FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 7 No. 4, August, 2023, pp 189 - 194
DOI: https://doi.org/10.33003/fjs-2023-0704-1917

ASSESSMENT OF NATURAL RADIONUCLIDES IN SOIL SAMPLES FROM MICHIKA, ADAMAWA, STATE NIGERIA

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ABSTRACT

Naturally occurring radionuclides in the environment constitute about 85% of public exposure to terrestrial gamma radiation. These radionuclides can be found in sands,clays, soils and rocks, and many ores and minerals, commodities, recycled residues, and other appliances used by humans. There is therefore the need to assess the occurrence of natural radionuclides in Soil Samples from Michika, Adamawa State Nigeria. Forty-six (46) soil samples were collected across different location in Michika, Adamawa State, Nigeria. Gamma ray spectroscopy was used for the analysis. The results obtained show that the mean activity concentration for ^{226}Ra, ^{232}Th and ^{40}K are 81.27, 101.28 and 324.79 Bq/kg respectively. These values are higher than the control value of 35,30 and 35 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K set by UNSCEAR. The absorbed dose rate (D) ranges from 60.77 to 248.65 nGy/h, which is above the maximum UNSCEAR accepted value of 59nGy/h. The values of total annual effective dose lie between 0.08 and 0.31 mSv y^{-1} with mean value of 0.14mSv y^{-1}. Also, the mean values of Radium Equivalent Activity were 251.11 Bq/kg. Almost all the value of R_{aeq} were below the maximum recommended value. The mean value of total cancer risk range from 3.28E-6 to 1.3E-5 with mean value of 5.93E-6. All the mean values were above the acceptable range. It can be concluded that the soil is radiologically unsafe for human and animal use. Continuous radiological monitoring of the soil is recommended to safeguard the health of the populace.

Keywords: Annual Effective Dose, Cancer risk, Michika, NORMS, Soil Samples

INTRODUCTION

Naturally occurring radioactive materials (NORM) due to presence of primordial ^{238}U ,^{232}Th and ^{40}K radionuclides constitute about 85% of public exposure to terrestrial gamma radiation in the environment (Bajoga et al., 2019; UNSCEAR, 2000). They can be found in clays, rocks, soil and sands, and many minerals and ores, recycled residues, commodities, , and other appliances used by humans. Despite the fact that their distribution depends and is not uniform on lithology and extent of mineralization of the rocks formation in a given area, shale and phosphate rocks have relatively high radiation levels. The natural radionuclides are normally found in air, water, plant, rocks and soil (Ibrahim et al., 1993; Malanca et al., 1996). The information about these natural radionuclide concentration levels and their environment effect is of paramount importance in several fields of engineering and science. Therefore, knowing the distribution source of rock materials with high levels of natural radionuclides in soil is very useful. (Aysha et al 2022).

Radiation health effects from uranium in the northern part of Adamawa state, Nigeria has attracted a lot of attention. It has been reported and confirmed from hospitals in the host communities that, several mysterious deaths, still born babies, deformed babies (like single leg, smooth featureless face) has been witnessed in the area. This was corroborated by a Daily Trust Newspaper report of 3rd August 2016 and Oak TV report of October 19, 2016, that uranium ore mineral radiation exists in communities of Michika LGA following activities of the defunct uranium mining company jointly owned by Nigeria and French Companies between 1980-1983. A research was carried out to asses radiometric geology survey at Ghumchi (Michika) by Saleem *et al*., (2017), and the result revealed that the radiometric survey shows a high anomaly, which is observed in the northward of the study area at a fault zone associated with Cataclasite and Mylonite which may be due to the concentration of radionuclide such as Potassium, Thorium and Uranium. Also another research was conducted by Zarma *et al*., to asses the level of heavy metals for drinking water in michika. And the result revealed that the water is not safe for drinking purpose. Thus, it is necessary to assess the safety and quality of different soils sources used in the area, especially for domestic purpose. This study attempts to assess the radiological status of different soil samples used for farming and building in Michika Local Government Area, Adamawa State, Nigeria.

