areas was 0.3 mSv y^{-1} with a standard deviation of 0.02 mSv y^{-1} and 0.3 mSv y^{-1} respectively. The mean for the study area was 0.2 mSv y^{-1}. ***Conclusion***: The mean annual outdoor effective dose values for the urban and rural areas, for the whole study area are higher than the world average annual outdoor terrestrial radiation value of 0.07 mSv y^{-1} reported by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) for individual members of the public.

Keywords: *Soil, natural radioactivity, radiation hazard, Oyo state, dose rates.*

INTRODUCTION

The environment in which man lives contains a natural background ionizing radiation level that is made up of contributions from cosmic ray and terrestrial radioactivity (from natural and man-made sources). The contributions from these components vary with local geology, altitude and geomagnetic latitudes. Activities like gas and oil exploitation as well as mining of solid minerals augment the natural sources. The natural terrestrial component is due to the radioactivity of members of the decay series of ^{238}U and ^{232}Th and the non-series ^{40}K that are present in environmental materials such as different types of rock, soil and the building materials composed of them. Activity concentrations in soil give rise to radionuclide loading in food and fodder crops, which in turn gives rise to internal exposure of humans [1-3].

The man-made terrestrial component is due to the deposition of radioactive fallout ^{137}Cs, ^{237}U, ^{239}Np, and others at any location. This deposition is dependent on latitude, precipitation and topography [4]. Caesium-137 (which was the only one measured in this work and taken as representative of the nuclear weapons tests, accidents/explosions and bomb era) is

absorbed and retained by soil particles as readily as are the natural radionuclides.

Estimated exposure to natural radiation from naturally occurring radionuclides has become environmental concern to the public and national authorities of many countries [5-12] because of its deleterious effects on human health. Therefore tremendous efforts are being made to locate and control the sources of natural radiation where economical interest exists and on which legislation must be applied. It has been reported that natural sources contribute almost 80% of the collective radiation exposure of the world's population [13]. Knowledge of the distribution pattern of both anthropogenic and natural radionuclides is essential in maintaining some sense of control of prevailing radiation levels. The objective of this work therefore, was to measure the activity concentrations of some natural radionuclides as well as fallout ^{137}Cs in surface soil samples collected from selected cities in Oyo State, Southwestern Nigeria with the aim of assessing radiation dose due to their presence in the soil.

Oyo State is one of the largest states in Nigeria. It lies within longitudes 2° 48' and 4° 36' E and latitudes 7° 3' and 9° 13' N with averagely high rainfall of about 1200 – 1350 mm annually.

Relative humidity is between 70% and 90% and temperature is between 27°C and 32°C. Ibadan, which is the state capital, is the largest city in West Africa. The baseline data that will result from this work will certainly be of importance in making estimations of population exposure in the study area.

Table 1. Sampling locations and their coordinates.

Serial Number	Location	Latitude/Longitude
1	Saki	N08^0 41'/E03^0 21'
2	Oyo	N07^0 46'/E03^0 56'
3	Ibadan	N07^0 22'/E03^0 58'
4	Ogbomoso	N08^0 08'/E04^0 15'
5	Fiditi	N07^0 45'/E03^0 53'
6	Egbeda	N07^0 30'/E04^0 01'
7	Igbeti	N08^0 44'/E04^0 08'
8	Eruwa	N07^0 30'/E03^0 30'

MATERIALS AND METHODS

Eight cities were selected in the study area (Oyo state, Nigeria) where surface soil samples were collected at different locations. The cities include Saki and Igbeti in region north; Ogbomoso in region east; Fiditi in region south-east; Eruwa in region south-west and Ibadan and Egbeda in region south of the state (figure 1), the coordinates of the cities are shown in table 1. The locations are characterized by different local geological formations. Ibadan is a very large city, densely populated with about 2 million inhabitants and averagely industrialized. It is generally a low land area with few hills and rocks. Oyo and Ogbomoso are ancient cities of averagely low land.

They are fairly large cities with average population density. Eruwa and Igbeti are rocky cities, not large and of low population density. Other cities like Egbeda, Fiditi and Saki are low lands with low population density.

