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Radiological hazard assessment of natural radionuclides in soils of Udege Mbeki Mining Area, Nasarawa State, Nigeria

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Abstract: Mining involves excavating soil with radioactive materials, which may enter the food chain and harm humans. This study evaluated the risks of exposure to ionizing radiation from radium-226, potassium-40, and thorium-232 in Udege Mbeki mining area of Nasarawa State, Nigeria. Twenty-one (21) soil samples were randomly collected in the mining site. The activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the samples ranged from 12.7462-430.8147 Bq/kg, 38.4147-725.4748 Bq/kg, and 22.3092-395.5596 Bq/kg respectively. The estimated effective dose in the Udege mined site soil samples was 19.7538-330.3428 mSvy^{-1}, with an average of 148.8091 mSvy^{-1} in the dump, 67.1197 mSvy^{-1} in the farmland, and 121.4909 in the surface soil. These values exceed ICRP's recommended reference level of 1mSvy^{-1} for public exposure and 20 mSvy^{-1} for workers. Thus, the mine is hazardous for both the public and workers. It is recommended that the implementation of a routine monitoring be implemented on the radiation levels in the mined tailings on a periodic basis, so as to keep track of the rise and fall in the radioactivity levels. This is necessary for a sensitization scheme to be put in place in order to educate the inhabitants of the area on the need for self-protection from the hazards of ionizing radiation as well as educating the workers on the necessity to follow the right procedure and use the necessary protective gears.

Keyword : Naturally occurring radionuclides, Radiological hazards, Ionizing radiation, Soil.

1. Introduction

The constant release of mining waste (tailings) into the biosphere may result in an accumulation of radioactive nuclides in the air, water and soil, which will impact both human and non-human biota (Aliyu *et al.,* 2015). The Nigeria Mining Corporation,

which is no longer in existence, was for many years the umbrella under which tin/columbite was being mined, implying that mechanized mining had for a long time been in practice in the Udege area (Aliyu et al., 1996). Owing to the collapse, in the early 70s, mechanized mining companies were abandoned in Udege area in the 1980s, thus negative environmental impact became significant. The mining activities have defaced the area by leaving behind devastated landscapes, exposed fertile lands, artificial dams, and abandoned ponds. Consequently, there is a continuous exposure of humans to natural background radiation day after day from building materials, the ground, food, air, outer space as well as elements in their own bodies (Saleh et al., 2013). The external exposure to natural radionuclides can vary significantly and may be up to 100 times higher than the average. Radon gas, which is formed during the decay of natural uranium in the soil, is a significant contributor to human exposure. The level of exposure from inhaling radon can vary depending on the local geology, building materials, and lifestyle factors. Approximately half of the average human exposure to natural sources can be attributed to inhalation of radon.

Surface and underground mining create huge amounts of waste rock, containing radioactive Radium and Lead, which is left as a waste rock dump. This heap emits Radon (Rn-222), which can cause lung cancer. The large volume of mined rocks also produces dust and releases radioactive noble gas, radon, which can easily be dispersed by wind. Radioactive tailings in the Udege Mbeki area can contaminate soil, water, and drinking water (Uranium Mining in and for Europe, 2012). One of the radionuclides found naturally in the soil is Potassium-40; a very vital element required in the human body during biological processes which can present both external and internal health hazards owing to the strong association of gamma radiation with the electron-capture decay process, and this makes external exposure to this isotope a concern. The health hazard resulting from exposure to potassium-40 is associated with cell damage caused by the ionizing radiation that results from radioactive decay, with the general potential for subsequent cancer induction (Human Health Fact Sheet, 2005). Thorium, which is also a radionuclide found naturally in the soil is a weakly radioactive alpha emitter, so external exposure is unlikely to harm cells. Inside the body, thorium could cause cancer in internal organs. Thorium decay also produces radioactive radon gas, which could accumulate to dangerous levels in a confined space. Studies have found that thorium workers breathing dust may develop lung disease, lung cancer, pancreatic cancer, and genetic changes (U.S. Public Health Service, 1990).

