Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 7 (11): 1534-1537, 2007
ISSN 1812-5654

Terrestrial Gamma Radiation and the Radiological Implication in South Western Nigeria

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Abstract: Gamma radiation level due to primeval radionuclides in surface soil in some South-Western cities in Nigeria has been carried out using a 7.6×7.6 cm NaI (Tl) detector. The mean absorbed dose rate and annual effective dose were evaluated from the measurement of ^{40}K; ^{238}U; ^{232}Th. The absorbed dose rates values ranged from 18.6 to 68.4 with a mean (±SD) value of 44.2±15.9 nGy h^{-1} in Lagos area; 26.8 to 145.6 with a mean value of 72.9±35.6 nGy h^{-1} in Ibadan area and 30.9 to 98.9 with a mean value of 64.2±26.5 nGy h^{-1} in Akure area. The mean effective dose for these locations is 56.5, 93.3 and 82.2 μSv $year^{-1}$, respectively. The mean value for the region is 0.8 mSv $year^{-1}$, which is less than the 1 mSv $year^{-1}$ recommended for normal environment by UNSCEAR.

Key words: Soil, dose, effective, collective, ^{40}K, ^{238}U, ^{232}Th, exposure

INTRODUCTION

The contribution of natural radionuclides in surface soil to the overall background radiation burden of an environment has been established (Unscear, 1988). Gamma radiation is present in the terrestrial materials such like rocks, soil, food crops and local vegetation due to the decay processes of some naturally occurring radionuclides in the environment (Ajayi *et al.*, 1996; Arogunjo *et al.*, 2004a; Ajayi and Kuforiji, 2001; Abbady, 2004). The distribution and availability of these radionuclides depend mainly on geological processes, atmospheric conditions and human activities (Wollenberg and Smith, 1990). Apart from the natural sources of radionuclides, anthropogenic sources have been a major source of concern for radioprotection programmes. Various environmental phenomena like environmental weapon test, researches in medical application of nuclides, mining and industrial applications of radionuclide prone minerals have been known to increase the radiation burden of the environment. The possible radon built up in indoor environment especially when radionuclide enriched soil is used as building materials call for detailed environment monitoring. In many parts of Nigeria, the major materials used for building in both urban and rural locations are made from the soil (Ademola and Farai, 2006) and most urban dwellers spend almost 78% of the their time indoor (Arogunjo *et al.*, 2004b). In order to assess level of contamination from various sources, the baseline radionuclides burden must be known. This study provides a reference base of absorbed dose from natural sources in some cities in the South-West of Nigeria as a baseline in case of any gross contamination of the area in the future and for proper and effective radioactive waste disposal management and control.

MATERIALS AND METHODS

Activity concentration measurement: Thirty soils samples (0-5 cm) were collected within Lagos, Ibadan and Akure areas. The samples were air dried under a laboratory with mean temperature of 27°C and mean relative humidity of about 70% for three days. The dry samples were homogenized and sieved through a 2.00 mm mesh. The samples were carefully weighed and sealed in a plastic container for a 40 day ingrowth's period to avoid radon diffusion and ensure secular equilibrium between ^{238}U, ^{232}Th and their respective progenies. The samples were then analyzed in the laboratory with a 7.6×7.6 cm NaI (TL) detector with a resolution of about 8.0% at 0.662 MeV gamma ray energy from ^{137}Cs. The detector was placed inside a lead shielded counting chamber and was coupled to a Canberra Series 10 plus miltichannel analyser. The gamma energies of 1.46, 1.7 and 2.62 MeV were used in the analysis of ^{40}K, ^{238}U and ^{232}Th, respectively. The peaks obtained were reasonably strong and clean, the peak area A for the radionuclides was computed using the algorithm of the MCA, which subtracts the background spectrum from the total peak counts. The activity concentrations, A_c (Bq kg^{-1}) of the radionuclides in the samples were estimated using the relation:

$$A_c = \frac{A}{\varepsilon P_r M} \qquad (1)$$

where A is in counts per second, ε is the detector efficiency for a particular gamma energy, P_r is the absolute transition probability of gamma decay and M is the mass (kg) of the sample. The calibration of the activity concentration was achieved by counting a mixed gamma standard soil of known activities of the radionuclides of interest under the same experimental conditions used for the soil samples. The spectra were collected for 36000 sec and the activity concentrations due to the radionuclides of interest in the soil samples were calculated from the concentration ratio between the standard and the sample using Eq. 1.