Sample collection

Soil samples were collected from suitable locations that are free of obstructions like buildings, trees, rocks and not near a road in the cities. At a location, samples were collected from the 4 vertices and the center of a 1-m square land area at a depth of between 5 cm and

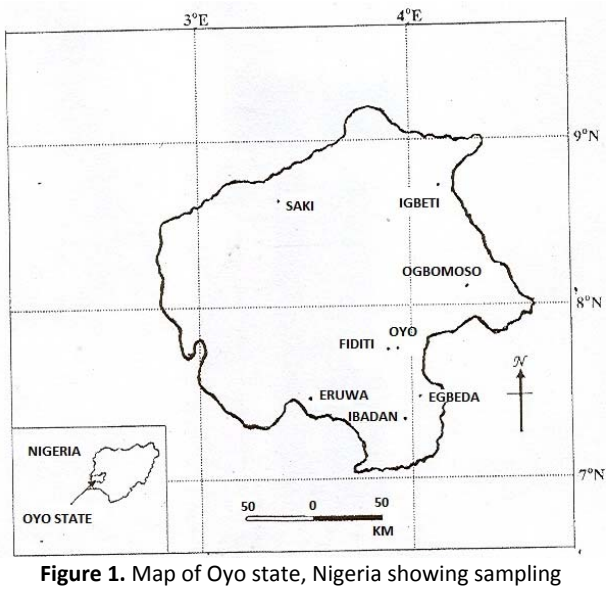

Figure 1. Map of Oyo state, Nigeria showing sampling locations.

10cm. The soil samples were thoroughly mixed together to form a single sample of about 400 g from each location in a town. The soil samples were packed in labeled cellophane bags for preparation for analysis.

Sample preparation

The soil samples were processed according to the recommended procedure by the International Atomic Energy Agency [14]. The samples were first sun-dried, then oven-dried at 110°C to constant weight. They were pulverized and sieved using a 2-mm mesh screen to obtain a fine-texture powder that would present uniform matrix to the detector. About 200 g of each sieved soil sample was poured into plastic container and sealed for about 30 days before analysis. This was to allow time for secular equilibrium between precursor and progeny radionuclide to be reached.

Sample analysis and activity concentration determination

Gamma-ray spectrometry analyses of the soil samples were carried out using high resolution coaxial-type germanium detector manufactured by Canberra Industries Inc. with a relative efficiency of 50% and having a resolution of 2.4 keV at 1.33 MeV of ^{60}Co. The system was set up to cover about 2 MeV photon energy ranges over 4k channels. The detector was properly shielded in lead castles to reduce background radiation. The energy and efficiency calibration of the measuring system was carried out using certified reference standards of known concentration of ^{238}U (RG-U), ^{232}Th (RG-Th) and ^{40}K (RG- K) obtained from the International Atomic Energy Agency (Vienna, Austria). Spectral analyses were performed with the Genie 2k spectrometry software version 2.1 (Canberra Industries Inc.). A library of radionuclides, which contained the energy of the characteristic gamma peaks for each nuclide analyzed and their corresponding emission probabilities was built from the data supplied in the software. Each sample and standard was counted under identical geometry for 86,400 s to achieve minimum counting error. The activity concentration of ^{40}K was measured directly using its own gamma photopeak of 1460.8 keV, that of ^{137}Cs was measured directly by using its own gamma-ray photopeak at 661.7 keV while that of ^{210}Pb was also measured directly using its own gamma-ray peak at 46.5 keV. The activity concentration of ^{224}Ra was measured by using the photopeak of its decay product ^{208}Tl at 583.2 keV, that of ^{226}Ra was measured using its own gamma ray photopeak at 186.1 keV (after subtracting the contribution of the gamma emission of ^{235}U at 185.7 keV) and the photopeaks of its decay product ^{214}Pb at 259.2 keV and 352 keV while that ^{232}Th was estimated by using the photopeaks of its decay products ^{228}Ac at 911.2 keV and 969 keV and that of ^{212}Bi at 727.3 keV. While the activity concentration of ^{235}U was measured directly by using its own gamma ray photopeak at 185.7 keV, that of ^{238}U was measured using the photopeaks of its decay products ^{214}Bi at 609.3 keV and 1764.5 keV and ^{234}Th at 92.5 keV. Where more than one decay products were used for the estimation of activity concentration, the estimation of a radionuclide was based on the weighted mean value of its decay products. Specific activity concentration of each radionuclide in soil was expressed in Bq kg^{-1} of dry mass of soil. The activity concentration of ^{224}Ra (half life = 3.6 days) was corrected for the time elapsed since the samples were collected in the field using [15].

$$A(t) = A_o e^{-\lambda t} \qquad (1)$$

where A(t) is the activity after a time t (between sample collection and analysis), A_o is the initial activity (at time t = 0) of ^{224}Ra and λ (=2.2×10^{-6} s^{-1}) is the disintegration constant of ^{224}Ra.