Soils play a major role in element cycling and heavy metal accumulation, which is higher than in water and air (Ashraf et al., 2011). Soils also store many hazardous elements, including heavy metals and trace metals, as well as elemental and biological constituents (Zimmerman & Weindorf, 2010). Terrestrial ecosystems contain most of the radioactivity, natural or artificial, in the soil. Soil-based exposures are important for radiation risk assessment and radioactivity levels in the soil depend on the parent materials that make up the soil type (Gabdo et al., 2014). This study therefore aims to measure the concentration of radionuclides in the soil and the potential hazard of

exposure. Data from this study could help provide information on how individuals are affected by mining and how to better protect them.

2. Materials and Method

2.1. Materials

The materials employed in this research are: a highly sensitive and accurate radiation survey meter (Ludlum Micro R meter, model 19) and a Global Positioning System (GPS), the hand trowel, the pulveriser, the sieve and Sodium Iodide (NaI) detector.

The Model 19 survey meter is a gamma μR/meter with a 2.5 cm x 2.5 cm NaI detector. It measures 0-50 μSv/h, or 0-5000 μR/hr. This aluminum-housed instrument has a separate battery compartment and metal handle, providing quality and durability. It measures 0 to 5000 μR/hr, and the rotary switch on the front panel sets the range of calibration labeled in black on the scale. If the rotary switch is on 25 or 250, readings are taken from the red scale. For example, if the switch is set to 500, readings range from 0-500μR/hr. In this case, the 0-50 scale has each 10 divisions representing 100 divisions. This expands the scale from 0-10 to 0-500.

2.2. The Study Area

The area under study which is located at the north central part of Nigeria is a small town in Nasarawa State and has for a long time embraced the practice of mining (Aliyu et al., 1996). It is situated approximately at latitude 80 21.97′ North and longitude 70 51.97′ East, covering a total area of approximately 400km2. It falls within the tropical guinea-savannah and characterized by two seasons known as dry season, lasting from November to March, and the rainy season lasting from April to October (Okegye & Gajere, 2015).

2.3. Sample Collection

With the survey meter held at about one meter (1m) above the ground level, the background radiations for twenty-one different locations in the mining dumps, farmland and surface were taken in micro Roentgen per hour ($\mu R hr^{-1}$) which is the default calibration of the survey meter. The soil samples at each of these locations were collected using the hand trowel and the samples were packaged in sample bags and taken to a suitable location where they were then crushed into fine tiny pieces. The samples were then sieved to obtain the fine powder and repackaged in bags which were labelled D1 to D7, F1 to F7 and S1 to S7 with the coordinates of the points where each sample was collected.

2.4. Sample Preparation

Each of the soil samples collected was dried and crushed into fine powder with the use of a pulveriser. Packaging of the samples into radon-impermeable cylindrical plastic containers which were selected based on the space allocation of the detector vessel

measuring 7.6cm by 7.6cm in dimension (geometry) was also carried out. To prevent radon-222 escaping, the packaging in each case was triple sealed.

The sealing process included smearing of the inner rim of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight-sealing lid-container with masking adhesive tape. Radon and its short-lived progenies were allowed to reach secular radioactive equilibrium by storing the samples for 30 days prior to gamma spectroscopy measurements.

2.5. Evaluation of Radioactivity of Samples

The analysis was carried out in the Centre for Energy Research and Training (CERT), Zaria, Nigeria using a 76x76mm NaI (Tl) detector crystal optically coupled to a photomultiplier tube (PMT). The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector is enclosed in a 6cm lead shield with cadmium and copper sheets. This arrangement is aimed at minimizing the effects of background and scattered radiation.