MATERIALS AND METHODS

Study Area

The study was carried out in Michika Local Government Area, Adamawa State, Nigeria (Figure 1). It comprise sisxteen (16) wards and eight (8) districts. The districts are Michika, Baza, Nkala, Ghumchi, Mbororo, Futu, Himike, Sina and Garta town. with population of 179,460 (2011 NPC projection) and an area of 967km^2. The area lies between the latitudes 10°32'N to 10°41'N and longitudes 13°19'E to 13°25'E, and it is bounded to the South by Mubi Local Government Area, to the East by Republic of Cameroon, , to the North by Madagali Local Government Area and to the West by Borno State, respectively. The area is relatively flat in the west and hilly in the eastern part. There are patches of outcrops of granitic rock except in the southeastern part where the elevations of the mountains attain over 2500 feet, There are many rivers originating from the mountains and generally flow towards west and northwest of the study area. The rivers include RafinWantse, Yedseram, and Rafin Nanda. The rocks aid in the formation of dendritic pattern of drainage network. The valleys that drained the rivers have alluvial flood plains comprising mainly of coarse quarzitic materials. However, granites ranging from fine course grained, pegmatite,

granodiorites and biotite granite predominantly occupy the southern part of the area. (Nur and Ayuni, 2011)

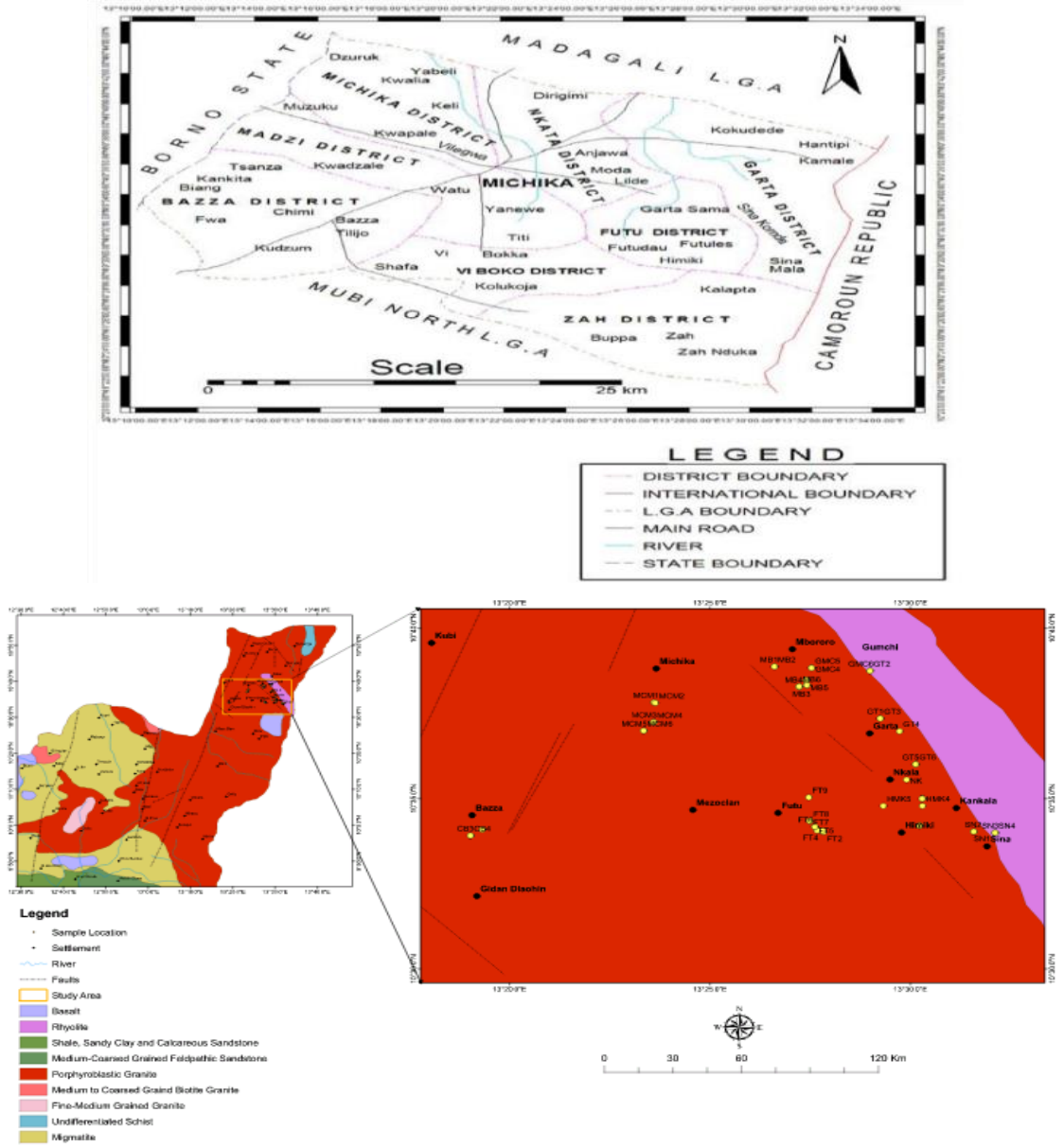

Figure 1: (a). Districts Map of Michika Local Government Area (Williams *et al.,* 2015) (b) Geological map of the study area (Nur and Ayuni 2011).

