Radiation Risk Assessment of Soil in Idomi, Cross River State, Nigeria

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ABSTRACT---- ***In this thesis work, the radiation risk from soil samples in Idomi community located at Yakurr Local Government Area of Cross River State, Nigeria was studied. This was because of an earlier study that revealed the presence of high radioactivity in the area. This study aim to determine the background radiation levels, estimate their effective dose, the mean activity concentrations of the radionuclide and the radiological implications of the radioactivity levels in Idomi. Thirty (30) soil samples were collected and analyzed. The baseline average annual outdoor effective dose, mean activity concentration, gamma absorbed dose and radiological hazard index were studied. Results from this study indicate that three (3) radionuclide namely ^{40}K, ^{238}U and ^{232}Th were present in the soil samples analyzed. The mean activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the soil samples were 506.13±9.30, 41.14±3.59 and 84.52±20.88 $Bqkg^{-1}$ respectively. The calculated mean external and internal hazard index was 0.62 and 0.71 respectively. The calculated mean gamma index was 0.86. The Ra_{eq} in the soil samples was 227.34 $Bqkg^{-1}$. The calculated absorbed gamma dose from the sample was 110.31nGy^{-1} and a mean annual outdoor effective dose of 1.35$mSvy^{-1}$. Compared with global average values of 10-200$nGyh^{-1}$, 2.4 $mSvy^{-1}$and Ra_{eq} of 370$BqKg^{-1}$ they can be said to be within the normal range. From this study, the chances of occurrence of health effects from exposure to natural terrestrial gamma radiation in Idomi can be said to be low. This may be possible if the baseline levels obtained from this study can be kept constant by keeping the environment free of radioactive pollution.***

Keywords--- Radiation, Risk, Assessment, Soil, Activity

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1. INTRODUCTION

Human being has been exposed to radiation, 85% of which is natural and 15% artificial (NRPB, 1994). Natural background radiation originates from the terrestrial environment and varies tremendously worldwide and within countries as well (Hendry *et. al*, 2009). About 90% of radiation from the ground are derived from the natural radioactivity originating from the top 15 to 23cm of the ground area with an outcrop of rock density 2.7glc.c or 30 to 45cm area with dry overburden with density of 1.5gl.c (Uwa, 1993). The remaining 10% or less comes from nuclear debris which occurs as a surface layer foliage containment.

The terrestrial component of the natural background radiation is dependent on the compositions of soil, rocks and some building materials which typically contain natural radionuclides Uranium-238 (^{238}u), Thorium-232 (^{232}Th) and Potassium-40(^{40}k). In the last decade plus, a lot of studies on soil radioactivity has been going on worldwide.

Aeoradiometric studies using a scintillometer of Ugep area in Cross River State, Nigeria shows exposure rates between 1.3 to 4.5 µR/h. (Uwah,1993). Idomi community is located within this area and recorded the highest exposure value. The aeroradiometric study shows that the area recorded the highest exposure rate (Ekwueme, 1990). This area is characterized by the upper Proterozoic garnetiferous mica schist intruded by a N-S foliated Pan- Africa porphyritic biotite granite body of older granite series (Ekwueme, 1995).

The presence of primordial radionuclides in granite is a potential source of terrestrial radioactivity in the environment. Hence, this study aims to establish the background level, activity, radiation hazards and distribution of these primordial radionuclides in the soil of Idomi.

2. STUDY AREA

Idomi community lies within Ugep area in Yakurr Local Government Area of Cross River State, Nigeria. It lies within the meridians $8^0 15^{'}$E and 5^0 40'N and 5^0 50'N. Its lithological formation indicates that it is made up of siltstone, sandstone, shale, Marl, Schist and Gneiss. The area covers 15km^2.It is an agrarian community surrounded by other communities with adjoining water bodies and hills.