The data acquisition software is Maestro by Camberra Nuclear Products. The samples were measured for a period of 29000 seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample by the use of equation:

$$\text{C (Bq.kg}^{-1}) = \frac{C_n}{C_{fk}} \quad (1)$$

where,

C = activity concentration of the radionuclides in the sample given in BqKg^{-1}

C_n = count rate (counts per second)

$$\text{Counts per second (cps)} = \frac{Net\ Count}{Live\ Time} \quad (2)$$

C_{fk} = Calibration factor of the detecting system.

Calibration of the system for energy and efficiency were done with two calibration point sources, Cs-137 and Co-60. These were done with the amplifier gain that gives 72% energy resolution for the 66.16KeV of Cs-137 and counted for 30minutes.

The standards used to check for the calibration are the IAEA gamma Spectrometric reference materials RGK-1 for K-40, RGU-1 for Ra-226 (Bi-214 peak) and RTG-1 for Th-232 (Ti-208).

3. Results

3.1. Data Presentation

The activity concentration in each soil sample collected from Udege Mbeki mining site was measured using a gamma-ray spectrometer and the radioactivity of natural radionuclides namely, radium, thorium and potassium was investigated in the soil samples. The primordial radionuclides of ^{226}Ra, ^{232}Th, and ^{40}K were the three most important radionuclides detected in the area.

Background radiation in micro-Roentgen per hour (μRhr^{-1}) and the coordinates of each point of collection is contained in Table (1.1)

Table 1.1. Background radiation at Udege Mbeki mined site

S/No	Sample ID	Latitude (in degrees)	Longitude (in degrees)	Background Radiation (μRhr^{-1})
1	D1	8.400013	7.868830	80
2	D2	8.400350	7.868518	95
3	D3	8.400238	7.868548	70
4	D4	8.399485	7.869127	70
5	D5	8.399042	7.869317	68
6	D6	8.424392	7.889985	170
7	D7	8.400387	7.868845	100
8	F1	8.426038	7.888160	35
9	F2	8.426232	7.888177	30
10	F3	8.425822	7.888517	40
11	F4	8.425405	7.884120	45
12	F5	8.424563	7.888277	60
13	F6	8.426165	7.888087	40
14	F7	8.424758	7.888068	40
15	S1	8.425782	7.888520	45
16	S2	8.426438	7.887772	35
17	S3	8.399337	7.868065	65
18	S4	8.399587	7.867992	100
19	S5	8.399103	7.868195	55
20	S6	8.425213	7.888395	55
21	S7	8.424523	7.888202	50

The collected samples were analyzed for thorium in Becquerel per kilogram (Bq/kg) and Counts Per Second (CPS). The activity concentration of the samples from the dump ranged from 38.4147 ± 2.3985 to 725.4748 ± 11.9923 Bq/kg, while the farmland ranged from 49.7385 ± 1.5728 to 384.5791 ± 7.5492 Bq/kg, and for the surface soils it ranged from 72.2683 ± 3.1455 to 739.5510 ± 12.3462 Bq/kg. Table 1.2 expresses in detail the result of the analysis.

Table 1.2. Activity Concentration of Thorium-232 (^{232}Th) in the soil samples collected from Udege Mbeki mining site

S/No	Sample ID	Th-232 (CPS)	Th-232 (Bq/kg)
1	D1	0.3779 ± 0.0074	430.8969 ± 8.4535
2	D2	0.0749 ± 0.0017	85.3615 ± 1.8873
3	D3	0.4426 ± 0.0090	504.6593 ± 10.2229
4	D4	0.3738 ± 0.0078	426.2179 ± 8.8861
5	D5	0.1664 ± 0.0038	189.7928 ± 4.2858
6	D6	0.0337 ± 0.0021	38.4147 ± 2.3985
7	D7	0.6362 ± 0.0105	725.4748 ± 11.9923