Methodology

Sample Collection

Soil samples were collected within the defund Uranium exploration area, farmlands and residential villages. The soil samples were collected using a mechanical hand auger to a depth of 25-30 cm. A Global Positioning System (GPS) was used to measure sampling point locations. Soil samples were collected from seven villages in the vicinity of the defunct uranium exploration area and two other villages far off from the exploration area to serve as control. One kilogram (1 kg) of each sample was collected in very clean polythene bag, well labeled and taken to the laboratory for analysis.

Sample Preparation and Analysis

The collected soil samples were air dried for 72hrs under laboratory temperature (ambient temperature of 27ºC) and average relative humidity of 70% (IAEA, 1989). The samples were then ground and packed to fill already weighed cylindrical plastic containers of dimension 7.2cm in diameter and 6.0cm high. (Ibeanu, 1999). Before sealing, the mass of each sample was determined and recorded.

In order to determine the activity concentrations of uranium, thorium, and potassium in the soil samples, NaI(Tl) detector gamma spectroscopy was used. The choice was based on its availability, speed of analysis, relative ease of sample preparations and the simplicity of the data reduction procedures.The characteristic photon energy was measured and used to quantify the different radionuclides. (Ibeanu, 1999).

The Radium Equivalent Activity (Ra_{eq}) was calculated from radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K, using Equation (1) (Jibiri*et al*., 2007; Belivermis*et al*, 2009).

$$Ra_{eq}\ (Bq / kg) = A_{Ra} + 1.43A_{Th} + 0.077\ A_K \qquad (1)$$

where A_{Ra}, A_{Th} and A_k are the specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. In defining Ra_{eq}, it is assumed that 10 Bq\kg of ^{226}Ra, 7 Bq\kg of ^{232}Th and 130 Bq\kg of ^{40}K produced equal gamma ray dose. 370 Bq\kg is the accepted value of Ra_{eq} (LydieandNemba, 2009)

Equation (2) was used to estimate the Absorbed Dose Rate (D) from the mean concentration of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples. (Belivermis*et al*, 2009 and Jibiri*et al*., 2007).

$$D(nGy/h) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (2)$$

Equations (3) to (5) were used to calculate Annual Effective Dose due to External gamma radiation (AEDγ), due to ingestion (AED_{ing}) and total annual effective dose (TAED) (UNSCEAR, 2000; ICRP, 2012).

$$AED\gamma = D\ (nGyh^{-1}) \times 8760h \times 0.2 \times 0.7Sv\ Gy \times 10^{-3} \quad (3)$$

$$AED_{ing}\ (mSvy^{-1}) = AR \times IR \times DCF \quad (4)$$

$$TAED = AED\gamma + ED_{ing} \quad (5)$$

where 0.7 $SvGy^{-1}$= conversion coefficients, 0.2 = occupancy factor, AR = mean activity concentration of radionuclides in a sample (Bq/kg), IR = the water consumption rate per year ($730Ly^{-1}$) (DEA, 2010). DCF = effective dose coefficient in $SvBq^{-1}$ for the ingestion of natural radionuclides of ^{226}Ra, ^{232}Th and ^{40}K with values of 4.50E-08.

Equations (6) –(9) were respectively used to calculate the external and internal hazards, gamma and alpha indices ($I\gamma$ and $I\alpha$) that could arise from the use of soil samples (Xinwei*et al*., 2006; Asaduzzaman*et al*., 2016).

$$Hex = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (6)$$

$$Hin = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (7)$$

$$I\gamma = A_{Ra}/300 + A_{Th}/2100 + A_K/3000 \quad (8)$$

$$I\alpha = A_{Ra}/200\ (Bq/kg) \quad (9)$$

The fatality cancer risk (FCR), hereditary cancer risk and total cancer risk (TCR) due to low doses without threshold dose known as stochastic effects was estimated using equations (10) –(12) respectively based on ICRP (2007) cancer risk assessment methodology.

$$FCR = total\ AED\ (Sv) * cancer\ nominal\ risk\ factor \quad (10)$$

$$Hereditary\ risk = total\ AED\ (Sv) * hereditary\ nominal\ risk\ factor \quad (11)$$

$$TCR = FCR + HCR \quad (12)$$

where HCR is the $Hereditary\ risk$.

