Journal of Environmental Protection, **2011, 2, 359-364**
doi: 10.4236/jep.2011.24039 Published Online June 2011 (http://www.SciRP.org/journal/jep)

Basement Data of the Terrestrial Radionuclide Level of Abuja Federal Capital Territory, (FCT), Nigeria

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Received October 18th, 2010; revised January 18th, 2011; accepted March 16th, 2011.

ABSTRACT

A total of 30 *samples were collected from six different locations from of Abuja Federal Capital Territory* (*FCT*), *the administrative capital of Nigeria which is situated in the central part of the country. The samples which were thoroughly prepared following known dosimetry procedures were analyzed for* ^{40}K, ^{238}U *and* ^{232}Th *by the method of Gamma ray spectrometry using NaI*(*TL*) *detector coupled to a multichannel analyzer. The activity concentrations in the top soils in these locations for* ^{40}K, ^{238}U *and* ^{232}Th *range from* 301 ± 26.52 *to* 928.84 ± 80.57, *Not detectable* (*ND*) *value to* 27.68 ± 8.21 *and* 4.65 ± 1.46 *to* 22.48 ± 5.26 *respectively. The average absorbed dose rate and the annual effective dose equivalent were found to be* 40.33 $nGyh^{-1}$ *and* 49.46 *μSv respectively. The value of annual effective dose equivalent is low compared to the world average of* 70 *μSv specified by UNSCEAR for an outdoor effective dose, hence the chances of radiological hazards to the health of the populace are generally low.*

***Keywords*:** *Gamma Ray Spectrometry*, *Soil*, *Radionuclides*, *Abuja FCT*, *Nigeria*

1. Introduction

The occurrence of natural radionuclide in soil depends primarily on the geological and geographical conditions, and appears at different levels in the soil of each region in the world [1-5]. For example, higher levels of radiation are associated with igneous rock such as granite and lower levels with sedimentary rocks. However, some shales and phosphate rocks have relative high content of those radionuclides [6-7]. The composition of these soils and rocks in which the natural radionuclides which are primarily ^{238}U, ^{232}Th and ^{40}K are contained are the major source of the terrestrial component of the natural background radiation and contributes significantly to the total dose from natural sources.

Abuja, the federal capital city of Nigeria which is home to about 800,000 people with ever increasing rural to urban migration rate is located between latitude 8°34′N, longitude 7°10′E and latitude 9°14′N, longitude 7°34′E and has a land area of 713 km^2 and density of 1091.9 km^{-2}. The city is also witnessing aggressive construction works to provide houses for this influx of people. ome papers have been published on the radioactivity level in some regions of Nigeria like [8-12] and more recently on the neutron activation analysis of soil and leaf samples from different parts of Abuja Metropolis [13-14] there is, however, no data is available for radionuclides content in soil samples in this city from the survey of literature and authors' knowledge. This work therefore focuses on the measurement of decay products of the ^{238}U and ^{232}Th series as well as of the primordial radionuclide ^{40}K. The baseline data of this type will certainly be of importance in making estimations of population exposures.

The map of Abuja FCT showing the locations from where the soil samples were collected is shown in **Figure 1** below.

2. Materials and Method

30 samples from the six districts of the Abuja Federal Capital territory were collected from top soil up to a depth of about 15 cm. The description of the samples is as below; 1-Municipal area council, 2-Kwali area council, 3-Abaji area council, 4-Kuje area council, 5-Gwagwal-