S/No	Sample ID	Th-232 (CPS)	Th-232 (Bq/kg)
8	F1	0.0712 ± 0.0012	81.2330 ± 1.3368
9	F2	0.0618 ± 0.0026	70.4203 ± 2.9489
10	F3	0.2134 ± 0.0050	243.3846 ± 5.6619
11	F4	0.0436 ± 0.0014	49.7385 ± 1.5728
12	F5	0.3373 ± 0.0066	384.5791 ± 7.5492
13	F6	0.0822 ± 0.0022	93.6972 ± 2.5164
14	F7	0.1949 ± 0.0047	222.2703 ± 5.3081
15	S1	0.6486 ± 0.0108	739.5510 ± 12.3462
16	S2	0.0864 ± 0.0021	98.4941 ± 2.3591
17	S3	0.4162 ± 0.0090	474.5803 ± 10.2229
18	S4	0.0844 ± 0.0032	96.2136 ± 3.6173
19	S5	0.0708 ± 0.0030	80.7219 ± 3.3814
20	S6	0.0634 ± 0.0028	72.2683 ± 3.1455
21	S7	0.1273 ± 0.0033	145.1657 ± 3.8139
	Mean	**0.2194 ± 0.0048**	**250.1493 ± 5.4241**

The analysis of the soil samples was also made for potassium-40. The activity concentration in Becquerel per kilogram (Bq/kg) and Counts per Second (CPS) were obtained after analysis and the results are tabulated in table 1.3 with the average activity 179.4876 ± 9.9237 Bq/kg.

Table 1.3. Activity Concentration of Potassium-40 (^{40}K) in the soil samples collected from Udege Mbeki mining site

S/No	Sample ID	K-40 (CPS)	K-40 (Bq/kg)
1	D1	0.0815 ± 0.0024	126.7764 ± 3.8076
2	D2	0.0438 ± 0.0023	68.1611 ± 3.6467
3	D3	0.1092 ± 0.0115	169.8933 ± 17.8581
4	D4	0.1927 ± 0.0120	299.6729 ± 18.7161
5	D5	0.0861 ± 0.0043	133.9626 ± 6.7571
6	D6	0.1279 ± 0.0021	198.8524 ± 3.3249
7	D7	0.1425 ± 0.0183	221.5906 ± 28.4228
8	F1	0.0143 ± 0.0022	22.3092 ± 3.4858
9	F2	0.0562 ± 0.0049	87.3599 ± 7.6152
10	F3	0.1238 ± 0.0070	192.4706 ± 10.8328
11	F4	0.1177 ± 0.0026	183.0858 ± 3.9685
12	F5	0.1042 ± 0.0086	162.0100 ± 13.2997
13	F6	0.0353 ± 0.0023	54.9150 ± 3.5394
14	F7	0.1321 ± 0.0044	205.4486 ± 6.9180
15	S1	0.1373 ± 0.0164	213.6000 ± 25.4733
16	S2	0.1885 ± 0.0024	293.1303 ± 3.8076
17	S3	0.2543 ± 0.0159	395.5596 ± 24.7761

S/No	Sample ID	K-40 (CPS)	K-40 (Bq/kg)
18	S4	0.2135 ± 0.0049	332.0641 ± 7.6152
19	S5	0.0990 ± 0.0036	153.9658 ± 5.5773
20	S6	0.0913 ± 0.0011	141.9531 ± 1.7161
21	S7	0.0723 ± 0.0047	112.4578 ± 7.2398
	Mean	**0.1154 ± 0.0064**	**179.4876 ± 9.9237**

Table 1.4 shows the primordial radionuclide obtained after analysis of the soil samples for radium. Radium-226 (^{226}Ra) was the most important detected and its activity concentration in Becquerel per kilogram (Bq/kg) and Counts Per Second (CPS) in the dump, farmland and surface soils are shown in details.