RESULT AND DISCUSSION

The results obtained for activity concentration and other related radiological parameters is presented in Table 1.

Table 1: Activity Concentration of ^{226}Ra, ^{232}Th and ^{40}K in ($Bqkg^{-1}$), Absorb Dose Rate, Annual Effective Dose Due to External Gamma Radiation, Annual Effective Dose due to Ingestion and Total Annual Effective Dose for Soil Samples

Sample ID	Ra-226	Th-232	K-40	D	AED gam	AED $_{ing}$	Total AED
B1	52.980	98.610	130.638	89.487	0.110	0.004	0.113
B2	76.760	80.407	215.584	93.018	0.114	0.004	0.118
B3	89.344	65.034	212.420	89.415	0.110	0.004	0.113
B4	101.011	25.911	159.007	68.948	0.085	0.004	0.088
B5	98.254	93.107	307.986	114.473	0.140	0.004	0.144
B6	114.676	123.304	189.146	135.343	0.166	0.004	0.170
N1	51.305	83.317	135.196	79.664	0.098	0.004	0.101
N2	108.882	64.680	119.108	94.337	0.116	0.004	0.119
N3	124.506	57.052	184.373	99.669	0.122	0.004	0.125
N4	120.590	38.886	131.978	84.703	0.104	0.004	0.107
N5	84.549	61.652	409.932	93.394	0.115	0.004	0.118
N6	28.210	120.434	294.364	98.050	0.120	0.004	0.124
N7	74.360	178.390	254.196	152.702	0.187	0.004	0.191
GH1	94.178	79.857	187.162	99.549	0.122	0.004	0.126
GH2	125.265	64.562	196.815	105.075	0.129	0.004	0.132
GH3	72.042	180.749	381.509	158.365	0.194	0.004	0.198
GH4	120.590	110.683	135.947	128.234	0.157	0.004	0.161
GH5	48.947	140.408	296.616	119.789	0.147	0.004	0.151
Z1	86.147	88.350	125.221	98.385	0.121	0.004	0.124
Z2	93.899	66.370	135.035	89.100	0.109	0.004	0.113
GA1	95.097	54.732	179.064	84.460	0.104	0.004	0.107
GA2	58.217	46.672	136.215	60.766	0.075	0.004	0.078
GA3	41.955	60.984	627.018	82.364	0.101	0.004	0.105
GA4	43.793	169.504	458.572	141.735	0.174	0.004	0.177
F1	121.908	51.744	134.016	93.164	0.114	0.004	0.118
F2	30.088	130.775	1286.909	146.553	0.180	0.004	0.183
F3	44.272	129.340	718.722	128.546	0.158	0.004	0.161
F4	36.281	81.980	523.623	88.114	0.108	0.004	0.112
F5	80.233	132.977	229.581	126.959	0.156	0.004	0.159
S1	115.316	71.246	130.316	101.743	0.125	0.004	0.128
S2	84.788	64.562	181.155	85.722	0.105	0.004	0.109
S3	20.298	55.951	611.680	68.679	0.084	0.004	0.088
S4	26.292	197.067	252.588	141.708	0.174	0.004	0.177
S5	29.248	181.221	289.108	135.026	0.166	0.004	0.169
MB1	98.294	75.453	184.534	98.681	0.121	0.004	0.125
MB2	261.558	141.863	1010.189	248.650	0.305	0.004	0.308

MB3	87.945	106.555	537.566	127.406	0.156	0.004	0.160
MB4	80.593	154.524	236.875	140.444	0.172	0.004	0.176
MC1	68.166	85.597	207.272	91.837	0.113	0.004	0.116
MC2	96.935	61.495	129.565	87.330	0.107	0.004	0.111
MC3	36.920	170.015	1414.651	178.737	0.219	0.004	0.223
MC4	70.124	176.149	363.866	153.965	0.189	0.004	0.192
MC5	54.182	146.660	331.742	127.448	0.156	0.004	0.160
MC6	124.146	127.512	289.376	146.440	0.180	0.004	0.183
HM1	84.509	71.993	138.736	88.312	0.108	0.004	0.112
HM2	80.633	90.512	135.142	97.557	0.120	0.004	0.123
Mean	81.267	101.279	324.789	112.261	0.138	0.004	0.141
Min	20.298	25.911	119.108	60.766	0.075	0.004	0.078
Max	261.558	197.067	1414.651	248.650	0.305	0.004	0.309