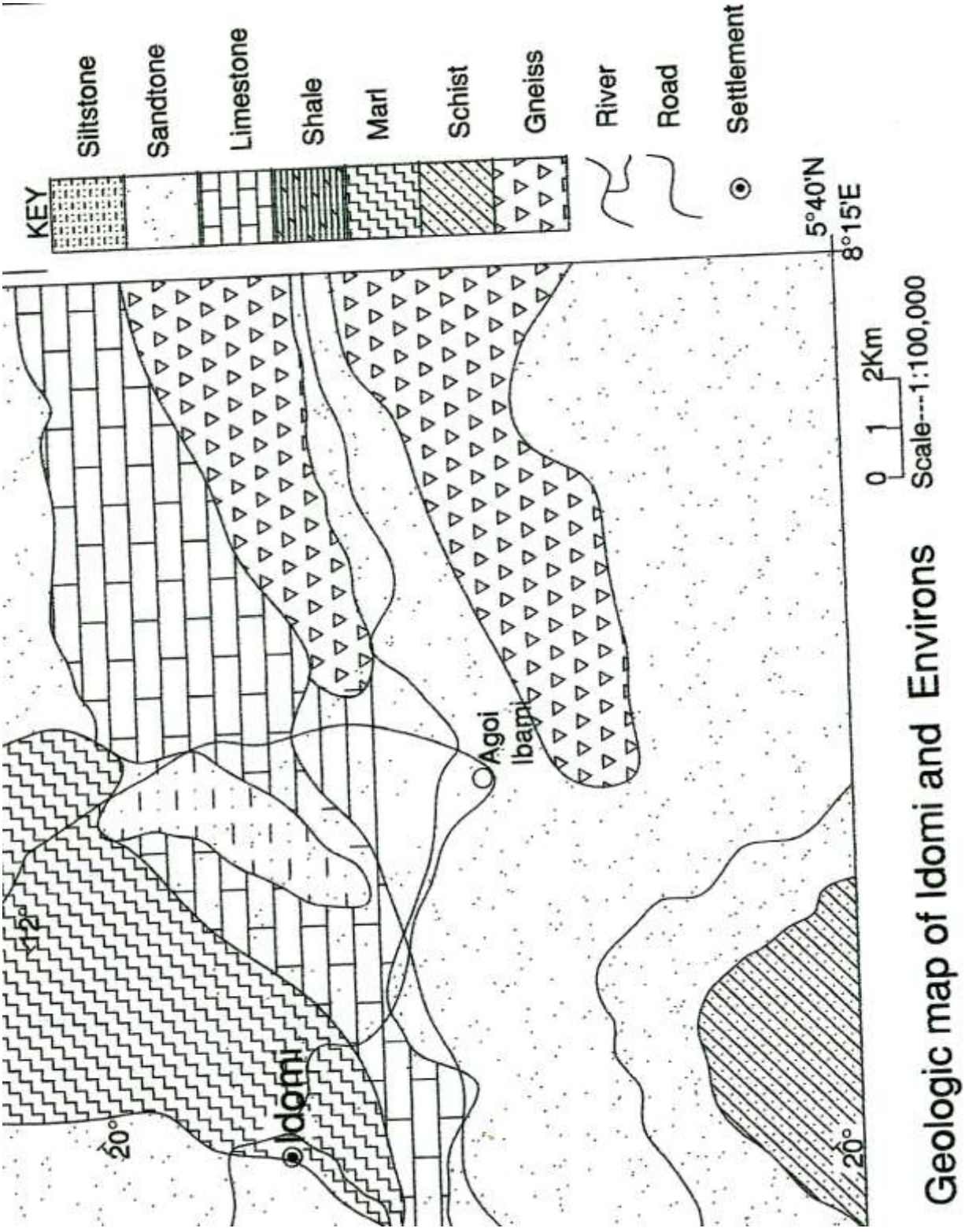

Fig. 1: Map of Idomi and environs with its Lithological formations

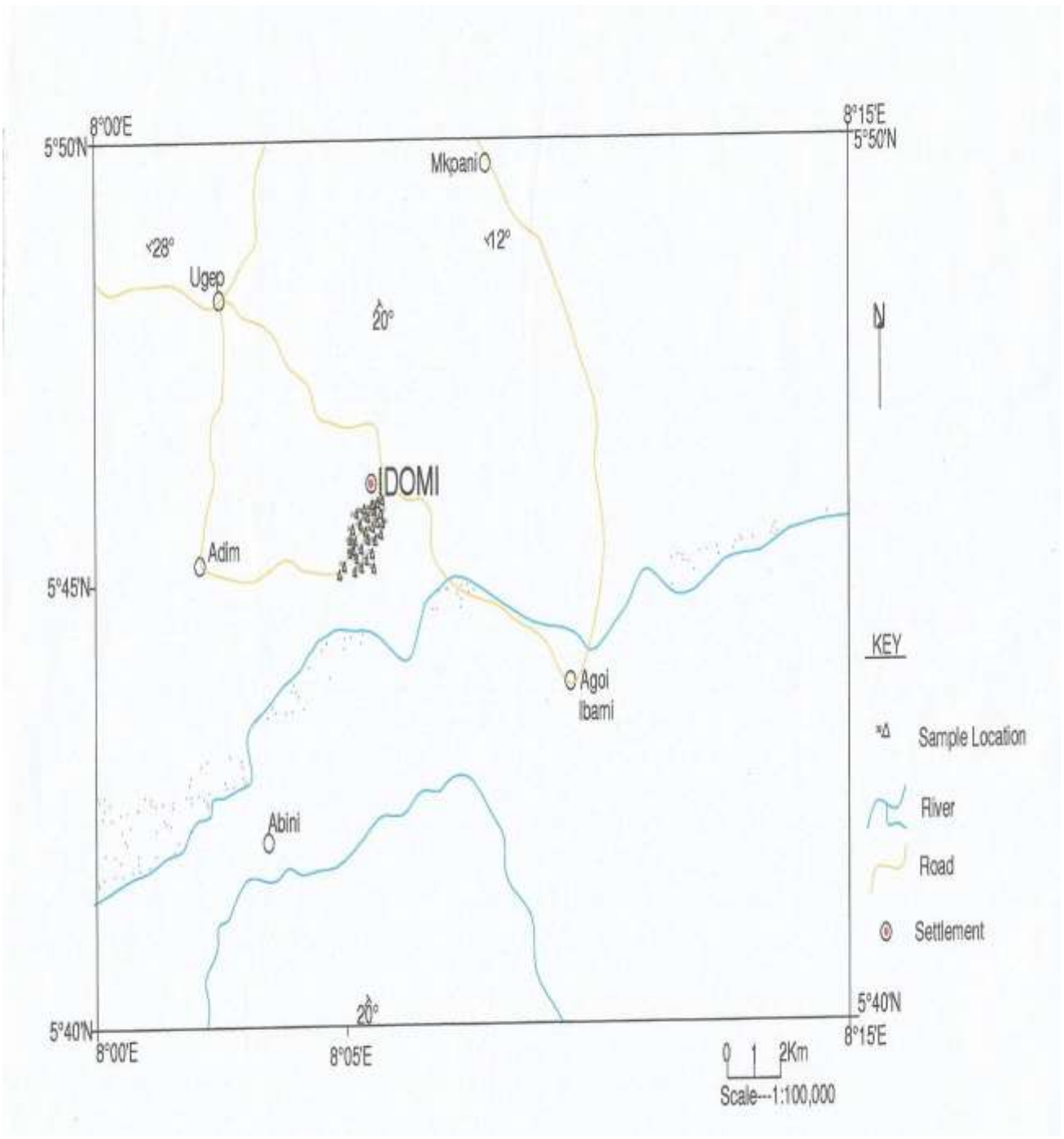

Fig 2: Map of Idomi and Environs showing sample collection positions

Determination of Soil Radioactivity

In order to determine soil radionuclide activity concentration, 30 stations which had different geological structure, were selected for this study (Fig.1). Soil samples were obtained from uncultivated locations that were close to settlements. Open, flat and undisturbed geographical locations which had good water permeability were selected as the sampling points (Fig. 2). Two hundred grams (200g) of soil was taken at 10cm below the topsoil. Foreign bodies were removed and the remaining soil was placed in clean, sealed and labelled bags. The samples were dried at 60 ^{o}C for 48 h, grained, passed through 2 mm sieves and placed in Marinelli type beakers. The samples were kept one month before the analysis at airtight condition to allow secular equilibrium between thorium and radium and their decay products. The system was calibrated using standard mixtures of gamma spectroscopy and was counted for 50000s using a gamma spectrometer. The gamma spectrometry analysis was done at the Centre for Energy and Research Development, Ile- Ife, Nigeria. The detector of the

gamma spectrometer used in this study was 7.6cm x7.6cm Na1 (TI) Crystal located inside a lead castle. Its accessories include a Canberra multichannel analyzer (MCA) and photomultiplier tube.