Table 1.4. Activity Concentration of Radium-226 (226Ra) in the soil samples collected from Udege Mbeki mining site

S/No	Sample ID	Ra-226 (CPS)	Ra-226 (Bq/kg)
1	D1	0.1002 ± 0.0092	116.1146 ± 10.7084
2	D2	0.0159 ± 0.0017	18.3801 ± 1.9978
3	D3	0.2348 ± 0.0104	272.0262 ± 12.0270
4	D4	0.1996 ± 0.0093	231.2303 ± 10.7484
5	D5	0.0686 ± 0.0037	79.4742 ± 4.2754
6	D6	0.0134 ± 0.0026	15.5033 ± 3.0367
7	D7	0.3718 ± 0.0173	430.8147 ± 20.0184
8	F1	0.0165 ± 0.0041	19.1393 ± 4.7149
9	F2	0.0150 ± 0.0047	17.3413 ± 5.3942
10	F3	0.0712 ± 0.0067	82.5109 ± 7.7117
11	F4	0.0119 ± 0.0022	13.7452 ± 2.5572
12	F5	0.0780 ± 0.0073	90.3424 ± 8.4709
13	F6	0.0388 ± 0.0019	44.9914 ± 2.1577
14	F7	0.0595 ± 0.0073	68.9256 ± 8.5108
15	S1	0.2419 ± 0.0114	280.2973 ± 13.1858
16	S2	0.0219 ± 0.0032	25.3326 ± 3.7160
17	S3	0.4171 ± 0.0144	483.2781 ± 16.7020
18	S4	0.0279 ± 0.0017	32.3251 ± 1.9978
19	S5	0.0196 ± 0.0043	22.7354 ± 4.9946
20	S6	0.0110 ± 0.0024	12.7462 ± 2.7970
21	S7	0.0500 ± 0.0028	57.9774 ± 3.2765
	Mean	**0.0993 ± 0.0084**	**115.0110 ± 7.0952**

3.2. Calculations for Radiological Hazards

For proper assessment of the radiological hazards associated with these radionuclides, the absorbed dose rate and the annual effective dose rate as well as the external hazard index were calculated and shown in table 1.6

3.3. Absorbed Dose

The absorbed dose rate was calculated in nano Gray per hour ($nGyh^{-1}$) using equation 3

$$D(nGyh^{-1}) = C_1 f + C_2 f + C_3 f \quad (3)$$

where D stands for dose rate, C represents the activity concentrations of the radionuclides 1, 2 and 3 and f is the dose rate conversion factor for the individual elements. For potassium, K = 0.0417, for Radium, Ra = 0.462, for Thorium, Th = 0.604

3.4. Annual Effective Dose Rate (AEDR)

The Annual Effective Dose Rate was calculated in milli Sievert per year ($mSvy^{-1}$) with the aid of equation 4

$$E(mSvy^{-1}) = D(nGyh^{-1})\ x\ 3650(h)\ x\ 0.2\ x\ 0.7(SvG^{-1})\ x\ 10^{-3} \quad (4)$$

where 0.2 is the outdoor occupancy factor, 0.7 SvG^{-1} is the conversion coefficient and 3650 (h) per year is the time spent.

3.5. External Hazard Index (H_{ex})

The external hazard index (H_{ex}) was calculated using equation 5

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (5)$$

where C represents the activity concentrations of the radionuclides Ra-226, Th-232 and K-40 in Bq/kg.

Table 1.5. Evaluation of radiation hazard indices for the radiological assessment of the soil in dumps

ID	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{226}Ra (Bq/Kg)	Absorbed Dose Rate ($nGyh^{-1}$)	Annual Effective Dose Rate ($mSvy^{-1}$)	External Hazard Index
D1	430.8969±8.4535	126.7764±3.8076	116.1146±10.7084	319.1941±10.2120	163.1082±5.2183	2.0039±0.0624
D2	85.3615±1.8873	68.1611±3.6467	18.3801±1.9978	62.8922±2.2150	32.1379±1.1319	0.3934±0.0134
D3	504.6539±10.2229	169.8933±17.8581	272.0262±12.0270	437.5749±12.4758	223.6008±6.3751	2.7190±0.0757
D4	426.2179±8.8861	299.6729±18.7161	231.2303±10.7484	376.7604±11.1134	192.5246±5.6789	2.3329±0.0673
D5	189.7928±4.2858	133.9626±6.7571	79.4742±4.2754	156.9382±4.8456	80.1954±2.4761	0.9754±0.0295
D6	38.4147±2.3985	198.8524±3.3249	15.5033±3.0367	38.6571±2.9903	19.7538±1.5280	0.2316±0.0182
D7	725.4748±2.3985	221.5906±28.4228	430.8147±20.0184	646.4635±17.6771	330.3428±9.0330	4.0115±0.0693
Mean	**342.9740±6.8752**	**174.1299±11.7905**	**166.2205±8.9732**	**291.2115±8.7899**	**148.8091±4.4916**	**1.8097±0.0480**