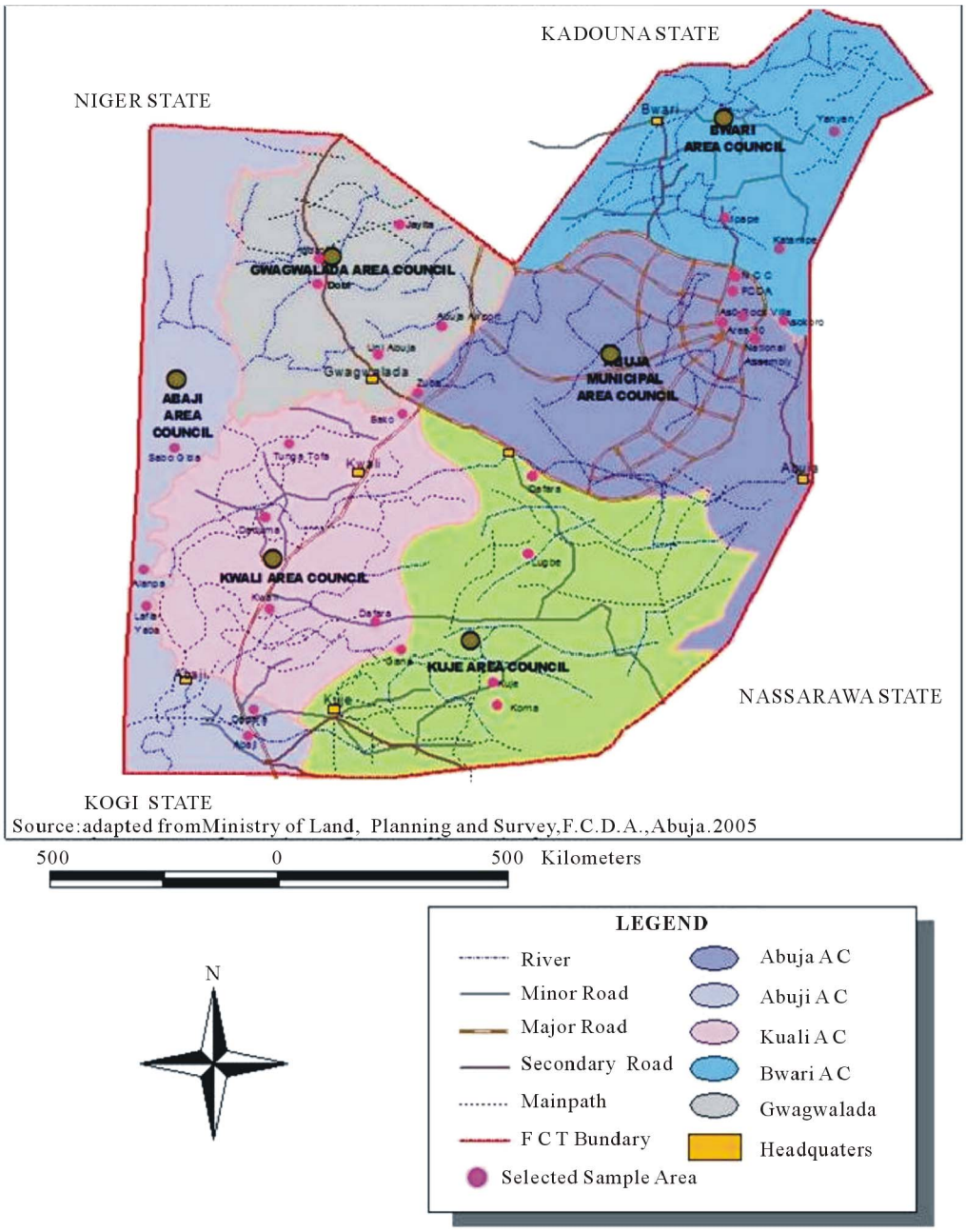

Figure 1. Sampling locations in the municipal council areas of Abuja city.

ada area council and 6-Bwari area council for the six area councils while S1a-FCDA, S1b-NCC, S1c-National Assembly, S1d-Aso-rock Villa, S1e-Area 10 Garki, S2a-Bako, S2b-Danduma, S2c-Darfa, S2d-Tunga Tofa, S2e-Kwali, S3a-Dapara, S3b-Sabo Gida, S3c-Abaji, S3d-Lafia-Yaba, S3e-Alampa, S4a-Gana, S4b-Koma, S4c-Lugbe, S4d-Kuje, S4e-Dafara, S5a-Dobi, S5b-Abuja airport, S5c-Iddo, S5d-University of Abuja, S5e-Jalita, S6a-Katampe, S6b-Aya Asokoro, S6c-Yanyan, S6d-Mpape, S6e-Zuba are the samples collected from the exact locations in the six area councils. Grass and pieces of wood were physically eliminated from the samples while pebbles and other unwanted sediments were sieved witha 2 mm mesh and store in plastic bags pending analysis. All soil samples were dried at 100˚C for 1.5 hours and kept in air-tight containers of 3 cm in diameter and 8 cm in height for about 28 days in plastic containers previously washed and rinsed with diluted sulfuric acid before analysis with the gamma-spectrometer [15] to ensure secular equilibrium between ^{227}Ra and ^{228}Th with their