The activities of the samples were determined using the total net counts under the selected photo peaks, the measured photo peak efficiency, gamma intensity and weight of the samples. After correcting for the background and Compton contribution, the activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs were determined. The ^{238}U and ^{232}Th were calculated assuming secular equilibrium was established with their decay products [238U series: ^{226}Ra (186.0keV) and ^{214}Bi (609.2keV):^{232}Th series: ^{228}Ac (911keV), ^{208}TI (583.1keV).

Radiological Hazard Index

These represent methods to assess the collective effect of the activity mass concentration of ^{40}K, ^{226}Ra and ^{232}Th present in a material in a single quantity.

External Hazard Index-

This is represented by the equation (Beretka and Mathew, 1985; Krieger, 1981).

$$Hex = \frac{Ra_{eq}}{370} = \frac{A_k}{4810} + \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} \quad - \quad - \quad - \quad - \quad (1)$$

Where A_k, A_{Ra} and A_{Th} represent the specific activities in $Bqkg^{-1}$ respectively of ^{40}K, ^{226}Ra and ^{232}Th in the equation. The symbol Ra_{eq} stands for radium equivalent activity in $Bqkg^{-1}$

To qualify for a safe material, therefore,

$$H_{ex} \leq 1$$

(Bereka and Mathew, 1985; Krieger, 1981; Krisiuk *et al*, 1971)

Or $Ra_{eq} \leq 370 Bqkg^{-1}$

$$Ra_{eq} = A_{Ra} + 1.43_{Th} + 0.077_{Ak} \quad - \quad - \quad - \quad - \quad - \quad (2)$$

Internal hazard index-

This is described by (Beretka and Mathew, 1985; Krieger, 1981; Krisivk *et al*, 1971).

$$H_{in} = \frac{A_k}{4810} + \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} \quad - \quad - \quad - \quad - \quad (3)$$

Also, $H_{in} \leq 1$

Gamma Index (Iγ)-

This is another radiation hazard index by European Commission (EC). It is calculated by the following formula (EC, 1999, Cottons, 1990).

$$I\gamma = \frac{AK}{3000} + \frac{ARa}{300} + \frac{ATh}{200} \quad - \quad - \quad - \quad - \quad (4)$$

Iγ is correlated with the annual dose rate due to gamma radiation.

Iγ $\leq$1 corresponds to an annual effective dose less than or equal 1 mSv while Iγ $\leq$0.5 corresponds to an annual effective dose less than or equal 0.3 mSv (EC, 1999; Righi and Bruzzi, 2006). The EC has suggested that building materials that do not increase the annual effective dose of a member of public by 0.3 mSv at the most should be exempted from all restrictions concerning a radioactivity hazard (EC, 1999).On the other hand, doses higher than 1 $mSvy^{-1}$ are allowed only on exceptional cases where materials are used locally.

External dose rate-

The external dose delivered by these radionuclide to the general public at a distance of 1m above the surface was estimated from the measured specific activities of these nuclides by the following relationship (UNSCEAR, 2000). The average value of background dose rate from soil is (5I $nGyh^{-1}$) (UNSCEAR, 2000)

$$D^* = 0.0417_{Ak} + 0.462_{ARa} + 0.604_{ATh}. \quad - \quad - \quad (5)$$

Where D* = Dose rate in $nGyh^{-1}$ at 1m above the ground surface.

Ak, ARa and ATh are the specific activities in $BqKg^{-1}$ of ^{40}K, ^{226}Ra and ^{232}Th respectively. The other radionuclide e.g. ^{137}Cs, ^{90}Sr and those present in the ^{235}U decay series, can be neglected as they contribute very little to the total dose from the environmental background. (Quindos *et al*, 1994; Deworm *et al*, 1998; Singh *et al*, 2005).