Table 1.6. Evaluation of radiation hazard indices for the radiological assessment of the surface soil

ID	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{226}Ra (Bq/Kg)	Absorbed Dose Rate (nGyh^{-1})	Annual Effective Dose Rate (mSvy^{-1})	External Hazard Index
S1	739.5510±12.3462	213.6000±25.4733	280.2973±13.1858	585.0933±14.0130	298.9827±7.1606	3.6574±0.0886
S2	98.4941±2.3591	293.1303±3.8076	25.3326±3.7160	201.2113±3.3005	102.8190±1.6866	0.5096±0.0199
S3	474.5803±10.2229	395.5596±24.7761	483.2781±16.7020	526.4158±14.9241	268.9985±7.6262	3.2208±0.0898
S4	96.2136±3.6173	332.0641±7.6152	32.3251±1.9978	111.2451±3.4254	56.8462±1.7504	0.5279±0.0209
S5	80.7219±3.3814	153.9658±5.5773	22.7354±4.9946	65.6802±4.5824	33.5626±2.3416	0.4051±0.0277
S6	72.2683±3.1455	141.9531±1.7161	12.7462±2.7970	55.4582±3.2637	28.3391±1.6678	0.3430±0.0199
S7	145.1657±3.8139	112.4578±7.2398	57.9774±3.2765	119.1551±4.1192	60.8883±2.1049	0.7406±0.0251
Mean	**243.8564±5.5552**	**234.6758±10.8865**	**130.6703±6.6671**	**237.7513±6.8040**	**121.4909±3.4769**	**1.3435±0.0417**

Table 1.7. Evaluation of radiation hazard indices for the radiological assessment of the soil in the farmland

ID	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{226}Ra (Bq/Kg)	Absorbed Dose Rate (nGyh^{-1})	Annual Effective Dose Rate (mSvy^{-1})	External Hazard Index
F1	81.2330±1.3368	22.3092±3.4858	19.1393±4.7149	58.8374±3.1311	30.0659±1.6000	0.3700±0.0186
F2	70.4203±2.9489	87.3599±7.6152	17.3413±5.3942	54.1884±4.5908	27.6903±2.3459	0.3369±0.0275
F3	243.3846±5.6619	192.4706±10.8328	82.5109±7.7117	193.1504±7.4342	98.6999±3.7989	1.2027±0.0450
F4	49.7385±1.5728	183.0858±3.9685	13.7452±2.5572	44.0270±2.2969	22.4978±1.1737	0.2673±0.0138
F5	384.5791±7.5492	162.0100±13.2997	90.3424±8.4709	280.7798±9.0279	143.4784±4.6133	1.7627±0.0548
F6	93.6972±2.5164	54.9150±3.5394	44.9914±2.1577	113.8027±2.6644	58.1532±1.3615	0.4948±0.0163
F7	222.2703±5.3081	205.4486±6.9180	68.9256±8.5108	174.6621±7.4266	89.2523±3.7950	1.0872±0.0449

ID	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{226}Ra (Bq/Kg)	Absorbed Dose Rate (nGyh^{-1})	Annual Effective Dose Rate (mSvy^{-1})	External Hazard Index
Mean	**163.6176± 3.8420**	**129.6570±7. 0942**	**48.1423±5 .6453**	**131.3497± 5.2246**	**67.1197±2. 6698**	**0.7888±0 .0316**