daughter products. Measurements on soil samples were carried out with a NaI(TL) detector which was connected to a multichannel analyzer. The same geometry was used for each sample, which was counted in sealed containers for 10 hrs (36,000 s). For calibration, a 500 cc sand standard radionuclide source was prepared using 0.07721 g measured gravimetrically from a master radionuclide solution source which was calibrated using a NaI(TL) gamma spectrometer system. The gamma spectroscopy analysis was based on a computer program which matched gamma energy at various energy levels to a library of possible isotopes. ^{232}Th concentration in soil was determined by the 911 keV gamma lines of ^{228}Ac while the ^{238}U concentrations were determined by the 609 keV gamma lines of ^{214}Bi. The activity concentration of ^{40}K was determined from the peak areas at 1460 keV.

The total absorbed dose rate in air, D (nGyh^{-1}) due to a partial evaluation of the radiological hazard posed by the exposure to these estimated radioactivity concentrations at 0.1 m above the ground was estimated using the empirical formula [16].

$$D = 0.042A_k + 0.428A_u + 0.666A_{Th}$$

where A_k, A_u, and A_{Th} are the specific activity concentration for K, U and Th respectively.

Also, using an outdoor occupancy factor of 0.20 and the conversion factor of 0.70 SvGy^{-1} (UNSCEAR, 1988), the annual effective dose equivalent (AEDE) from the calculated outdoor terrestrial gamma radiation at 1 m above the ground in Abuja FCT were calculated using the relation

$$AEDE = ADRA \times DCF \times OF \times T$$

where T is 8760 h.

3. Results

3.1. Radionuclide Levels of Soil Samples

Table 1 shows the dry-weight activity concentrations of

Table 1. Radioactivity concentrations of ^{40}K, ^{238}U series, and ^{232}Th series in Abuja soil samples.

Municipal Area Council	Samples collected In location	^{40}K (BqKg^{-1})	^{238}U (^{226}U) (BqKg^{-1})	^{232}Th (^{228}Th) (BqKg^{-1})
	S1a	412.10 ± 36.06	15.93 ± 2.79	18.83 ± 3.98
	S1b	503.18 ± 43.88	24.10 ± 4.56	22.48 ± 5.26
S1	S1c	801.56 ± 69.59	8.91 ± 2.11	13.78 ± 3.80
	S1d	432.73 ± 37.77	10.98 ± 2.41	4.90 ± 1.03
	S1e	529.72 ± 46.12	7.72 ± 1.38	4.65 ± 1.46
	S2a	760.69 ± 66.06	16.91 ± 4.06	13.49 ± 3.54
	S2b	928.84 ± 80.57	13.07 ± 5.94	14.78 ± 2.61
S2	S2c	587.08 ± 51.09	5.63 ± 1.90	10.31 ± 2.68
	S2d	645.15 ± 56.05	21.87 ± 5.17	12.77 ± 2.93
	S2e	486.23 ± 42.37	17.28 ± 2.43	7.80 ± 1.58
	S3a	462.61 ± 40.37	9.87 ± 2.27	17.32 ± 3.75
	S3b	325.41 ± 28.65	17.02 ± 2.86	19.38 ± 4.20
S3	S3c	794.44 ± 68.98	17.16 ± 4.86	21.86 ± 4.10
	S3d	800.78 ± 69.49	19.81 ± 4.91	19.99 ± 5.43
	S3e	409.48 ± 35.77	11.85 ± 2.76	9.56 ± 2.06
	S4a	622.86 ± 54.17	24.46 ± 5.73	21.43 ± 3.09
	S4b	375.72 ± 32.92	20.55 ± 4.98	11.35 ± 1.90
S4	S4c	499.54 ± 43.58	10.28 ± 2.97	13.28 ± 3.55
	S4d	301.87 ± 26.52	ND	8.13 ± 1.77
	S4e	661.71 ± 57.48	3.07 ± 0.17	12.22 ± 3.54
	S5a	908.17 ± 78.80	8.28 ± 1.42	16.46 ± 4.03
	S5b	923.57 ± 80.12	18.92 ± 4.85	19.96 ± 2.86
S5	S5c	739.56 ± 64.24	27.68 ± 8.21	6.33 ± 1.29
	S5d	709 ± 61.66	22.89 ± 5.72	9.25 ± 2.32
	S5e	494.34 ± 43.06	18.04 ± 4.61	9.45 ± 1.06
	S6a	450.64 ± 39.35	10.43 ± 2.33	12.28 ± 2.54
	S6b	492.60 ± 42.96	10.57 ± 3.51	18.66 ± 2.60
S6	S6c	491.47 ± 42.87	18.47 ± 4.92	22.33 ± 3.74
	S6d	714.61 ± 62.05	24.92 ± 6.19	7.84 ± 1.87
	S6e	587.41 ± 39.92	8.44 ± 2.17	9.92 ± 2.42