Effective Dose Rate -

The absorbed dose rate in air due to measured specific activities of the primary radionuclide in the sample was converted to effective dose rate by the following relationship. (UNSCEAR,2000; Akhtar and Tufail, 2007).

$$E = D^* \times 0 \times C \times 8760 \times 10^{-6} \quad - \quad - \quad - \quad - \quad (6)$$

Where:

E = Effective dose rate ($mSVy^{-1}$)

*D = Absorbed dose rate in air ($nGyh^{-1}$) at 1m above the sample surface

0 = 0.2 (Outdoor occupying factor)

C = 0.7 $SvGy^{-1}$ (conversion factor from the absorbed dose in air to the effective dose received by an adult person). The average background outdoor effective dose rate from soil for an adult person is 0.07 mSv. (UNSCEAR, 2000).

3. RESULTS

Table 1: Counts per second due to background radiation

^{238}U	^{232}Th	^{40}K
0.01572±0.0007	0.03142±0.0008	0.08674±0.0001

Table 2: Mean and standard deviation of the concentration of the radionuclide in soil samples ($Bqkg^{-1}$)

S/n	Sample names/location	K-40	U-238	Th-232
1	S1	525.30±4.82	50.03±4.06	100.12±23.86
2	S2	1033.30±7.05	63.68±4.94	130.46±28.93
3	S3	1222.03±7.88	108.89±7.42	159.48±34.93
4	S4	599.22±5.06	60.20±4.71	171.66±36.74
5	S5	570.13±4.81	54.80±4.40	82.15±20.02
6	S6	440.37±4.25	29.25±2.88	28.33±9.42
7	S7	539.04±102.30	4.46±1.41	13.37±2.33
8	S8	893.33±6.56	37.22±3.34	67.51±17.79
9	S9	743.92±5.65	37.06±3.43	83.08±20.67
10	S10	850.86±6.20	28.50±2.90	26.51±9.30
11	S11	762.00±5.77	37.19±3.40	86.08±20.43
12	S12	1054.54±7.09	33.65±3.18	70.41±17.77
13	S13	975.90±6.90	39.01±3.41	99.73±23.29
14	S14	669.21±5.52	43.16±3.68	111.80±25.53
15	S15	1215.74±7.89	34.08±3.22	60.25±15.88
16	S16	1049.82±7.25	46.11±3.90	132.82±29.17
17	S17	1494.12±9.15	31.26±3.02	114.89±26.07
18	S18	609.44±5.25	49.11±4.19	86.32±20.91
19	S19	1178.00±7.74	24.62±2.62	93.34±21.91
20	S20	1026.23±7.22	35.08±3.31	132.43±29.44
21	S21	741.56±5.85	61.10±4.69	101.74±23.77
22	S22	968.82±6.79	23.58±2.63	67.71±17.26
23	S23	437.23±4.33	37.06±3.38	112.49±25.74
24	S24	982.19±6.74	35.69±3.35	100.51±23.36
25	S25	754.93±5.74	46.13±3.79	75.22±18.68

26	S26	1160.70±7.69	46.13±3.79	48.51±13.53
27	S27	886.25±6.27	37.91±3.38	74.59±18.31
28	S28	460.82±4.42	33.53±3.15	54.55±14.48
29	S29	792.67±6.12	40.32±3.54	78.56±19.37
30	S30	570.91±4.82	25.29±2.62	71.15±17.48
	Mean	506.13±9.30	41.14±3.59	84.52±20.88
	Maximum	1494.12±9.15	108.89±7.42	171.66±36.74
	minimum	437.23±4.33	4.46±1.41	13.37±2.33

TABLE 3: Radiation hazard indices of soil samples

S/n	Sample names/location	External hazard (H_{ex})	Internal hazard
1	S1	0.64	0.77
2	S2	0.88	1.05
3	S3	1.16	1.46
4	S4	0.94	1.14
5	S5	0.59	0.74
6	S6	0.28	0.36
7	S7	0.17	0.18
8	S8	0.55	0.65
9	S9	0.57	0.67
10	S10	0.36	0.43
11	S11	0.59	0.69
12	S12	0.58	0.67
13	S13	0.70	0.80
14	S14	0.56	0.67
15	S15	0.57	0.66
16	S16	0.85	0.98
17	S17	0.83	0.92
18	S18	0.59	0.70
19	S19	0.67	0.73
20	S20	0.81	0.91
21	S21	0.71	0.87
22	S22	0.52	0.59
23	S23	0.62	0.72
24	S24	0.69	0.78
25	S25	0.57	0.70
26	S26	0.55	0.68
27	S27	0.57	0.67
28	S28	0.40	0.49
29	S29	0.57	0.68
30	S30	0.46	0.55
	Average	0.62	0.71
	Maximum	1.16	1.46
	Minimum	0.17	0.18