Table 1.8. Comparison between the mean radiological hazard indices of natural radioactivity of soils in the present study and similar investigations performed in other states of Nigeria

State	^{226}Ra Mean (Bq/kg)	^{232}Th Mean (Bq/kg)	^{40}K Mean (Bq/kg)	H_{ex} Mean	Reference
Sikiti (Oyo State)	28.15±16.93	107.30±23.83	465.95±129.19	0.5873±0.11	Ibrahim *et al* (2014)
Nasarawa Central(Nasarawa State)	43.32±6.56	50.81±3.71	399.11±8.63	0.41±0.032	Ibrahim *et al* (2013)
Kaduna North (Kaduna State)	212.4779±9 .42	95.3643±6.3 107	360.3414±22.9 079	1.0136 --	Taiwo *et al* (2014)
Jos (Plateau State)	762.4±151. 31	17258.3±19 5.68	5901.4±280.15	70.1693 --	Davou & Mangset (2015)
Ife-Central (Osun State)	24.00 --	128.00 --	850 --	0.74±0.03	Gbenu *et al* (2016)
Ekiti (Ekiti State)	18.7±6.2	39.8±3.5	351.1±3.1	0.28±0.03	Fasae (2013)
Udege Mbeki (Nasarawa State)	115.0110± 7.0952	250.1493± 5.4241	179.4876± 9.9237	1.3140±0.0 404	Present Work

4. Discussion

The specific activity due to ^{232}Th, ^{40}K and ^{226}Ra, in the soil in the mining area of Udege Mbeki has been analyzed as shown in tables 1.3, 1.4 and 1.5. In the dump, the activity concentration of ^{232}Th was found between the ranges of (38.4147 ± 2.3985) to (725.4748 ± 2.3985) Bq/kg with an average of (342.9740 ± 6.8752) Bq/kg and ^{40}K ranged from (68.1611 ± 3.6467) to (299.6729 ± 18.7161) Bq/kg with an average of

(174.1299 ± 11.7905) Bq/kg while ^{226}Ra ranged from (15.5033 ± 3.0367) to (430.8147 ± 20.0184) Bq/kg with a mean of (166.2205 ± 8.9732) Bq/kg.

The activity concentration of these radionuclides in the farmland was observed to range from (49.7385 ± 1.5728) to (384.5791 ± 7.5492) with an average of (163.6176 ± 3.8420) Bq/kg for ^{232}Th and spanned between (22.3092 ± 3.4858) to 205.4486 ± 6.9180) with an average of (129.6570 ± 7.0942) Bq/kg for ^{40}K while for ^{226}Ra it ranged from (13.7452 ± 2.5572) to (90.3424 ± 8.4709) with an average of (48.1423 ± 5.6453) Bq/kg.

In the surface soil, the activity concentration of the primordial radionuclides ^{232}Th, ^{40}K and ^{226}Ra respectively ranged from (72.2683 ± 3.1455) to (739.5510 ± 12.3462) with an average of (243.8564 ± 5.5552) Bq/kg, (112.4578 ± 7.2398) to (395.5596 ± 24.7761) with an average of (234.6758 ± 10.8865) Bq/kg and (12.7462 ± 2.7970) to (483.2781 ± 16.7020) with an average of (130.6703 ± 6.6671) Bq/kg.

It follows that there is variation in the activity concentration of the different radionuclides in the various locations where the soil samples were obtained. In the dump, sample D6 is observed to have the lowest ^{232}Th activity concentration while D7 has the highest ^{232}Th activity concentration. On the other hand, D2 has the lowest ^{40}K activity concentration while D4 has the highest ^{40}K activity concentration. Sample D6 contains the lowest activity concentration for ^{226}Ra while D7 has the highest ^{226}Ra activity concentration.

In the farmland, sample F4 appears to record the lowest thorium concentration while F5 has the highest. Similarly, sample F1 has the lowest ^{40}K activity concentration while sample F7 records the highest. It is also observed that sample F4 shows the lowest ^{226}Ra activity concentration while sample F5 is observed to have the highest.