the main gamma-emitting radionuclides of the K, U, and Th series in the soil samples. For ^{40}K concentration, Danduma in Kwali area council has the highest value of (928.84 ± 80.57) Bqkg^{-1} while the lowest value of 301.87 ± 26.52 is found in Kuje in Kuje area council. ^{238}U has its highest and lowest values of 27.68 ± 8.21 and ND at Iddo (Gwagwalada area council) and Kuje (Kuje area council) respectively.

NCC has the highest value of ^{232}Th of 22.48 ± 5.26 while the lowest value of 4.65 ± 1.46 is found in Garki area 10 all in the municipal area council. The mean activity concentrations of ^{40}K, ^{238}U and ^{232}Th in Abuja FCT surface soil samples area are 596.92, 14.84 and 13.36 Bqkg^{-1}, respectively.

3.2. Absorbed Dose Rate in Air (ADRA)

The results of the total absorbed dose rate at 1.0 m above the soil are summarized in **Table 2**. It varies between 18.09 - 60.20 nGyh^{-1} with an average of 40.33 nGyh^{-1}. The highest dose rate was recorded at location 22 with absorbed dose rate of 60.20 nGyh^{-1} which also revealed the overall highest contribution in activity concentration for all the radionuclides identified.

3.3. Annual Effective Dose Equivalent (AEDE)

Arising from this, the AEDE were found to be between 22.19 and 73.82 μSv for Kuje and airport respectively while the average AEDE of 49.46 μSv is recorded.

Table 2. Radioactivity concentrations of ^{40}K, ^{238}U series, and ^{232}Th series in Abuja soil samples, the absorbed dose rates from gamma radiation and the annual effective dose equivalent.

S/N	Sample	^{40}K (BqKg^{-1})	^{238}U (BqKg^{-1})	^{232}Th (BqKg^{-1})	Absorbed Dose Rate in air nGyh^{-1})	Annual effective dose equivalent (μSv)
1	S1a	412.12 ± 36.66	15.93 ± 2.79	18.83 ± 3.98	36.68	44.98
2	S1b	503.18 ± 43.38	24.10 ± 4.56	22.48 ± 5.26	34.98	42.90
3	S1c	801.56 ± 69.59	8.91 ± 2.11	13.78 ± 3.50	40.99	50.27
4	S1d	432.73 ± 37.77	10.98 ± 2.47	4.90 ± 1.03	26.15	32.07
5	S1e	529.72 ± 46.12	7.72 ± 1.38	4.65 ± 1.46	25.94	31.81
6	S2a	760.69 ± 66.06	16.91 ± 4.06	13.49 ± 3.54	48.18	59.09
7	S2b	928.84 ± 80.57	13.07 ± 5.94	14.78 ± 2.61	54.46	66.79
8	S2c	587.08 ± 51.09	5.63 ± 1.90	10.31 ± 2.68	21.02	25.78
9	S2d	645.15 ± 56.05	21.87 ± 5.17	12.77 ± 2.93	44.98	55.16
10	S2e	486.23 ± 42.37	17.28 ± 2.43	7.80 ± 1.58	22.52	27.62
11	S3a	462.21 ± 40.37	9.87 ± 2.27	17.32 ± 3.75	35.18	43.14
12	S3b	325.41 ± 28.65	17.02 ± 2.86	19.32 ± 4.20	33.84	41.50
13	S3c	794.44 ± 68.98	19.81 ± 4.91	21.86 ± 4.10	55.27	67.78
14	S3d	800.78 ± 69.49	11.85 ± 2.76	19.99 ± 5.43	55.44	67.99
15	S3e	409.48 ± 35.77	24.46 ± 5.23	9.56 ± 2.06	28.65	35.14
16	S4a	622.86 ± 54.17	20.55 ± 4.98	21.43 ± 3.09	50.93	62.46
17	S4b	375.72 ± 32.92	10.28 ± 2.97	11.35 ± 1.90	32.16	39.44
18	S4c	499.54 ± 43.58	10.28 ± 2.97	13.28 ± 3.55	34.24	41.99
19	S4d	301.87 ± 26.52	ND	8.13 ± 1.77	18.09	22.19
20	S4e	661.71 ± 57.48	3.07 ± 0.17	12.22 ± 3.54	37.25	45.68
21	S5a	908.17 ± 78.80	8.28 ± 1.42	16.46 ± 4.03	52.66	64.58
22	S5b	923.57 ± 80.12	18.92 ± 4.85	19.96 ± 2.86	60.20	73.82
23	S5c	739.56 ± 64.24	27.68 ± 8.21	6.33 ± 1.29	47.15	57.82
24	S5d	709.98 ± 61.66	22.89 ± 5.72	9.25 ± 2.32	45.80	56.17
25	S5e	494.34 ± 43.06	18.04 ± 4.61	9.45 ± 1.06	34.79	42.67
26	S6a	450.64 ± 39.35	10.43 ± 2.33	12.28 ± 2.54	31.58	38.73
27	S6b	492.60 ± 42.96	10.57 ± 3.51	18.66 ± 2.60	37.65	46.17
28	S6c	491.47 ± 42.87	18.47 ± 4.92	22.33 ± 3.74	43.44	53.27
29	S6d	714.61±62.05	24.92± 6.19	7.84 ± 1.87	45.93	56.33
30	S6e	587.41±39.92	8.44 ± 2.17	9.92 ± 2.42	34.90	42.80
	Average	**596.92 ± 51.42**	**14.84 ± 3.61**	**13.36 ± 2.90**	**40.33**	**49.46**