TABLE 4: Gamma index of soil samples

S/N	Sample names/locations	Gamma Index (Iγ)
1	S1	0.85
2	S2	1.20
3	S3	1.57
4	S4	1.26
5	S5	0.78
6	S6	0.39
7	S7	0.26
8	S8	0.76
9	S9	0.79
10	S10	0.51
11	S11	0.80
12	S12	0.83
13	S13	0.96
14	S14	0.92
15	S15	0.82
16	S16	1.16
17	S17	1.17
18	S18	0.79
19	S19	0.94
20	S20	1.12
21	S21	0.96
22	S22	0.74
23	S23	0.83
24	S24	0.95
25	S25	0.78
26	S26	0.78
27	S27	0.80
28	S28	0.53
29	S29	0.78
30	S30	0.63
	Mean	0.86
	Maximum	1.57
	Minimum	0.26

TABLE 5: Radium equivalent activity of soil samples

S/N	Sample names/locations	Radium equivalent activity ($Bqkg^{-1}$)
1	S1	23365
2	S2	329.8
3	S3	431.05
4	S4	351.81
5	S5	216.17
6	S6	103.67
7	S7	65.09
8	S8	202.55
9	S9	213.14
10	S10	131.93
11	S11	218.95
12	S12	215.54
13	S13	256.76
14	S14	254.56

15	S15	213.85
16	S16	316.88
17	S17	206.47
18	S18	219.48
19	S19	228.81
20	S20	303.45
21	S21	263.69
22	S22	195.01
23	S23	231.59
24	S24	255.05
25	S25	211.82
26	S26	204.87
27	S27	212.81
28	S28	147.02
29	S29	213.70
30	S30	170.99
	Mean	227.34
	Maximum	431.05
	Minimum	65.09

4. DISCUSSION

From this study, it was seen that the radionuclide in the soil samples from Idomi were Potassium – 40, Uranium – 238 and Thorium – 232.

The mean activity concentrations and their standard deviations of radionuclide in soil samples from Idomi were 506.13±9.30, 41.14±3.59 and 84.52±20.88 $Bqkg^{-1}$ respectively for ^{40}K, ^{238}U and ^{232}Th (Table 2). The worldwide median values are 35, 30 and 400 $BqKg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K respectively (UNSCEAR, 2000). Hence, the mean activities of these radionuclide in the sampling locations are comparable with world median ranges. The variation in their activities may be attributed to the types, moisture content, inhomogenity of its permeability (Varley and Flowers, 1998), formation, transport processes and geomorphology (El-Arabi, 2005) associated with meteorological conditions.

Their external (Hex) and internal (Hin) hazard indices was 0.62 and 0.71 respectively (Table 3). The calculated gamma index was 0.86 and had a range 1.57- 0.26 (Table 4). These radiation hazard indexes are less than 1 and are indicative that soils from Idomi can be used for construction purposes (EC 1999).

The mean radium equivalent activity of soil samples from Idomi is 227.34 $Bqkg^{-1}$ (Table 5). This is less than 370 $Bqkg^{-1}$ which is the world average (Tsai *et al*, 2008). The calculated absorbed gamma dose from the soil samples 1m above the ground level was 110.31$nGyh^{-1}$ and ranges between 32.62 to 198.08$nGyh^{-1}$. This range falls within the typical range for measured absorbed dose rate in outdoor air which is 10-200 $nGyh^{-1}$(UNSCEAR, 2000).

The calculated mean annual outdoor effective dose of soil samples from Idomi was 1.35$mSvy^{-1}$. This is lower than the global average of 2.4$mSvy^{-1}$ (UNSCEAR, 2000).

5. CONCLUSION

The radiation hazard indices, absorbed and effective doses from soil samples can be said to be low when compare with their corresponding global average. The probability of occurrence of health effects from exposure to natural terrestrial gamma radiation in Idomi can be said to be low. This may be possible if the baseline level(s) can be kept constant by keeping the environment free of radioactive pollution or waste.

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