Sample S6 is observed to have the lowest ^{232}Th activity concentration for surface soil while sample S1 records the highest. Consequently, the activity concentration for ^{40}K shows sample S7 to have the lowest while sample S3 has the highest, while sample S6 records the lowest activity concentration of ^{226}Ra with sample S3 having the highest.

The external hazard index which is expected to lie within the limits $0 \leq H_{ex} \leq 1$ for the radiation hazard to be insignificant was observed to range between 0.2316 ± 0.0182 to 4.0115 ± 0.0693 with an average of 1.8097 ± 0.0480 in the dump, 0.2673 ± 0.0138 to 1.7627 ± 0.0548 with an average of 0.7888 ± 0.0316 in the farmland, and for the surface soil, 0.3430 ± 0.0199 to 3.6574 ± 0.0886 with 1.3435 ± 0.0417 as mean.

In the year 2015, Davou L.C. and Mangset W.E. carried out an experiment on the "Evaluation of Radiation Hazard Indices and Excess Lifetime Cancer Risk due to Natural Radioactivity in Mined Tailings in some locations in Jos, Plateau State, Nigeria". This experiment saw samples taken from fourteen (14) different sites within Jos and analysis of the results showed that the radioactivity in the soil samples was very high compared to the standard or threshold limits 400Bqkg^{-1} for ^{40}K, 35Bqkg^{-1} for ^{226}Ra and 30Bqkg^{-1} for ^{232}Th as stipulated by UNSCEAR in the year 2000. The same applied to the external hazard index which is 70.1693 as against the standard limit which is 1. This is extremely on the high side. The results obtained by Davou and Mangset are similar to the results obtained from this research work carried out in Udege Mbeki,

Nasarawa State. In this case, the mean radioactivity for ^{226}Ra, ^{232}Th and ^{40}K in the soil sample were 115.0110 $Bqkg^{-1}$, 250.1493 $Bqkg^{-1}$and 179.4876 $Bqkg^{-1}$ respectively, and the mean external hazard index was 1.3140. These are also very high for ^{226}Ra and ^{232}Th except for ^{40}K which is within limit. Other results obtained as recorded on table 1.8 are within the safe limit for the external hazard index except for the research conducted by Taiwo *et al (2014)* in Kaduna North, Kaduna State, which is also above 1.

It is clear that mining within these high risk areas are uncontrolled and that has consequently given rise to a large accumulation of radioactive nuclides in the atmosphere, thereby posing serious health hazards which could include genetic mutation, cancer, asthma, and so on to the people living, working or faming within the areas under study.

5. Conslussion

Based on the International Commission on Radiation Protection (ICRP) recommendations, the public must not be exposed to any form of radiation such that the effective dose is above one milli Sievert per year (1mSv/yr), and the effective dose on occupational exposure should not exceed 20mSv/yr averaged over a period of five years.

In this research, the estimated effective dose in the soil samples from Udege mined site ranged from 19.7538 $mSvy^{-1}$ to 330.3428 $mSvy^{-1}$ with an average of 148.8091 $mSvy^{-1}$ in the dump, 67.1197 $mSvy^{-1}$ in the farmland and 121.4909 in the surface soil. These values are above the recommended reference level of 1$mSvy^{-1}$ for public exposure and 20 $mSvy^{-1}$ for workers by ICRP. Hence, the mining area can be said to be unsafe for both the public and workers.

6. Recommendations

- It is recommended that the implementation of a routine monitoring be implemented on the radiation levels in Udege mining and residential areas on a periodic basis, to keep track of the rise and fall in the radiation levels. This would enable the government to ascertain the safety of the inhabitants of the area.
- It is necessary for a sensitization scheme to be put in place in order to educate the inhabitants of the area on the need for self-protection from the hazards of ionizing radiation as well as educating the workers on the need to follow the right procedure and use the necessary protective gears.

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