The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg for soilsample ranged between 20.30, 25.91 and 119.1 Bq/kg to 261.6, 197.1 and 1414.7 Bq/kg respectively. The minimum values were obtained from S3, B4 and N2 sample location while the maximum values were obtained from MB2, S4 and MC3 sample locations for ^{226}Ra, ^{232}Th and ^{40}K respectively. The mean value of ^{226}Ra and ^{232}Th were almost three times higher than the UNSCEAR, 2000 recommended value of 35 and 30 Bq/kg respectively. All the sample locations had ^{226}Ra concentrations higher than the permissible limits except for four locations (S5, S3,F2, N6) with values below the accepted value of 35 Bq/kg as set by UNSCEAR (2000). For ^{232}Th concentration, only B4 had a value within the recommended value of 30 Bq/kg. However, only eight out forty-six sample locations had the value above maximum concentration. The variation of the concentration of this radionuclide may be due to geological conditions like transport process and formation of rocks (Choubey*et al*., 1999). Considering ^{40}K as the only natural isotopes of potassium the high concentration of may also be due to the use of fertilizer rich in potassium.

The calculated absorbed dose rate ranges from 60.77 nGy/hr (GA2 sample) to 248.65 nGy/hr (MB2 sample) , with mean value of 112.26. These values were found to be higher than the recommended value of 59 nGy/hr (UNSCEAR, 2000).The total annual effective dose was found to be between 0.08 mSv to 0.31mSv with mean value of 0.14 mSv. All the obtained values are less than world average value of 0.5 mSv. From the result obtained it clearly shows that the annual effective dose for soil samples is within the world average value.

Table 2: Hazard Indices for Soil Samples

Sample ID	Raeq	Hex	Hin	Igam	Ialp	HCR	FTCR	TCR
B1	204.057	0.551	0.694	0.761	0.265	4.65E-06	1.13E-07	4.76E-06
B2	208.340	0.563	0.770	0.867	0.384	4.82E-06	1.18E-07	4.94E-06
B3	198.698	0.537	0.778	0.890	0.447	4.64E-06	1.13E-07	4.76E-06
B4	150.308	0.406	0.679	0.807	0.505	3.61E-06	8.82E-08	3.7E-06
B5	255.112	0.689	0.955	1.079	0.491	5.9E-06	1.44E-07	6.05E-06
B6	305.565	0.825	1.135	1.280	0.573	6.95E-06	1.7E-07	7.12E-06
N1	180.858	0.488	0.627	0.692	0.257	4.15E-06	1.01E-07	4.25E-06
N2	210.546	0.568	0.863	1.000	0.544	4.89E-06	1.19E-07	5.01E-06
N3	220.286	0.595	0.932	1.089	0.623	5.16E-06	1.26E-07	5.29E-06
N4	186.360	0.504	0.829	0.982	0.603	4.41E-06	1.07E-07	4.51E-06
N5	204.276	0.552	0.780	0.887	0.423	4.84E-06	1.18E-07	4.96E-06
N6	223.096	0.602	0.679	0.714	0.141	5.08E-06	1.24E-07	5.2E-06
N7	349.031	0.943	1.144	1.237	0.372	7.83E-06	1.91E-07	8.02E-06
GH1	222.785	0.602	0.856	0.975	0.471	5.15E-06	1.26E-07	5.28E-06
GH2	232.743	0.629	0.967	1.125	0.626	5.43E-06	1.32E-07	5.56E-06
GH3	359.890	0.972	1.167	1.257	0.360	8.11E-06	1.98E-07	8.31E-06
GH4	289.335	0.782	1.107	1.260	0.603	6.6E-06	1.61E-07	6.76E-06
GH5	272.570	0.736	0.868	0.930	0.248	6.17E-06	1.51E-07	6.32E-06
Z1	222.129	0.510	0.833	0.941	0.431	5.09E-06	1.24E-07	5.22E-06
Z2	199.206	0.538	0.792	0.910	0.469	4.63E-06	1.13E-07	4.74E-06
GA1	187.152	0.506	0.762	0.885	0.475	4.39E-06	1.07E-07	4.5E-06
GA2	135.446	0.366	0.524	0.597	0.291	3.2E-06	7.81E-08	3.28E-06
GA3	177.442	0.479	0.593	0.646	0.210	4.29E-06	1.05E-07	4.39E-06
GA4	321.494	0.868	0.987	1.041	0.219	7.27E-06	1.77E-07	7.45E-06
F1	206.221	0.557	0.887	1.040	0.610	4.83E-06	1.18E-07	4.95E-06
F2	316.188	0.854	0.937	0.973	0.150	7.52E-06	1.83E-07	7.7E-06
F3	284.570	0.768	0.888	0.944	0.221	6.61E-06	1.61E-07	6.77E-06
F4	193.831	0.523	0.621	0.667	0.181	4.58E-06	1.12E-07	4.69E-06
F5	288.068	0.778	0.995	1.096	0.401	6.53E-06	1.59E-07	6.69E-06