The minimum detectable activity concentration (Bq kg^{-1}) of each radionuclide, at 95% confidence level, was calculated for the measurement system using [16-17].

$$M_{DAC} = \frac{1.64\,\sigma_c}{\varepsilon_D P_\gamma t w_{ds}} \qquad (2)$$

where σ_c is the square root of the number of counts for the background spectrum, ε_D is the efficiency of the detector, P_γ is the emission probability of the gamma decay, t is the counting time (in seconds) and w_{ds} is the of the weight of dried soil sample (in kg). The calculated

minimum detectable activity concentration of ^{40}K, ^{137}Cs, ^{238}U, ^{232}Th, ^{235}U, ^{224}Ra, ^{226}Ra and ^{210}Pb was 0.50 Bq kg^{-1}, 0.06 Bq kg^{-1}, 0.11 Bq kg^{-1}, 0.69 Bq kg^{-1}, 0.44 Bq kg^{-1}, 1.22 Bq kg^{-1}, 1.40 Bq kg^{-1} and 1.22 Bq kg^{-1} respectively.

Calculation of dose rates in air

The risk associated with exposure to ionizing radiation in an environment due to radioactivity in the soil can be evaluated when the soil activity concentration is converted to absorbed gamma dose rates in air. The absorbed dose rate in outdoor air for decay series of ^{238}U and ^{232}Th and the nuclides ^{40}K and ^{137}Cs uniformly distributed in the soil was calculated using the following expression [9].

$$D_a = 0.0421S_K + 0.470S_U + 0.572S_{Th} + 0.156S_{Cs} \quad (3)$$

where D_a is the absorbed dose rate in air (nGy h^{-1}) at 1.0 m average gonadal height above the ground containing gamma emitter, S_K, S_U, S_{Th} and S_{Cs} are the soil specific activity concentrations (Bq kg^{-1}) of ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs respectively. The conversion factors 0.0421, 0.470, 0.572 and 0.156 are given in the units of nGy h^{-1} per Bq kg^{-1}.

Calculation of outdoor effective dose equivalent

In estimating the outdoor effective dose equivalent in any environment, we consider two factors of importance – the conversion factor from Gy h^{-1} to Sv h^{-1} and the outdoor occupancy factor. While the former gives the human dose equivalent (Sv y^{-1}) from the absorbed dose rate in air (Gy h^{-1}), the latter gives the fraction of the time that an individual is exposed to the outdoor radiation. The occupancy factor depends on the living style of the people which is not the same in rural and urban areas. A typical resident in a rural area spends more time outdoor (on the farm, trekking from one place to another, etc) than a typical resident in an urban area (inside motor vehicles, offices, workshops, etc). We used outdoor occupancy factor of 0.2 [6] and 0.3 (about 8h out of 24h of the day) for urban and rural dwellers respectively with the conversion factor of 0.7 Sv Gy^{-1} [6] to calculate the annual outdoor effective dose equivalents in this work given by

$$A_E = D_a O_f T_y C_f \quad (4)$$

where A_E is the annual effective dose (mSv y^{-1}), D_a is absorbed dose rate in air (nGy h^{-1}), O_f is occupancy factor (0.2 for urban areas and 0.3 for rural areas), T_y is number of hours in 1y (24 h × 365.25 d to take care of the leap year) and C_f is the conversion factor (0.7 Sv Gy^{-1}). For the purpose of this study, the rural areas are Fiditi, Egbeda, Igbeti and Eruwa while the urban areas are Ibadan, Oyo, Ogbomoso and Saki.

Calculation of Radium equivalent activity

The calculation of the absorbed dose rates in air assumes a uniform distribution of natural radionuclide in the soils under investigation. In reality, the distribution is hardly uniform. A common radiological index, called the radium equivalent activity, Ra_{eq}, which can be used to assess the real activity level of ^{40}K, ^{226}Ra and ^{232}Th in the soil samples is required. Radium equivalent activity was calculated in this work using equation 5 [18].

$$Ra_{eq} = C_{Ra} + 1.429\ C_{Th} + 0.077\ C_K \quad (5)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq kg-1) of ^{226}Ra, ^{232}Th and ^{40}K respectively in the soil samples.