The activity concentration was converted to the absorbed dose rate (D) in air using the Beck *et al*. (1972) formula:

$$D\ (\text{nGy h}^{-1}) = \{0.051(a/m)_u + 0.076(a/m)_{th} + 0.0048\,(a/m)_k\} \times 8.73 \quad (2)$$

where $(a/m)_I$ are the activity of natural radionuclides at 1.0 m above the ground.

The mean annual effective dose to man (H) was calculated using the conversion factor of 0.7 SvG year^{-1} for dose rates in air and an outdoor occupancy ratio of 0.2 (Unscear, 1988)

RESULTS AND DISCUSSION

The activity of naturally occurring radionuclides, the estimated absorbed dose rates and the annual effective dose for thirty locations (Table 1) in the South-western region of Nigeria are presented in Table 2-4. The Fig. 1 shows the distribution of effective dose in the region. ^{40}K activity range from 16.3 Bq kg^{-1} at Ikeja to 319.0 Bq kg^{-1} at Oshodi; ^{238}U activity ranged from 4.9 Bq kg^{-1} at Festac to 37.7 Bq kg^{-1} at Ikeja and ^{232}Th activity ranged from 17.5 Bq kg^{-1} at Festac to 76.7 Bq kg^{-1}at Ikeja in Lagos area. ^{40}K activity ranged from 60.0 Bq kg^{-1} at Government house to 1877.9 Bq kg^{-1} at Yidi; ^{238}U activity ranged from 9.6 Bq kg^{-1} at Eleiyele to 76.9 Bq kg^{-1} at Government house and ^{232}Th activity ranged from 26.7 Bq kg^{-1} at New Gbagi market to 134.9 Bq kg^{-1} at Government house in Ibadan area. ^{40}K activity ranged from 175.4 Bq kg^{-1} at Oke Aro Tuntun to 606.3 Bq kg^{-1} at Shagari Village; ^{238}U activity ranged from 12.1 Bq kg^{-1} at Okuta Elerinla to 56.8 Bq kg^{-1} at Oja Oba Area and ^{232}Th activity ranged from 18.3 Bq kg^{-1} at both Ala and Fanibi to 102.6 Bq kg^{-1} at Oshinle in Akure area. The thorium/uranium ratio ranged from 0.5 at Oja Oba in Akure area to 7.8 at Ojota in Lagos area. The activity concentrations presented in the 2nd, 3rd and 4th columns in Table 2-4 were converted to the absorbed dose in air (column 5 of Table 2-4) using Eq. 2. The values in Lagos, Ibadan and Akure ranged from 18.6 to 68.4 μGy h^{-1} with mean of 44.2±15.9 μGy h^{-1}, 26.8 to 145.6 μGy h^{-1} with mean of 72.9±35.6 μGy h^{-1} and 30.9 to 98.9 μGy h^{-1} with mean of 64.2±26.5 μGy h^{-1},

Table 1: Locations where samples were taken in the region

No.	Location	No.	Location	No.	Location
1	Oshodi	11	Orita Challenge	21	NTC
2	Apapa	12	Ijebu Ode Road	22	Children Home School
3	Ikeja	13	Express Road	23	Adeoyo Hospital
4	Iyana Ipaja	14	Yidi	24	Oja Oba Area
5	Ifako	15	New Gbagi Mkt	25	Oshinle
6	Mushin	16	Oke Imole Area	26	Shagari Village
7	Ikorodu	17	U.I. 2nd Gate	27	Okuta Elerinla
8	Festac	18	Eleiyele	28	Ala Quarters
9	Obalende	19	Govt. House	29	Fanibi
10	Ojota	20	UTC Stores	30	Oke Aro Titun