4. Discussion of Results

Figure 2 shows the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the 30 samples collected. The activity concentration of the collected soil samples compare reasonably well with the worldwide average concentrations of 400, 40, 40 $Bqkg^{-1}$, respectively [17] as reported by UNSCEAR. Also, these values for U and Th values are less than the world average while the soil in Abuja has higher concentrations of K, perhaps due to the geological features of the city.

Figure 3 shows the AEDE values which were found to be between 22.19 and 73.82 μSv for Kuje and airport respectively while the average AEDE of 49.46 μSv is recorded. This value represents about 70.7% of the world average of 70 μSv (UNSCEAR, 1988). However, this value is just about 4.9% of the 1.0 mSv recommend by the International Commission on Radiological Protection (ICRP, 1992) [18] as the maximum permissible AEDE for members of the public. This value clearly establishes the fact that there is no potential danger to the health of the citizenry of the Abuja Federal Capital Territory (FCT) due to radiological hazards.

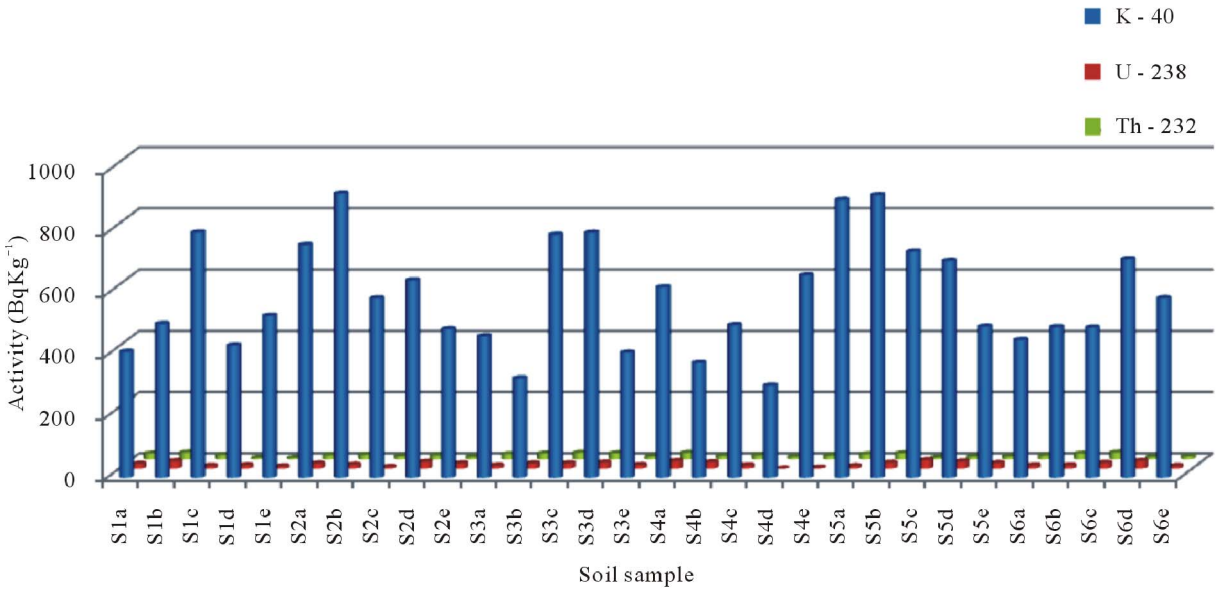

Figure 2. Pictorial representation of the ^{40}K, ^{238}U and ^{232}Th in the samples.

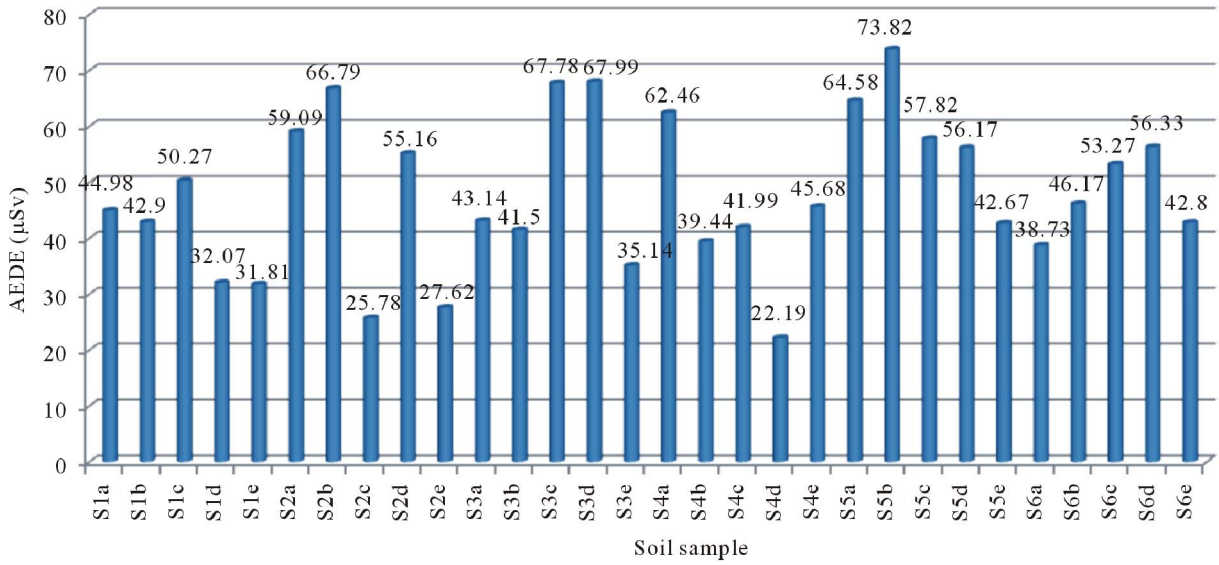

Figure 3. Pictorial representation of the Annual Effective Dose Equivalent (AEDE).

5. Conclusion

A total of 30 measurements were made covering the sampling stations in Abuja FCT comprising six area councils. The concentration of the radionuclides ^{40}K, ^{238}U, and ^{232}Th in soil samples were measured. The absorbed dose rate and annual effective dose equivalent were also calculated. The value of the annual effective dose equivalent of 40.33 $nGyh^{-1}$ is low compared to the world average of 70 μSv specified by UNSCEAR for an outdoor effective dose, hence the chances of radiological hazards to the health of the populace is generally low. However, it may be necessary to determine the radioactivity concentrations in soils of other adjoining states bordering Abuja city to be able to draw better conclusions on the radioactivity levels in the central part of Nigeria. Also, the results may be useful as reference data for monitoring possible radioactivity pollutions in the future.

6. Acknowledgements

The technical support of the Center for Energy Development of the Obafemi Awolowo University, Ile-Ife, Nigeria is appreciated. Mrs. Awodugba C.S. efforts at proof-reading the manuscript is also equally valued.

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