RESULTS AND DISCUSSION

The result of the gamma-ray spectrometry analysis of the soil samples is presented in table 2. The mean activity concentration of ^{40}K ranged from 86±4 Bq kg^{-1} in Egbeda soil sample to 1190±30 Bq kg^{-1} in Eruwa soil sample, with overall mean of 463 Bq kg^{-1} and standard deviation of 326 Bq kg^{-1}. The activity concentration of ^{40}K is found to be high in Eruwa and Ibadan, but compared well with world wide average value of 420 Bq kg^{-1} [7] in Saki, Oyo and Igbeti. That of ^{238}U ranged from 19±5 Bq kg^{-1} in Egbeda soil sample to 164±20 Bq kg^{-1} in Igbeti soil sample, with a mean of 75 Bq kg^{-1} and standard deviation of 53 Bq kg^{-1}. The activity concentration of ^{238}U is found to be high in Igbeti

and Eruwa and the mean for the study area more than doubled the world wide average value of 33 Bq kg^{-1}. The mean activity concentration of ^{232}Th ranged from 54±4 Bq kg^{-1} in Ibadan soil sample to 502±20 Bq kg^{-1} in Eruwa soil sample with a mean of 137 Bq kg^{-1} and standard deviation of 140 Bq kg^{-1}. The mean value for the study area is found to be about 3 times the world average value of 45 Bq kg^{-1}. The activity concentration of ^{232}Th is found to be higher in Eruwa and Igbeti than at other locations. This may be due to radioactivity placer mineral deposits in the parent rocks from which these soils are derived. The ^{232}Th activity concentration was found to be higher than that of ^{238}U in all samples but one (Igbeti). This may be due to the different chemical behaviour of thorium and uranium in soils or parent rocks from which the soils are derived. The activity concentration ratio Th/U in the soil samples is greater than unity in all except one of the locations. This reflects the tendency of higher association of thorium isotopes in solid state matter and its low geo-chemical mobility.

These results show that elevated activity concentration values in comparison with other parts of the world have occurred for ^{238}U and ^{232}Th in the study area. Compared to the world-wide average activity concentration values of 420, 33 and 45 Bq kg^{-1} [7] for ^{40}K, ^{238}U and ^{232}Th respectively, the mean activity concentration values obtained in this work is about two times and three times higher for ^{238}U and ^{232}Th respectively.

Caesium-137 has extremely low activity concentration in those samples in which its presence was detected. The total ^{137}Cs activity concentration value of 5 Bq kg^{-1} is equivalent to a deposition value of 934 Bq kg^{-1} in the study area. The presence of this radionuclide in these samples is traceable mainly to fallout of nuclear weapon testing, especially in the 1960s.

The mean activity concentration of ^{235}U ranged from 1±0.3 Bq kg^{-1} in Egbeda soil sample to 17±0.3 Bq kg^{-1} in Igbeti soil sample with a mean of 7 Bq kg^{-1} and standard deviation of 6 Bq kg^{-1}. The activity concentration of ^{224}Ra varied from 21±8 Bq kg^{-1} in Saki to 82±8 Bq kg^{-1} in Igbeti with a mean of 40 Bq kg^{-1} and a standard deviation of 22 Bq kg^{-1} for the study area. The activity concentration of ^{226}Ra ranged from 16±20 Bq kg^{-1} in Igbeti soil sample to 154±20 Bq kg^{-1} in Eruwa soil sample with a mean value of 49 Bq kg^{-1} and a standard deviation of 43 Bq kg^{-1}. This mean activity concentration value of ^{226}Ra obtained in this work was higher than the 9.83 Bq kg^{-1} obtained by Isinkaye [19]for bituminous soil in Agbabu southwest Nigeria; the 26.2 Bq kg^{-1} obtained by Shiva Prasad *et al.* [20]for the soils of Bangalore region in India but much lower than the 216.9 Bq kg^{-1} obtained by Jibiri *et al.* [3] for Bitsichi soils in Plateau State, Nigeria. The activity concentration of ^{210}Pb varied from 23 Bq kg^{-1} in Ibadan soil sample to 690 Bq kg^{-1} in Igbeti soil sample with a mean of 173 Bq kg^{-1} and a standard deviation of 217 Bq kg^{-1}. It should be noted that maximum activity concentration was recorded for four (^{40}K, ^{137}Cs, ^{226}Ra and ^{232}Th) out of the eight radionuclides selected in these soil samples in Eruwa soil sample while minimum activity concentration value was obtained for ^{40}K, ^{238}U and ^{235}U in Egbeda soil sample. We note that the highest activity concentration for all radionuclides was obtained in the rocky rural areas (Eruwa and Igbeti). Both regions are in the rural area group. Table 2 shows that ^{40}K accounted for the largest contribution to the total specific activity concentration in all soil samples. This may be attributed to the presence of silica in the soil parent Precambrian metamorphic rock underlying the territory and the use of phosphate fertilizer by farmers in the areas [11, 21].