S1	227.233	0.614	0.926	1.071	0.577	5.26E-06	1.28E-07	5.39E-06
S2	191.061	0.516	0.745	0.852	0.424	4.46E-06	1.09E-07	4.57E-06
S3	147.407	0.398	0.453	0.479	0.101	3.6E-06	8.78E-08	3.69E-06
S4	327.547	0.884	0.956	0.980	0.131	7.27E-06	1.77E-07	7.45E-06
S5	310.656	0.839	0.918	0.955	0.146	6.94E-06	1.69E-07	7.11E-06
MB1	220.401	0.595	0.861	0.985	0.492	5.11E-06	1.25E-07	5.23E-06
MB2	542.207	1.465	2.172	2.501	1.308	1.27E-05	3.09E-07	1.3E-05
MB3	281.711	0.761	0.999	1.109	0.440	6.55E-06	1.6E-07	6.71E-06
MB4	319.802	0.864	1.082	1.1832	0.404	7.21E-06	1.76E-07	7.39E-06
MC1	206.531	0.558	0.742	0.828	0.341	4.77E-06	1.16E-07	4.88E-06
MC2	194.850	0.526	0.788	0.911	0.485	4.54E-06	1.11E-07	4.65E-06
MC3	388.970	1.050	1.150	1.197	0.185	9.14E-06	2.23E-07	9.36E-06
MC4	350.035	0.945	1.135	1.223	0.351	7.89E-06	1.92E-07	8.08E-06
MC5	289.450	0.782	0.928	0.996	0.271	6.56E-06	1.6E-07	6.72E-06
MC6	328.770	0.888	1.224	1.380	0.621	7.51E-06	1.83E-07	7.69E-06
HM1	198.142	0.535	0.764	0.870	0.423	4.59E-06	1.12E-07	4.7E-06
HM2	220.472	0.595	0.813	0.915	0.403	5.05E-06	1.23E-07	5.18E-06
MEAN	251.105	0.678	0.898	1.000	0.406	5.79E-06	1.41E-07	5.93E-06
MIN	135.446	0.366	0.453	0.479	0.101	3.2E-06	7.81E-08	3.28E-06
MAX	542.207	1.465	2.172	2.501	1.308	1.27E-05	3.09E-07	1.3E-05

MB2 with value of 542 is the sample location with highest value of Radium equivalent. It is also the only location that exceeded the recommended value of 370 Bq/kg set by OECD (1979). All the remaining locations have values lower than the accepted value. The values of H_{ex}, H_{in}, $I\gamma$ and $I\alpha$ lies in the range of 0.37 to 1.46, 0.45 to 2.17, 0.48 to 2.50 and 0.10 to 1.31, with mean value of 0.68, 0.90, 1.00 and 0.41 respectively. Almost all the value of both external and internal hazard indices are less than unity except two samples for H_{ex} and nine samples for H_{in}. The total excess life cancer risk ranged between 3.28E-6 to 1.3E-5, with mean value of 5.93E-6. All the values were found to be within the accepted range, as they are all less than unity (Dankawu *et al*., 2021).

CONCLUSION

Assessment of Natural Radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the Soil Samples collected from different locations of Michika Local Government Area, Adamawa State Nigeria, was carried out using gamma spectroscopy. The result shows that the mean activity concentration of ^{226}Ra and ^{232}Th were almost three times higher than the recommended value. However, the concentration of ^{40}K in all samples were above the accepted ranges, except for four samples namely: S5, S3, F2 and N6 with value below the accepted value of 35 Bq/kg. The value of the absorbed dose values was found to be higher than the recommended value of 59 nGy/hr. The result obtained clearly shows that the annual effective dose for soil is within the world average value. Radium Equivalent value for all samples location is within recommended value except for one sample location MB2 with value below 370 Bq/kg. Almost all the values of both external and internal hazard indices and excess life cancer risk are less than unity. Therefore, the soil for this study area is safe for farming and construction material.

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