Table 2: The mean activities concentrations, total absorbed dose rates in air and effective dose in Lagos area

	^{40}K	^{238}U	^{232}Th		Absorbed Dose	Effective Dose
Location	(Bq kg^{-1})			Th/U	(nGy h^{-1})	(μSv year^{-1})
1	319.0	13.7	53.3	3.89	54.83	70.18
2	233.9	10.2	31.8	3.11	35.44	45.36
3	16.3	37.7	76.7	2.03	68.35	87.49
4	214.4	15.3	64.9	4.24	58.85	75.33
5	194.1	37.2	18.7	0.50	37.10	47.49
6	113.5	8.1	21.7	2.67	22.75	29.13
7	121.6	31.4	54.7	1.74	55.36	70.87
8	115.5	4.9	17.5	3.57	18.63	23.84
9	208.6	11.0	46.7	4.24	44.62	57.11
10	194.6	6.7	52.0	7.76	45.63	58.41
Mean	173.15	17.62	43.80	3.38	44.16	56.52
SD	83.64	12.77	20.45	1.95	15.91	20.36

Table 3: The mean activities concentrations, total absorbed dose rates in air and effective dose in Ibadan area

	^{40}K	^{238}U	^{232}Th		Absorbed Dose	Effective Dose
Location	(Bq kg^{-1})			Th/U	(nGy h^{-1})	(μSv year^{-1})
11	169.3	24.4	60.6	2.48	58.16	74.451
12	163.5	10.1	65.2	6.45	54.60	69.89
13	564.0	13.9	61.6	4.43	70.69	90.48
14	1877.9	55.4	63.7	1.14	145.62	186.39
15	304.9	33.4	26.7	0.79	45.36	58.06
16	209.2	22.0	62.1	2.82	59.76	76.49
17	809.8	28.1	112.7	4.01	121.21	155.16
18	96.3	9.6	27.9	2.90	26.82	34.33
19	60.0	76.9	134.9	1.75	126.25	161.60
20	284.4	12.3	81.2	6.60	71.26	91.22
21	46.1	11.7	90.4	7.72	67.11	85.91
22	198.7	24.3	40.9	1.68	46.28	59.24
23	661.1	18.0	27.5	1.52	53.96	69.07
Mean	418.86	26.16	65.80	3.10	72.85	93.25
SD	498.67	19.70	32.82	2.36	35.57	45.53

Table 4: The mean activities concentrations, total absorbed dose rates in air and effective dose in Akure area

	^{40}K	^{238}U	^{232}Th		Absorbed Dose	Effective Dose
Location	(Bq kg^{-1})			Th/U	(nGy h^{-1})	(μSv year^{-1})
24	205.5	56.8	29.7	0.52	53.60	68.61
25	437.0	28.1	102.6	3.65	98.89	126.58
26	606.3	25.9	81.3	3.13	90.87	116.32
27	228.8	12.1	86.4	7.14	72.29	92.54
28	248.6	23.5	18.3	0.77	33.02	42.26
29	198.3	23.5	18.3	0.77	30.91	39.57
30	175.4	26.8	76.0	2.83	69.70	89.22
Mean	299.98	28.10	58.94	2.70	64.18	82.16
SD	160.77	13.71	35.61	2.04	26.46	33.88