The results of the calculation of Ra_{eq} are displayed in table 3. Ra_{eq} values vary from 104 to 810 Bq kg^{-1} with a mean value of 257 Bq kg^{-1} and a standard deviation of 231 Bq kg^{-1}. The mean value is lower than the permissible maximum value of 370 Bq kg^{-1} [6]. Only Eruwa showed higher value of more than 20 times the world average value. Since radium equivalent activity value of 370 Bq kg^{-1} corresponds to an effective dose of 1.0 mSv [18], the obtained mean Ra_{eq} value of 257 Bq kg^{-1} gives an annual effective dose of about 0.7 mSv to the general population of the study area.

Table 2. Activity concentrations of radionuclides ($Bqkg^{-1}$) in soil samples.

Location	N	Range	^{40}K	^{137}Cs	^{238}U	^{232}Th	^{235}U	^{224}Ra	^{226}Ra	^{210}Pb	Th/U
Urban areas											
Saki	5	Min	456	ND	32	70	3	10	9	71	
		Max	510	ND	72	125	4	34	80	179	
		Mean ± SD	480 ± 20	ND	58 ± 20	100 ± 20	4 ± 2	21 ± 8	22 ± 28	127 ± 39	1.7
Oyo	5	Min	455	1	49	74	3	21	41	121	
		Max	489	1	81	95	4	39	61	251	
		Mean ± SD	471 ± 20	1 ± 0.3	66 ± 7	83 ± 8	3 ± 0.4	29 ± 7	51 ± 7	187 ± 52	1.3
Ibadan	5	Min	591	ND	21	48	5	ND	18	16	
		Max	630	ND	33	58	6	ND	36	34	
		Mean ± SD	619 ± 20	ND	26 ± 5	54 ± 4	5 ± 1	ND	26 ± 7	23 ± 6	2.1
Oghomoso	5	Min	230	1	38	103	10	32	13	50	
		Max	273	1	66	86	8	49	71	142	
		Mean ± SD	260 ± 11	1 ± 0.4	58 ± 20	95 ± 7	9 ± 1	36 ± 7	43 ± 36	98 ± 40	1.6
Range			260-619	1-1	26-66	54-100	3-9	21-36	22-51	23-187	1.3-2.1
Mean			458	1	52	83	5	29	36	109	1.7
SD			±100	±0.1	±20	±20	±2	±6	±10	±60	±0.3
SEM			64	0.1	8	9	1	3	6	30	0.2
Rural Areas											
Fiditi	5	Min	112	ND	36	81	3	20	51	10	
		Max	142	ND	63	65	4	41	67	82	
		Mean ± SD	6	ND	48 ± 9	71 ± 6	4 ± 0.3	32 ± 7	59 ± 5	47 ± 30	1.5
Egdeda	5	Min	82	1	11	61	1	ND	13	20	
		Max	90	1	29	76	1	ND	23	66	
		Mean ± SD	86 ± 4	1 ± 0.3	19 ± 5	68 ± 5	1 ± 0.3	ND	17 ± 5	41 ± 20	3.6
Igbeti	3	Min	455	1	141	113	16	70	6	580	
		Max	490	1	181	135	17	92	59	720	
		Mean ± SD	473 ± 20	1 ± 0.3	164 ± 20	124 ± 7	17 ± 0.3	82 ± 8	16 ± 20	689 ± 60	0.8
Eruwa	5	Min	1110	1	142	481	13	ND	150	ND	
		Max	1200	2	180	530	21	ND	190	ND	
		Mean ± SD	1190 ± 30	1 ± 0.7	162 ± 20	502 ± 20	16 ± 3	ND	154 ± 20	ND	3.1
Range			1110-1190	1-1	19-163	71-502	1-17	32-82	16-154	41-689	0.8-3.6
Mean			467	1	98	192	9	57	61	259	2.2
SD			± 400	± 0.1	± 70	± 200	± 7	± 30	± 60	± 300	± 1.2
SEM			222	0.1	33	90	4	18	28	176	0.6
General Study Area											
Range			85-1190	1-1	19-164	71-502	1-17	21-82	16-154	23-689	0.8-3.6
Mean			463	1	75	137	7	40	49	173	2.0
SD			± 300	± 0.2	± 50	± 100	± 6	± 20	± 40	± 200	0.9
SEM			115	0.1	18	49	2	10	15	82	0.1

ND = No Determination
SD = Standard Deviation
SEM = Standard Error of the Mean

We present the absorbed dose rates (nGy h^{-1}) at 1.0 m average gonadal height above the surface of the ground containing gamma emitters and annual outdoor effective dose rates (mSv y^{-1}) values in table 4. The absorbed dose rate varied from 52 nGy h^{-1} in Egbeda (a rural area) to 414 nGy h^{-1} in Eruwa (another rural area) with a mean value of 133 nGy h^{-1} and a standard deviation of 111 nGy h^{-1}. This range is much higher than the range 30 to 70 nGy h^{-1} of absorbed dose rate given by UNSCEAR [6] and the mean is about two times the worldwide average value of 59 nGy h^{-1} [7] for areas of normal background radiation. The mean absorbed dose rate for the urban and rural areas is 91 nGy h^{-1} and 176 nGy h^{-1} respectively. The standard deviation from the mean is 13 nGy h^{-1} and 145 nGy h^{-1} for urban and rural areas respectively. These values represent the spread in the absorbed dose rate at the different locations in the study area.

The annual effective dose equivalent varied from 0.1 mSv y^{-1} in Ibadan to 0.8 mSv y^{-1} in Eruwa. The mean annual effective dose equivalent for the whole territory studied is 0.2 mSv y^{-1} while the standard deviation is 0.2 mSv y^{-1}. The mean for urban and rural areas is 0.1 mSv y^{-1} and 0.3 mSv y^{-1} respectively, and the standard deviation is 0.02 mSv y^{-1} and 0.3 mSv y^{-1} respectively. The annual effective dose equivalent in all of the 8 cities studied is higher than the global average outdoor terrestrial radiation value of 0.07 mSv y^{-1} reported by UNSCEAR [7] for individual members of the public. The annual effective dose equivalent in Ibadan and Egbeda compared well with the worldwide average value but that in Eruwa and Igbeti was more than ten times and four times respectively the worldwide average value.

Table 3. Radium equivalent activity Ra_{eq} (Bq kg^{-1}).

Location	Ra_{eq} (Bq kg^{-1})
Saki	201
Oyo	184
Ibadan	125
Ogbomoso	192
Fiditi	143
Egbeda	104
Igbeti	296
Eruwa	810
Range	104-810
Mean	257
SD	231

Table 4. Absorbed dose rate in air and annual outdoor effective dose rates at different locations in the study area due to terrestrial radiation.

Location	Absorbed Dose (nGy h^{-1})	Annual Effective Dose (mSv y^{-1})
Urban Areas		
Saki	105	0.1
Oyo	98	0.1
Ibadan	69	0.1
Ogbomoso	93	0.1
Range	69-105	0.1-0.1
Mean	91	0.1
Standard Deviation	± 10	± 0.02
Rural Areas		
Fiditi	69	0.1
Egbeda	52	0.1
Igbeti	168	0.3
Eruwa	414	0.8
Range	52-414	0.1-0.8
Mean	176	0.3
Standard Deviation	± 100	± 0.3
General Study Area		
Range	52-414	0.1-0.8
Mean	133	0.2
Standard Deviation	± 111	± 0.2
SEM	39	0.1

SEM = Standard Error of the Mean

CONCLUSION

The results of this study showed that Igbeti and Eruwa soils contain the highest level of natural radioactivity while Egbeda soil contains the lowest level. The study showed that the health burden due to natural background radiation from soils on the inhabitant of the area of study is generally low and carried insignificant radiation hazard except for two locations - Igbeti and Eruwa.