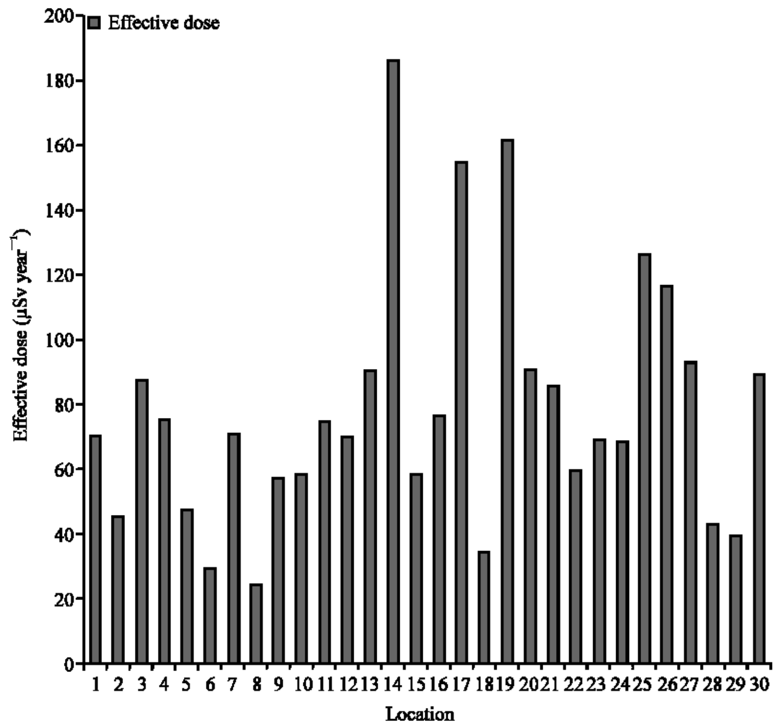

Fig. 1: Variation of Effective dose in the surveyed locations in southwestern Nigeria

respectively and the stated errors are the standard deviation. Using the factor 0.7 $SvGy^{-1}$ recommended by UNSCEAR and the outdoor occupancy factor of 0.2 recommended for the world average, the annual outdoor effective dose in Lagos, Ibadan and Akure ranged from 23.8 to 87.5 μSv $year^{-1}$ with mean of 56.5±20.4, 34.3 to 186.4 μSv $year^{-1}$ with mean of 93.3±45.5 and 39.6 to 126.6 μSv $year^{-1}$ with mean of 82.2±33.9 μSv $year^{-1}$, respectively.

The activity concentration of natural radionuclide in the region is in agreement with the global trend on the distribution of natural radionuclide in the soil. The variation observed in the different locations is a function of the local geology, which could be attributed to the physical and chemical sorting processes from location to location. Apart from these natural processes, human activities like agricultural practices in which fertilizer are applied to enhance crop yield have been known to contribute to the variation. Phosphate rock is a major raw material for fertilizer production and has been proved to contain varying degree of radionuclides concentrations (Ibrahiem *et al*., 1993; Farai and Ademola, 2001; Jibiri and Farai, 1998; Arogunjo and Farai, 2003). The high values of ^{40}K in some locations might have been due the above reasons. The high activity concentration observed at Ibadan, when compared to that obtained for Lagos is due to the fact that the cities are located in different geological zones. Extrusive granites rocks characterize the geology of Ibadan while Lagos is situated on a sedimentary basin. The result is in trend with the result of Wollenberg and Smith (1990) that there is a relationship between radioactivity levels and local geology of an area.

Thorium/uranium ratio in most locations is greater than unity, which could be attributed to the difference in their solubility under similar chemical conditions. Uranium has been known to form complexes with water, which tends to enhance its solubility when compared with that of thorium. Hence, uranium is expected to percolate to higher depth thereby leaving lower concentration in the surface soil.

CONCLUSION

The absorbed dose and the annual outdoor effective dose for some Cities in the South-western part of Nigeria have been determined. The mean value from the data for these Cities has been taken as the estimated value for the region. The estimated value for the absorbed dose and the effective dose ranged from 18.6 to 145.6 μGy h^{-1} with a mean of 61.3±30.2 μGy h^{-1} and 23.8 to 186.4 μSv $year^{-1}$ with a mean of 78.4±38.6 μSv $year^{-1}$. The stated mean for the effective dose is about 12% higher than the world average value of 70.0 μSv $year^{-1}$. In spite of the fact that some of the data might have been taken from disturbed locations, especially, location from Ibadan area, this study still provides data helpful for future assessments in case of gross contamination of the area in the future.

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