REFERENCES

1. IUR (1989) The 11th report of the working group on soil-to-plant transfer factors. *International Union of Radioecologists, The Netherlands pp, 22-26*.
2. Badran HM, Sharshaar T, Elnmimer T (2003) Levels of ^{137}Cs and ^{40}K in edible parts of some vegetables consumed in Egypt. *J Environ Radioact,* ***67:****181-190*.
3. Jibiri NN, Farai IP, Alausa SK (2008) Activity concentrations of ^{226}Ra, ^{228}Th and ^{40}K in different food crops from a high background radiation area in Bitsichi, Jos Plateau Nigeria. *Radiat Environ Biophys, DOI 10.1007/s00411-006-0085-9*.
4. Krstic D, Nikezic D, Stevanovic N, Jelic M (2004) Vertical profile of ^{137}Cs in soil. *Appl Radiat Isot,* ***61:****1487-1492.*
5. Kitto MD, Fielman EM, Hartt GM, Gillen EA, Semkov TM, Pareckh PP, Bari A (2006) Long-term monitoring of radioactivity in surface air and deposition in New York state. *Health Phys,* ***90:****3 1-37*.
6. UNSCEAR (1988) United Nations Scientific Committee on Effects of Atomic Radiation. Sources and effects of ionizing radiation. New York: UN.
7. UNSCEAR (2000) United Nations Scientific Committee on Effects of Atomic Radiation. Report to the General Assembly, Report Vol I. Sources and Effects of Ionizing Radiation
8. Babalola IA and Oresegun MO (1993) The environmental gamma radiation level of Jos Nigeria. *Nig Journ Sci,* ***27:****263-268*.
9. Markkanen M (1995) Radiation dose assessments for materials with elevated natural radioactivity. *Report STUK-B-STO 32. Radiation and Nuclear Safety Authority – STUK.*
10. Arvela H, Hyvonen H, Lemmela H, Castren O (1995) Indoor and outdoor gamma radiation in Finland. *Radiat Prot Dosim,* ***59(1):****25-32*.
11. Ajayi OS(2000) Environmental gamma radiation indoors at Akure, Southwestern Nigeria. *J Environ Radioact,* ***50:****263-266*.
12. Ogunleye PO, Mayaki MS, Amapu IY (2002) Radioactivity and heavy metal composition of Nigerian phosphate rocks: possible environmental implications. *J Environ Radioact,* ***62:****39-48.*
13. UNSCEAR (1993) United Nations Scientific Committee on Effects of Atomic Radiation. Sources and effects of ionizing radiation. Report to the General Assembly, with Scientific . Annexes New York: UN.
14. IAEA (1989) Measurement of radionuclides in food and the environment. Vienna: *IAEA.Technical Report Series No. 295.*
15. Shepherd W and Shepherd DW (1999) Energy studies. Imperial College Press. London. Pp. 164.
16. Currie LA (1968). Limits for qualitative detection and quantitative determination.*Anal Chem,* ***40:****586-593*.
17. Turhan S, Gunduz L, (2008). Determination of specific activity of ^{226}Ra, ^{232}Th and ^{40}K for assessment of radiation hazards from Turkish pumice samples. *J Environ Radiat,* ***99:****332-342*.
18. Tahir SNA, Jamil K, Zaidi JM, Arif M, Ahmed N, Ahmed SA (2005) Measurements of activity contents of naturally occurring radionuclides in soil samples from Punjab province of Pakistan and assessment of radiological hazards. *Radiat Prot Dosim,* ***113:*** *421-427*.
19. Isinkaye MO (2008) Radiometric assessment of natural radioactivity levels of bituminous soil in Agbabu, southwest Nigeria. *Radiat Meas* ***43:****125-128*.
20. Shiva Prasad NG, Nagaiah N, Ashok GV, Karanukara N (2008) Concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soils of Bangalore Region, India. *Health Phys,* ***94(3):*** *264-271*.
21. Khan K, Khan HM, Tufail M, Khatibeh AJAH., Ahmad N (1998) Radiometric analysis of Hazara phosphate rock and fertilizers in Pakistan. *J Environ Radioact,* ***38(1):****77-84*.